

# TeMA

Journal of  
Land Use, Mobility and Environment

This special issue collects a selection of peer-review papers presented at the 8th International Conference INPUT 2014 titled "Smart City: planning for energy, transportation and sustainability of urban systems", held on 4-6 June in Naples, Italy. The issue includes recent developments on the theme of relationship between innovation and city management and planning.

Tema is the Journal of Land use, Mobility and Environment and offers papers with a unified approach to planning and mobility. TeMA Journal has also received the Sparc Europe Seal of Open Access Journals released by Scholarly Publishing and Academic Resources Coalition (SPARC Europe) and the Directory of Open Access Journals (DOAJ).

# INPUT 2014

papers selected

## Smart City

planning for energy, transportation  
and sustainability of the urban system

## SMART CITY

## PLANNING FOR ENERGY, TRANSPORTATION AND SUSTAINABILITY OF THE URBAN SYSTEM

Special Issue, June 2014

**Published by**

Laboratory of Land Use Mobility and Environment  
DICEA - Department of Civil, Architectural and Environmental Engineering  
University of Naples "Federico II"

TeMA is realised by CAB - Center for Libraries at "Federico II" University of Naples using Open Journal System

Editor-in-chief: Rocco Papa  
print ISSN 1970-9889 | on line ISSN 1970-9870  
Licence: Cancelleria del Tribunale di Napoli, n° 6 of 29/01/2008

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# TeMA

Journal of  
Land Use, Mobility and  
Environment

TeMA. Journal of Land Use, Mobility and Environment offers researches, applications and contributions with a unified approach to planning and mobility and publishes original inter-disciplinary papers on the interaction of transport, land use and environment. Domains include engineering, planning, modeling, behavior, economics, geography, regional science, sociology, architecture and design, network science, and complex systems.

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Journal of  
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Environment

This special issue of TeMA collects the papers presented at the 8th International Conference INPUT 2014 which will take place in Naples from 4th to 6th June. The Conference focuses on one of the central topics within the urban studies debate and combines, in a new perspective, researches concerning the relationship between innovation and management of city changing.



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## EIGHTH INTERNATIONAL CONFERENCE INPUT 2014

### SMART CITY. PLANNING FOR ENERGY, TRANSPORTATION AND SUSTAINABILITY OF THE URBAN SYSTEM

This special issue of TeMA collects the papers presented at the Eighth International Conference INPUT, 2014, titled "Smart City. Planning for energy, transportation and sustainability of the urban system" that takes place in Naples from 4 to 6 of June 2014.

INPUT (Innovation in Urban Planning and Territorial) consists of an informal group/network of academic researchers Italians and foreigners working in several areas related to urban and territorial planning. Starting from the first conference, held in Venice in 1999, INPUT has represented an opportunity to reflect on the use of Information and Communication Technologies (ICTs) as key planning support tools. The theme of the eighth conference focuses on one of the most topical debate of urban studies that combines , in a new perspective, researches concerning the relationship between innovation (technological, methodological, of process etc..) and the management of the changes of the city. The Smart City is also currently the most investigated subject by TeMA that with this number is intended to provide a broad overview of the research activities currently in place in Italy and a number of European countries. Naples, with its tradition of studies in this particular research field, represents the best place to review progress on what is being done and try to identify some structural elements of a planning approach.

Furthermore the conference has represented the ideal space of mind comparison and ideas exchanging about a number of topics like: planning support systems, models to geo-design, qualitative cognitive models and formal ontologies, smart mobility and urban transport, Visualization and spatial perception in urban planning innovative processes for urban regeneration, smart city and smart citizen, the Smart Energy Master project, urban entropy and evaluation in urban planning, etc..

The conference INPUT Naples 2014 were sent 84 papers, through a computerized procedure using the website [www.input2014.it](http://www.input2014.it) . The papers were subjected to a series of monitoring and control operations. The first fundamental phase saw the submission of the papers to reviewers. To enable a blind procedure the papers have been checked in advance, in order to eliminate any reference to the authors. The review was carried out on a form set up by the local scientific committee. The review forms received were sent to the authors who have adapted the papers, in a more or less extensive way, on the base of the received comments. At this point (third stage), the new version of the paper was subjected to control for to standardize the content to the layout required for the publication within TeMA. In parallel, the Local Scientific Committee, along with the Editorial Board of the magazine, has provided to the technical operation on the site TeMA (insertion of data for the indexing and insertion of pdf version of the papers). In the light of the time's shortness and of the high number of contributions the Local Scientific Committee decided to publish the papers by applying some simplifies compared with the normal procedures used by TeMA. Specifically:

- Each paper was equipped with cover, TeMA Editorial Advisory Board, INPUT Scientific Committee, introductory page of INPUT 2014 and summary;
- Summary and sorting of the papers are in alphabetical order, based on the surname of the first author;
- Each paper is indexed with own DOI codex which can be found in the electronic version on TeMA website ([www.tema.unina.it](http://www.tema.unina.it)). The codex is not present on the pdf version of the papers.

## SMART CITY PLANNING FOR ENERGY, TRANSPORTATION AND SUSTAINABILITY OF THE URBAN SYSTEM Special Issue, June 2014

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Journal of  
Land Use, Mobility and Environment

TeMA INPUT 2014  
Print ISSN 1970-9889, e- ISSN 1970-9870

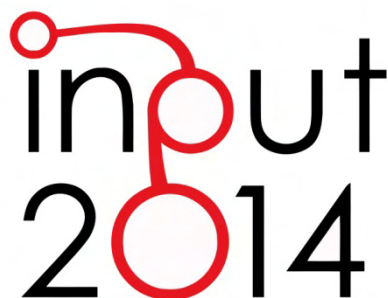
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SPECIAL ISSUE

Eighth International Conference INPUT  
Smart City - Planning for Energy, Transportation and Sustainability  
of the Urban System

*Naples, 4-6 June 2014*

The logo for the INPUT 2014 conference. It features the word "input" in a lowercase, sans-serif font, with the "i" and "n" connected by a red line that forms a circle. Below "input" is the year "2014" in a larger, bold, sans-serif font, with the "0" also connected to the red line above it.

## WALKABILITY EXPLORER.

AN EVALUATION AND DESIGN SUPPORT TOOL  
FOR WALKABILITY

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### ABSTRACT

Walkability Explorer is a software tool for the evaluation of urban walkability which, we argue, is an important aspect of the quality of life in cities. Many conventional approaches to the assessment of quality of life measure the distribution, density and distances of different opportunities in space. But distance is not all there is. To reason in terms of urban capabilities of people we should also take into account the quality of pedestrian accessibility and of urban opportunities offered by the city. The software tool we present in this paper is a user-friendly implementation of such an evaluation approach to walkability. It includes several GIS and analysis features, and is interoperable with other standard GIS and data-analysis tools.

### KEYWORDS

Walkability, Evaluation, Decision support, GIS, ELECTRE TRI

## 1 INTRODUCTION

In this paper we present Walkability Explorer, a software tool for the evaluation of urban walkability.

Walkability of places is an important aspect of the quality of life in cities. Making cities more walkable does not merely improve the accessibility of places, it also is beneficial to the quality of the public use of space and the social climate in general. Ultimately, making places more walkable may expand capabilities of inhabitants, visitors and city-users, especially of those “week population” whose capabilities are curtailed by the predominant motorized practices of the use of space.

We use 'capability' here in specific sense of the so called capability approach (Sen 1993): a person's capabilities are valuable states of being that a person has effective access to. Thus, a capability is the effective freedom of an individual to choose between different things to do or to be that she has reason to value. In this conception, a capability constitutively requires two preconditions: (1) the ability, person's internal power, detained but not necessarily exercised, to do and to be, and (2) the opportunity, presence of external conditions which make the exercise of that power possible. A person is thus capable, has the capability to do or to be something, only if both conditions – internal and external, ability and opportunity – allow her to. The physical urban space – the city's hardware – influences capabilities primarily through the channel of the opportunity component of capabilities.

Many conventional approaches to the assessment of quality of life usually measure the distribution, density and distances of different opportunities in space. But distance is not all there is. If we want to reason in terms of capabilities, we should also take into account the quality of accessibility and the quality of urban opportunities. Besides the mere distance, it matters a great deal if a place can be reached also by foot or by bicycle, if the pedestrian route is pleasant and spatially integrated with the surrounding by good urban design, if it is brimful of urban activities, if it is well maintained and (perceived as) secure, if it is not submissive and surrendering to the car traffic whether by design or by predominant social practices of use of that space. At the same time we need to go beyond the simple presence of urban services, to understand their characteristics, if they are able to serve different categories of individuals, if their relevance is on the neighbourhood, urban or metropolitan/regional level, if there are possibilities of choice between two or more relevant places.

For Walkability Explorer, the software tool which is the focus of this paper, we have developed evaluation approaches which attempt to take into account the aforementioned facets of walkability. The assumption of an accessibility-enhancing perspective requires a very strict integration and collaboration between transportation planning, land-use planning and urban design. Walkability Explorer is therefore a milestone in our ongoing research to build evaluation models and a planning and design support tools that takes into consideration many of these concerns, and focuses on the quality of accessibility as an important factor for the extension of urban capabilities.

## 2 EVALUATING WALKABILITY

### 2.1 THE DATA

The evaluation of walkability is based on the exploration of how someone at different points in space can walk to destinations of interest in an urban area. A destination of interest is a place, service or facility which promotes an urban opportunity.

The concept of walkability pinpoints at features beyond the geometry of urban space. Besides mere presence of places of interest and their distances, factors related to the quality of pedestrian routes such as



urban design and quality, track and road conditions, land-use patterns, building accessibility, degree of integration with the surrounding, safety and other features and practices of use of space, are all potentially relevant for walkability.

Therefore, for an operational evaluation of walkability, much richer spatial datasets are required. Our starting point are: (1) a detailed graph representation of the street network and (2) a detailed map of relevant places (destinations).

The street network graph is the cartographic base for the pedestrian route analysis. Besides their geometric properties, the edges hold relevant features for the walkability of a pedestrian route. In Table 1. we report an example list of edge attributes we used in our experimental runs of WE.

URBAN DESIGN	VALUES	DESCRIPTION
Building density	(qualitative) dense – rarefied – undeveloped	Describes the density of the urban fabric surrounding the edge.
Degree of integration	(qualitative) Integrated – filtered – separated	Describes how the pedestrian pathway is integrated with the surrounding buildings and areas. “Integrated” stands for complete integration and permeability; “filtered” means that the access is possible but “filtered” with specific points of access, pathways, etc.; “separated” stands for a complete separation (e.g. a wall or fence).
Street type	access – residential – crossing/bypass	The predominant type of the street: “access” to services, shops, offices, etc.; “residential”; or a “crossing/bypass”
Physical features		
Bicycle track	present – absent	
Number of car lanes	(number)	
Car speed limit (in km/h)	(number)	
One-way street	yes – no	
Car parking along the road	not allowed/practiced – allowed/practiced	Whether cars are parked/allowed to park along the motor lane
Footway width (in meters)	(number)	
Degree of maintenance	(qualitative) good – average – bad	A qualitative evaluation of the degree of maintenance (footpath, illumination, trash bins, flowerbeds, etc.)
Land-use pattern		
Commercial activities	(qualitative) predominant – present – absent	Whether commercial activities (shops, bars, restaurants, etc.) are predominant, present or absent
Services and offices	(qualitative) predominant – present – absent	Whether services, businesses and offices are predominant, present or absent

Tab.1 Example of edge attributes

This, of course, is only an example and far from a complete list. Many other attributes could be useful to assess walkability, and we are surely failing to account for important aspects such as practices of use of space, social climate, perception of personal security, and many more. WE is a flexible tool and can import any set of attributes which scholars and users may consider of relevance for the evaluation of walkability in accordance to particular normative assumptions, empirical findings and available data.

The map of relevant places describes the spatial distribution of places, services and facilities and represent the information base for the analysis of particular attributes determinant for the promotion of urban opportunities. These attributes may in principle describe the quality of places, design of space, capacity to attract different categories of peoples at different times of the day, capacity to favour different uses in the space (play, meetings, study, ...), and other features important for the accessibility of the space, intended as the possibility of appropriation of the urban space in respect to human needs. For the example runs of WE, we have classified destinations of interest in three categories: commercial (shops, bars, restaurants, etc.), services (schools, health services, libraries, etc.) and recreational and leisure areas (green areas, urban parks, sport facilities open to public). In Fig. 1 we show a screen capture of the maps with these three types of destinations.

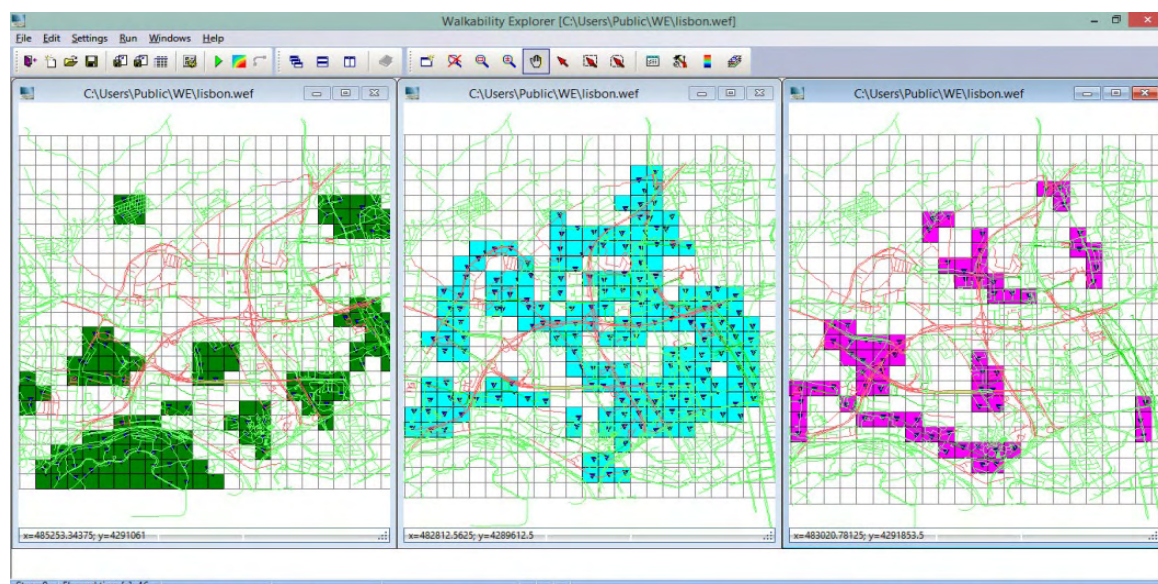


Fig. 1 A screen capture of WE representing the destination cells for different type of attractions and the destination node for each cell

## 2.2 EVALUATION MODELS

In the following we propose two different models for evaluating and comparing the pedestrian routes along a street network, considering their quality and walkability (Livi *et al.*, 2004) and the quality of urban opportunities.

- The first model aims to evaluate the walkability by the analysis of pseudo-utilities. For each category of destinations, we define the pedestrian behaviour as an utility maximisation problem given the distance and the quality of pedestrian accessibility of destination places belonging to that category.
- The second aims to assign an opportunity rating to each point in space. For each category of destinations, we define the pedestrian behaviour as a pedestrian class maximization problem given the distance, the quality of pedestrian accessibility of destinations belonging to that category and the quality of destination places.

2.2.1 WALKABILITY AS A PSEUDO-UTILITY

We assume that a resident living at one point in space will walk to available destinations a certain amount of times, and will from that derive utility defined by the following constant elasticity of substitution (CES) function:

$$U = \left( \sum_{i=1}^n X_i^\rho \right)^{\frac{1}{\rho}} \tag{1}$$

where  $n$  is the number of available destinations,  $X_i$  is the number of times the resident visits the  $i$ -th destination and  $1/(1 - \rho)$  is the elasticity of substitution among destinations.

The constraint imposed upon the pedestrian is:

$$\sum_{i=1}^n c_i X_i \leq M \tag{2}$$

where  $c_i$  is the cost the pedestrian foregoes to reach the destination  $i$ , and  $M$  is the available budget with a conventional constant value.

A path from an origin to a destination is a set of  $p$  interconnected edges. Besides sole distances, we describe edges on further attributes which shape the quality of the pedestrian accessibility, characteristics such as physical features, urban design, presence (or absence) of variety of urban activities. These attributes serve to model the cost of a path used in the constraint expression (2). We define the cost of a path of  $p$  edges as:

$$c = c_0 + \sum_{k=1}^p l_k \left( 1 - \left( \sum_{l=1}^r w_l a_{k,l}^r \right)^{\frac{1}{r}} \right) \tag{3}$$

where  $c_0$  is the fixed cost,  $l_k$  is the length of the  $k$ -th edge in the path,  $a_{k,l} \in [0, 1]$  is the value of that edge's  $l$ -th attribute,  $w_l$  is the weight of the attribute ( $\sum w_l = 1$ ), and  $r$  is a parameter with  $1/(1 - r)$  being the elasticity of substitution among attributes. This expression yields unit variable cost of 1 when all attributes are at their lowest value (i.e. 0), and approaches 0 when attributes approach the highest value of 1.

Among many alternative paths from an origin to a destination in a street network, we plug the cheapest one into the expression (2).

Under the constraint (2), the utility in expression (1) is maximised when:

$$X_i = \frac{c_i^{\frac{1}{\rho-1}} M}{\sum_{j=1}^n c_j^{\frac{1}{\rho-1}}} \tag{4}$$

2.2.2 A NESTED ELECTRE TRI FOR OPPORTUNITY RATING

Here we concentrate to describe an alternative model based on the ELECTRE TRI rating procedure. In particular, for the purpose of rating urban opportunities we adapted the ELECTRE TRI approach in a particular nested procedure.

The aim of the evaluation model is to assign an “opportunity rating” to each point in space, that is to say, to put it in one among several classes of urban opportunity (one class for each among different types of urban opportunities). The core idea of the evaluation approach we propose is based on nesting several ELECTRE

TRI evaluation procedures, one within another. So before laying down our “nested” model, let us briefly recall the basic general ELECTRE TRI model.

Among the methods for multiple criteria evaluation of ratings (Bouyssou *et al.* 2006) , the so called ELECTRE TRI model (Yu 1992; Roy *et al.* 1993) is a prominent classification approach. This rating approach possesses several desirable properties for our purposes: (1) it allows a complete classification, and the aggregation over multiple criteria is fairly flexible, permitting to account for (2) the importance (weights) of criteria, (3) coalitions (majority rule and threshold) and (4) possible veto powers. Besides, as it will be shown, out nesting ELECTRE TRI procedure allows a careful aggregation over criteria at each level of nesting in a controllable and meaningful way more in accordance with “natural” human reasoning.

The general ELECTRE TRI procedure works as follows. Given a set of objects, evaluated on a set of criteria  $h_1, \dots, h_n$ , to be assigned a rating class from a set of classes with ordinal property  $C^1 \dots C^m$ , ELECTRE TRI first requires that the so called limiting profiles be defined for each class. That is to say, each class  $C^k$  is defined by a limiting profile  $\pi^k$  on  $m$  criteria:  $\pi^k = (\pi_1^k, \dots, \pi_n^k)$ . To respect the ordinality of classes, the limiting profiles should be defined so that  $\pi_i^k < \pi_i^{k+1}$  for every  $i=1, \dots, n$ .

To assign an object  $a$  to a rating class we then apply the following two rules (Bouyssou *et al.*, 2006):

- if the object  $a$  has the same or higher evaluation on the  $m$  criteria than  $\pi^k$ , it should at least belong to the class  $C^k$ ;
- if  $\pi^{k+1}$  has the same or higher evaluation on the  $m$  criteria than the object  $a$ , then it should at most belong to class  $C^k$ .

Formally:

$$a \in C^k \Leftrightarrow a P \pi^k \wedge \pi^{k+1} P a \quad (5)$$

where  $P$  is the binary outranking relation meaning “belongs to the same or a higher class than”.

The binary outranking relation  $P$  uses a crisp relation based on a concordance-discordance principle, that is to say, an object  $a$  outranks a limiting profile  $\pi^k$  if there is a “significant” coalition of criteria for which “ $a$  belongs to the same or higher class than  $\pi^k$ ” (concordance principle) and there are no “significant opposition” against this proposition (discordance principle). In other words:

$$a P \pi^k \Leftrightarrow C(a, \pi^k) \wedge \neg D(a, \pi^k) \quad (6)$$

where:

- $C(a, \pi^k)$  means there is a majority of criteria supporting the proposition that  $a$  outranks (“is at least as good as”)  $\pi^k$ ;
- $D(a, \pi^k)$  means there is a strong opposition, that is to say a veto, to the proposition that  $a$  outranks (“is at least as good as”)  $\pi^k$ .

Following Roy (1968), for two evaluation profiles  $x$  and  $y$ , we use the following definitions of  $C(x, y)$  and  $D(x, y)$ :

$$C(x, y) \Leftrightarrow \frac{\sum_{i \in H(x, y)} w_i}{\sum_{j=1}^n w_j} \geq \gamma \quad (7)$$

$$D(x, y) \Leftrightarrow \exists h_i : h_i(y) - h_i(x) > v_i \quad (8)$$

where:

- $h_i, i = 1, \dots, n$  are the criteria (the higher the value the higher the class);

- $w_i$  are the importance coefficients (weights) associated to each criterion;
- $h_i(x)$  is the evaluation of  $x$  on the criterion  $h_i$ ;
- $H(x,y)$  is the set of criteria for which  $x$  has the same or higher evaluation than  $y$ , that is, for which  $h_i(x) \geq h_i(y)$ ;
- $\gamma$  is the majority threshold;
- $v_i$  is the veto threshold on criterion  $h_i$ .

After this recall of the basic ELECTRE TRI rating procedure, let us now lay down the specific nested procedure which we have developed for evaluating urban opportunities in space.

Let us define a set of ordinal opportunity classes from lowest to highest,  $O^1 \dots O^m$ . Again, our objective is to assign to each point in space one and only one class by taking into consideration both (1) the quality and (2) the accessibility of destinations of interest from that point.

Each destination may fall into one or more types of urban opportunity (e.g. green areas, retail, services, etc.). To represent this fact, each destination  $d$  is evaluated in terms of “quality” per each type of opportunity, which we will denote with  $q_l(d)$ , where  $l$  stands for the type of opportunity.

To evaluate the accessibility, we use a detailed graph representation of the street network. A path from an origin to a destination is a set of interconnected edges. Besides their length, edges are described with further attributes which shape the quality of pedestrian accessibility, with characteristics such as physical features, urban design, presence (or absence) of variety of urban activities, and so on (see Table 1. above for an example of edge attributes). Hence, in general terms, for every edge  $i$  in a path from one point in space to one destination, we have the edge’s length  $l$  and a set of attributes  $a_1, \dots, a_p$  which describe its characteristics.

Given such a configuration of definitions and available data, the “nested ELECTRE TRI” procedure we propose proceeds in four steps:

- Step 1: Assign a walkability class to each edge in the path;
- Step 2: Aggregate the walkability of edges in the path (from Step 1) to assign an overall walkability class to the entire path;
- Step 3: Combine the walkability class of the path (from Step 2) with its length to assign an accessibility class to the couple origin-destination
- Step 4: Combine the accessibility of all the destinations (of one type of urban opportunities) reachable from an origin, to assign an urban opportunity score/class to that origin (for that type of urban opportunities)

**Step 1. Edge walkability rating.** In this step we use ELECTRE TRI to assign a walkability rating to each edge, using edge attributes as criteria. The step further requires that a corresponding set of criteria weights, possible veto thresholds, and the majority threshold be defined.

**Step 2. Path walkability rating.** Here, the ELECTRE TRI serves to assign a *walkability rating to the entire path*, by using the edges themselves as criteria. Their walkability classes (obtained in the Step 1) are used as criteria values, while their lengths are used as weights. So, this step only requires the definition of the majority threshold and possible vetos.

**Step 3. Accessibility rating of each couple origin-destination.** We now need to evaluate the overall *accessibility* of the destination from the origin. The accessibility should take into account both the quality of walk, i.e. walkability, and the distance. Therefore, for this purpose we again employ ELECTRE TRI, this time using two criteria: the walkability of the path (obtained in the Step 2) and its length. This step therefore requires to further settle the respective weights of the two criteria, as well as the majority and possible veto thresholds.

**Step 4. Urban opportunity scores/rating.** This is the final phase in which we assign the final urban opportunity ratings to the origin point in space. It combines the information about the quality of the destinations which are reachable from that origin with their accessibility rating (obtained in the Step 3). Therefore, this step may be performed only after all the accessibility ratings have been assigned to every couple origin-destination. Also, since different destinations are, as we said, relevant for different types of urban opportunity, we proceed separately and independently, calculating an opportunity score per each type of opportunity. The opportunity score of an origin  $U(o)$  is obtained with:

$$U(o) = \sum_{i \in D} q(d_i) a(o, d_i) \quad (1)$$

- where  $D$  is the set of reachable destination relevant for the type of opportunity under assessment;
- $q(d_i)$  is the quality score of the destination  $i$ ;
- $a(o, d_i)$  is the accessibility score of the destination  $i$  from the origin  $o$ ; the accessibility scores are accessibility ratings (obtained in Step 3.) transformed into numeric factors [0,1].

In the end, having calculated the urban opportunity scores for each type of opportunity, the final urban opportunity ratings are assigned by defining fuzzy thresholds on scores per each different type of urban opportunity.

### 3 A GENERAL OVERVIEW OF WALKABILITY EXPLORER

We are currently working on fully implementing the two evaluation models in Walkability Explorer (WE). WE is an application running on Microsoft Windows whose user interface allows an easy assessment of the walkability. It furthermore allows a comparison in terms of walkability between the current situation and hypothetical projects concerning features relevant for the walkability, in terms of the evaluation model described above.

In Fig. 2 we show the standard workflow to perform a walkability evaluation in We.

First, the user is asked to provide the road networks in the format defined by the Open Street Map (OSM) project (see screen capture in Fig. 3) OSM is a collaborative project for the creation of street maps that currently makes available a huge data base covering most part of the world. In addition to the availability of street network data, the advantage of using OSM for this application lies in the ease of introducing new attributes and topological changes that affect the graphs. For this purpose there are indeed several effective editing applications freely available. If the purpose is to compare the current situation with a future project, a further road network with the features modified by the project has to be provided.

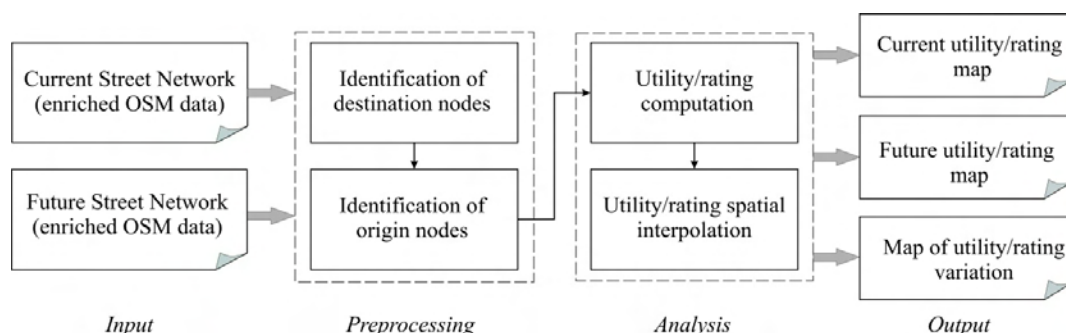


Fig. 1 The typical WE workflow. The required input data are the current and future street network in OSM with graph edges enriched with attributes relevant to the walkability (e.g. Tab. 1). After the preprocessing and analysis phases, the main output is represented by the utility-score maps (if using the pseudo-utility evaluation model) or ratings (if using nested ELECTRE TRI procedure) at the desired resolution

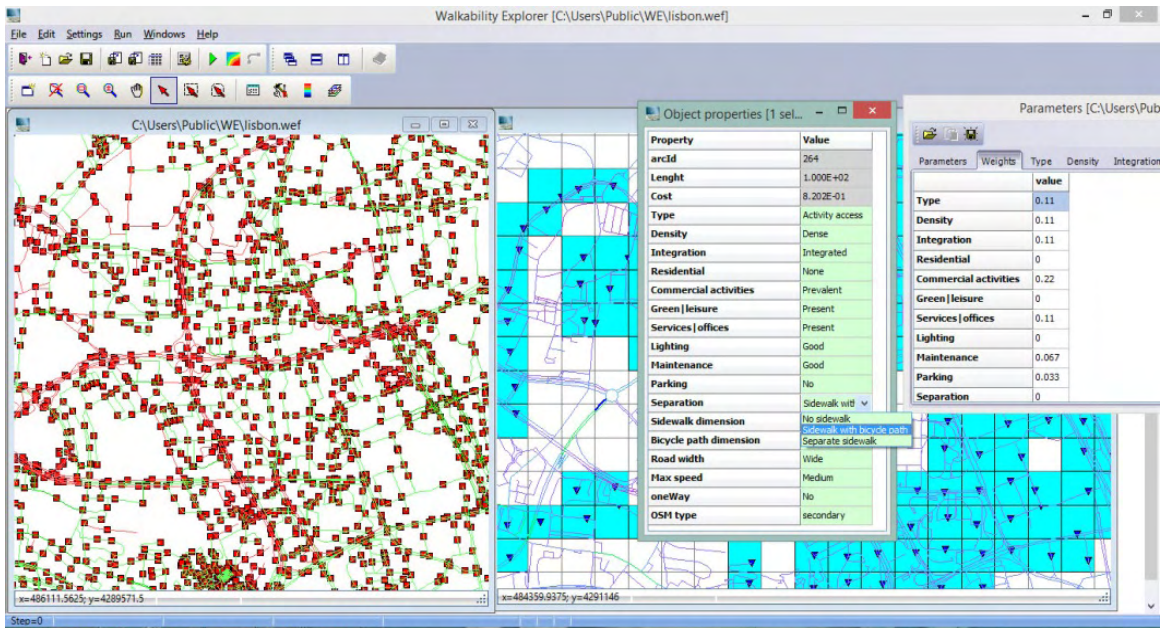


Fig. 3 A screen capture of WE representing the street network with the visualization of the edge parameters and an object property

Given the OSM data enriched with the set of edge attributes, the program identifies the areas of attractions using a regular grid of cells, according to a resolution set by the user, and constructs the sets of destination nodes (for an example see Fig. 1 above).

It is worth noting that the size of cells can be set independently for the different types of attractions. In particular, WE identifies the areas with prevalence of retail/commercial and service activities using the specific attributes attached to the edges in the OSM data. For the green/recreational attractions, the current implementation of WE exploits the polygons representing such urban areas, which are typically included in the OSM data. The program builds the set of destination nodes by finding for each attractive cell the node of the street network which is closer to its centroid (Fig. 4).

WE determines the origin nodes for both the current and future street network. It is worth noting that, to increase the comparability of results, during the filtering process the program tries to make sure that the origin nodes of current and future road networks coincide. This is not possible in areas where there are geometrical and topological changes of the network.

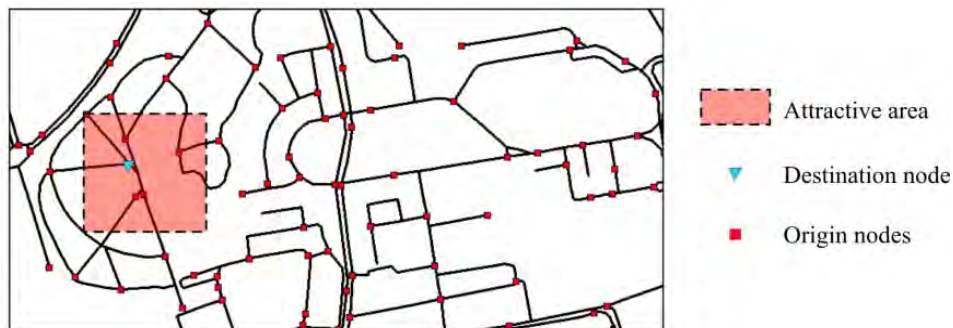


Fig 4 Origin nodes, attractive area and the corresponding destination node

The analysis run allows to calculate the utility-scores (if using the evaluation mod-el based on pseudo-utility functions) or ratings (if using nested ELECTRE TRI procedure). The computation is carried out for the

current and the future street network and for the each types of attraction. In order to shorten the run-time, WE exploits the available multi-core CPU computers implementing a parallel multi-thread approach.

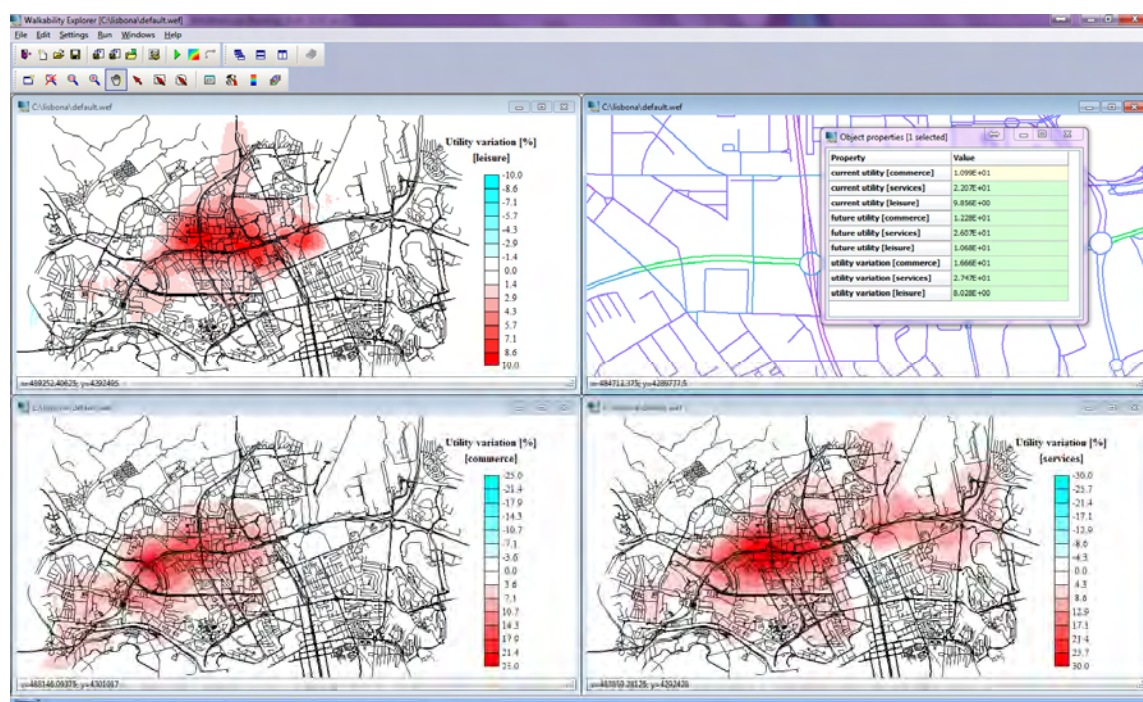


Fig. 5 A screen capture of WE representing georeferenced pseudo-utility maps for different types of attractions

The final output of the program are the georeferenced utility-score maps (e.g. Fig. 5) or ratings for both the current and future street networks and for all the types of attractions. Moreover, WE provides the map of utility/rating variation due to the project. All the above maps can be exported in a suitable GIS format for further elaborations.

The processing described above require to extensively operate with geo-referenced data, as well as the possibility to efficiently perform spatial queries. For this reason, the program has been implemented using the C++ MAGI library (Blečić *et al.* 2009; Blečić *et al.* 2009), which makes available the necessary functions of spatial indexing.

Besides producing georeferenced maps, WE allows the results to be exported in the open csv format for further analysis in other GIS and statistical analysis tools. One such possible analysis is to calculate indicators for comparing the aggregate variation of walkability between alternative scenarios as well as its spatial distribution and dispersion in relation to the populations inhabiting the urban area under consideration.

## 4 CONCLUSIONS

Capability approach coupled with the analysis of accessibility provides a compelling theoretical framework for assessing relevant aspects of the quality of life in cities. The space and urban environment are important constituent of certain human capabilities and are determinant for the individual life in cities. Among other dimensions of individual wellbeing (health, education, political participation, and so on), the way our cities and physical environment ‘functions’ – the way they are shaped, organized, and used by social practices – matters.



Architects, urban planners and policies makers could use urban capabilities to read and interpret the multiple relations between the individual and the city, to unveil the circumstances in which the city is an 'obstacle' to the needs and aspirations of its inhabitants, to better define and govern urban design processes which aim at removing these obstacles, to promote the right to the city (Lefebvre 1978; Harvey 2009; Soja 2010) for all.

Such design attitude requires tools. Walkability Explorer is an attempt to implement evaluation models and to provide an user-friendly tool for assessing walkability which may prove useful for improving effectiveness, relevance, and inclusiveness of urban design and transport planning.

There is further work to be done and there are many areas in which we plan to extend WE's features. Foremost, to become a more complete decision support for assessing urban capabilities, besides walkability it should also be able to take into account the car and public transportation accessibility, and the way they interact with the pedestrian accessibility. Such incorporation of non-pedestrian mobility into WE would be an indispensable step to also take into account the quality of accessibility of not only neighbourhood-level destinations, but also those on the urban and metropolitan/regional level, which of course also play a relevant role in shaping overall urban capabilities of people.

We intend to pursue these objectives in our future work.

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## IMAGES SOURCES

Fig. 1, 2, 3, 4, 5: personal elaboration.

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