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Interactive localisation System for Urban Planning Issues

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1. Introduction

The paper discusses the benefits of specific user's oriented tools in urban planning processes, throughout the applications of an original system devised to define the localisation of urban services based on traffic distribution. Operative examples concern the Italian city of Pavia.

The system ULISSE (Urban Location Interactive System for SErvices), created by the author, uses a static model of network optimization which minimizes the global access cost (in term of time) faced by clients of a predefined service location. With a client-server structure and a friendly user interface, ULISSE provides in one single process all the classical results such as minimum paths research, definition of services influence area and access time to reach each service.

ULISSE is useful for planners to test traffic and environmental effects of localisation hypotheses, or to find the best localisation solution for specific urban functions in terms of accessibility. The paper shows examples of related applications on the city of Pavia: check of traffic pressure on environment; examination of efficiency of a new public mobility service (bus); best localisation of emergency services.

After a brief presentation of the cultural background about localisation models and urban planning, author describes: the analogical network, the calculation model, the system ULISSE and its applications.

2. Background

When approaching to regional and urban planning it is necessary to control a wide group of issues, themes, techniques and models. After the unpredictable transformations that the industrial revolution caused to the cities, modern urban planning was born as a new discipline that took its basis from architecture, engineering, hygiene, social science, aesthetics (Gabellini, 2001).

As any design process, urban planning is an extremely involved activity characterized by an iterative operative procedure strongly related to the designer's experience and know-how. For this reason, it cannot be described as a fixed series of phases, since even at intermediate steps, some corrections or modifications of the initial stage could become mandatory. Moreover, in the last decades, planning activity is oriented to divide the structural/strategic phase from the operative one (Mazza, 1997). With reference to the first phase, to define a

general shape of the territory (at the urban or regional scale), planners have to access to specific models and data processing systems with friendly user interface, while it is not essential to have very detailed and precise outputs. In other words, at the beginning of planning process it is important to have the order of magnitude of a complete variety of phenomena, which in the following phases can be completed in an exhaustive way.

2.1 Urban planning and location problems

Urban planning is the instrument to improve the best distribution of human activity on the territory (Benevolo, 1963). Planners developed localisation theory at the same time with the analysis of urban models since the mono-centre scheme deepened by Von Thünen (1826). His model of land use, that connected market processes and land use, was based on the assumption of maximizing the profits by the actors (farmers). Localisation was closely connected to the physical distance among different land uses. This deterministic and static concept took its stands on the principle of equilibrium status.

As a simplified scheme, it was related to a specific problem, and localisation itself must be considered as a particular theme into a wide-ranging and integrated model. However, at the urban scale, localisation theory always referred to the most relevant topics that strongly characterized the growth of the cities: first the agriculture land use, then the industrial areas and the big residential districts, until the commercial facilities and the distribution of urban public services (the service-oriented city).

Until 1954, general localisation theory has been related to a specific geometrical scheme (MacKinder in 1902 and Weber in 1909, which Christaller developed in his Central Place Theory in 1933), always in relation to new cities addressed to industrial settings, showing a restricted application domain. In 1954 Mitchel and Rapkin put in rigid connection land use and urban traffic also considering the modal split; this idea was used in the transportation plans of Chicago and Detroit, showing its practical use in city planning.

The Gravity Model by Lowry and Garin (developed in 1963), applied in Pittsburgh, offered a new understanding both in the field of a general urban model and in the definition of two sub-models regarding economic topics and localisation (assigning to this last theme a specific role). Even considering Von Neumann's and Morgenstern's criticism of the rational research of optimal solutions with the introducing of the concept of sub-optimal, urban models concerning location like problems spread in the last 40 years in many real contexts at urban and regional scale.

It is important not to merge localisation models with Operational Large Scale Urban Models (OLSUMs) that are mathematical simulation models describing comprehensive urban systems in great details (spatial, with a fine zoning of the territory, and functional, with a disaggregated account of urban activities and infrastructures)[1].

2.2 Localisation and accessibility in consolidated or historical cities

Application of location and accessibility models to real contexts implies the definition of the invariant conditions: consolidated and historical cities can not be warped with new mobility

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[1] Born in USA late '50s of the last century, these models flourishes at best in '60s and '70s, especially in UK in a large number of applications for sub-regional territorial planning. The critics of Lee in 1973, in his very famous paper "Requiem for large-scale models", helped the lost of interest in '80s and '90s. Since the end of the XX century a slow but growing interest can be remarked.

nets (neither underground for archaeology rests nor in elevation for landscape facets) and the search of the best location for destination places (such as public services) becomes as crucial as the improvement of the existing mobility net.

However, saturation of the built territory places further problems connected to the settled urban texture, when searching new locations for different functions (i.e. impossibility to change the land destination, cost of the area, compatibility among functions and existing buildings); in this context, it is inadequate to analyze an ideal distribution of functions based on a perfect mobility net.

For these reasons it is crucial to find sub-optimal solutions considering all the existing bonds, taking into consideration the best benefits for citizens; and citizens themselves try to attain the same goal. In fact, auto-organisation of all urban systems is nowadays a milestone of urban theories (Bertuglia, 1991, Donato and Lucchi Basili, 1996). Auto-organisation in some way can be associated to the old general notion of level of satisfaction on the same indifference curve from the Bid-Rent Theory (Alonso, 1964).

3. General description

Considering the cultural background, the system ULISSE (Urban Location Interactive System for SErvices) here described is based on a model developed to help the planners in finding the sub-optimal location for public services, considering the access time (that the users spend) as a function to be minimized (De Lotto and Ferrara, 2001).

The system is based on a static model associated with the analysis of location-like problems in an urban context (Drezner, 1995). This kind of problem is usually stated as follows: given m clients and n potential sites for locating prespecified facilities, taking into account the profit deriving from supplying the demand and the cost for setting up the facility in question, select an optimal set of facility locations (Dell'Amico et al. 1997).

In order to face the problem, a classical way is to define a global cost function associated with a certain location decision to be minimized. The cost function (named C in this paper) can rely, for instance, on the actual cost to build and run the facility together with the costs paid by the facility clients. The first type of cost can be reasonably regarded as independent of the site chosen for location and it is not so relevant in the minimization process. In contrast, the costs paid by the facility clients determine a distribution of the potential users on the territory, significantly influencing the traffic flows through the transportation networks connecting the possible facility locations.

In a real urban context, the concept of "client" can be naturally replaced with the concept of "vehicle" or "transportation means", since it is impossible to ignore the presence of an underlying transportation network through which the i-th client reaches the j-th facility (Cascetta 1990, Gelmini 1986). According to this basic consideration, the model proposed in this paper describes the road network as an electric network, enabling to evaluate the incremental traffic due to the access to the service. It describes each lane of a road as an oriented link, characterized by (time-varying) parameters, such as the travel time at given unsaturated conditions. Road intersections are represented as nodes with inflows and outflows. The propagation delays due to the presence of traffic lights (Cantarella and Festa, 1998) and non homogeneous flows are also taken into account. Finally the effect of the location of a facility in a precise site over the surrounding extended area is modeled.

The evaluation of the "temporal" use of the urban services is nowadays a fertile investigation field (Bonfiglioli, 1997).

The proposed model allows urban operators to retrieve a significant number of related results, such as the influence area of each service site, the degree of utilization of each service, the induced traffic flow increment on each road, the total cost of any given service location. Moreover, other relevant information can be obtained: the minimum path matrix for all the nodes of the network; the distribution of traffic due to a given origin-destination matrix. For these reasons, the proposed model can be the basis of an interactive software tool to be used as a decision support system, for instance, by Urban Planning Experts or Public Administrators.

3.1 The model
- In order to define the model (Biancardi, De Lotto and Ferrara, 2000), the problem is to consider M facilities Sj, 1≤j≤M of a certain nature to be located in a urban context under the following assumptions:
- each facility has the assigned capacity to serve Cj clients per hour;
- the spatial distribution of the potential clients over the urban territory is known (more precisely, the spatial distribution is discretized into elementary units called "cells");
- each cell i, $1 \leq i \leq N$, contains $p_i(t)$ potential clients (time function valued in number of clients per hour);
- the i-th cell is centred in the i-th road intersection, $1 \leq i \leq N$, N being the total number of roads intersections of the urban transportation network considered.

The p_i-th client's choice of the facility to reach is dictated by the cost to access the facility. In the case of transportation by means of private vehicles, such a cost can be modelled as directly proportional to the vehicle travel time $t(i,j)$ from the i-th road intersection, from which the p_i-th client starts, to the j-th road intersection, where the facility is located. The global vehicle travel time is obviously the sum of the travel times associated with the links of the transportation network through which the client moves to reach the facility.

The urban transportation network can be represented by a graph with N nodes and a set of oriented branches $l(i,j)$, $i \leq N$, $j \leq N$, connecting the i-th node with the j-th node, with the travel direction from i to j. Each link is marked by a label which defines the time-varying travel time law on the link itself as a function of the traffic volume $n_{ij}(t)$. To further refine the model of the access to a facility the following aspects should be determinable:
- for any node, the time to access the nearest facility;
- the nodes "captured" by a facility, and the corresponding burden in terms of clients. This, in turn, allows one to identify the influence area of each facility delimited, on the nodes map, by the border lines connecting the nodes with associated longer access time;
- the number of clients reaching each facility;
- the induced traffic variation in each branch of the transportation network;
- the total cost for the users which is implied by the selected facility location: this quantity can be computed by summing up all the access times associated with the nodes multiplied for the number of clients arriving from each node.

3.2 The access time computation
To determine the quantities indicated above, it is necessary to compute the travel time corresponding to each link of the considered transportation network, making reference to the particular traffic conditions in the time interval of interest. The travel time is provided as a function of the traffic intensity, of the parameters which determine the traffic fluidity, and

the possible presence of traffic light (Cascetta 1990). Yet, in our case, the point is to evaluate the traffic variation due to the location of a certain facility in a certain area.

Then, the mentioned function can be linearly approximated by the tangent in the operation point in question. More precisely, given the regular traffic in the considered link, one can determine the corresponding travel time $t_0\ (i,j)$. Then, the travel time after that the facility has been located can be written as

$$t(i,\ j) = t_0(i,\ j) + R[n(i,\ j) - n_0(i,\ j)] = t_0(i,\ j) + R_{ij}\Delta n(i,\ j) \tag{1}$$

where $\Delta N(i,j)$ is the traffic intensity induced by the considered facility and

$$R_{ij} = \left. \frac{dt(i,\ j)}{dn(i,\ j)} \right|_0 \tag{2}$$

Clearly, in searching the optimal facility location, it is the average access time to be crucial rather than the access time of a single client. This is the reason why a macroscopic continuous-time model turns out to be the correct choice. Moreover, since there are plenty of efficient commercial tools for the analysis of electrical networks, it seems natural to depict an electrical equivalent of each link of the transportation network (Figure 1) in fact representing this latter as an electric network.
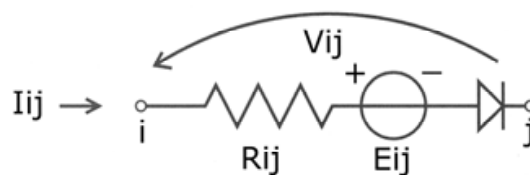

Fig. 1. The electric equivalent of a link of the transportation network

Note that, in the electric equivalent of a link, the presence of a diode guarantees that the current flows in a unique direction, and so does the traffic. The role of the voltage generator E_{ij} is to polarize the diode, thus representing the original travel time $t_0(i,j)$. The value of the resistor R_{ij} describes the dependence on the current I_{ij}, i.e., on the induced traffic intensity $\Delta n(i,j)$. Finally, the voltage V_{ij} represents the link travel time $t(i,j)$.

To determine the electric equivalent parameters corresponding to each link of the transportation network the following considerations can be made. The travel time, in seconds, along an urban road in regular traffic conditions is given by

$$t = \frac{3600\ \Lambda}{v} + t_s \tag{3}$$

where Λ is the length in Km of the path between two subsequent road intersections, v is the mean speed (Km/h) of the vehicles, t_s is the additional time due to the presence of a traffic light; t_s can be determined by well known empirical expressions which interpolate experimental data (Cascetta, 1990).

3.3 The model of the clients population

Relying on the electrical modeling equivalent, the clients' population can be modeled by means of ideal current generators which inject their current in the nodes of the

transportation network where the center of mass of each cell is located. The values of the currents (clients) are expressed in terms of the number of vehicles per hour (veh/h). They account for both the time distribution and the socioeconomic features of the clients population, this through a parameter related to the "appeal" of each facility. Note that with the term facility "appeal", author means the capability that a certain type of facility has to attract the clients' population. Data relevant to this capability can be acquired from national statistical studies centers (for instance, CENSIS). Generally, the available data provide the number of families attracted by the considered facility type, the number of persons for family unit, their distribution over the territory.

From the modeling point of view, each facility, regarded as incapacitated, is described by setting at a null potential the corresponding node where it is assumed to be located. The usage intensity of the considered facility is given by the sum of the currents entering such a node.

In alternative, as long as the facility has a limited capacity C_j (in clients/hour), the node where the facility is placed is not directly put to mass, but its connection to the null potential level is that depicted in Figure 2, where V_j is equal to zero until $I_j \leq C_j$, that is up to the facility saturation.
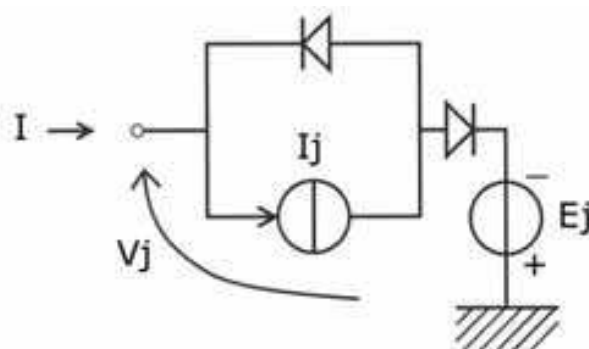

Fig. 2. The electric equivalent of a capacitated facility located in the j-th node

As soon as $I_j > C_j$, the diode is cut-off and V_j increases, practically re-distributing the clients among the other facilities, while keeping $I_j = C_j$. It is worth noting how this electrical effect resembles a waiting-in-queue time. More precisely, the queuing time of the j-th facility is modelled by the potential V_j.

E_j and the diode connected to it represent the facility appeal, measured as the extra-time the client accepts to spend to reach the service because of its appeal level, determined by statistical evaluation of fuzzy decision techniques (Lee and Zadeh, 1969) on clients' opinions.

3.4 Network solution

Given the parameters E_{ij} and R_{ij} for any link of the electric network representing the transportation network as a function of the operating point and of the dependence of the travel time on the traffic intensity, specified, in each node, the magnitude of the current generators modelling the clients population, and, finally, chosen a feasible location of the considered facilities, then, solving the network means to determine:

- the voltage at each node on the basis of which it is possible to quantify the access times, the border lines and the consequent partition of the network nodes which identifies the influence areas of each facility. Note that the facility access time is given by the

difference between the potential of the source node, i.e., the starting point, and the destination node, namely the node where the facility is located;

- the current in each link of the network which represents the traffic variation induced by the facility;
- the current in the node where the facility is located which describes the degree of utilization of the facility.
- It is worth noting that the network solution, relying on the analogy between voltage at the nodes and travel times, and on the analogy between currents in the links and induced traffic, leads to the determination of the minimum of the cost function C (Di Barba and Savini, 1996). Indeed, according to (Maxwell 1892), in a circuit made up by resistors, independent voltage and current sources, the currents tend to reach a distribution such that the dissipated power is minimum.

It is interesting to note that the total cost gives the number of vehicles the chosen location induces in the road network, so its minimization means the minimization of induced traffic pollution.

The advantage of the modeling analogy pursued is mainly tied to the possibility of exploiting the huge capabilities of commercial electrical networks analyzers to determine the relevant parameters characterizing the behavior of the clients' population with respect to a certain choice of the facilities location.

To this end, one of the most common tools is SPICE, which can be regarded as a standard all over the world to analyze and simulate electric networks (Nagle 1975).

The problem of solving the electric networks which accounts for the effects on the underlying transportation network of the facility location choice belongs to the class of problems that can be easily dealt with by SPICE. Moreover, the computing time is such that even a general-purpose PC can be used. Once that the features of the considered network have been acquired by SPICE, it computes the voltage at each node and the currents in the links.

4. The system ULISSE

The main purpose of ULISSE consists of creating an unmediated interaction with context data and of supporting the urban planner in the investigation of planning choice effects.

The first difficulty is that no circuit simulation program has a user interface that can be adapted to the urban context; the only option would be to translate the viability graph into a net-list describing the whole graph element by element, but this operation would lose any geographical information defining the location of the graph nodes.

On the other hand, Geographical Information Systems (GIS) cannot be of any help either, since the problem lies in the way circuit parameters are managed and related to geographical information. So the choice author made has been of developing an ad-hoc tool that could interact with SPICE to process the traffic network data, yet let urban planners investigate their alternatives in a totally graphical way.

A typical working session would begin with the designer setting up the planning scenario as follows:

- read a map of the town or the area to be studied;
- mark on the map, and enter the respective parameters of, facility locations, client cells (nodes that represent the population of a neighborhood), and transportation network additional nodes;

- define the connection arcs and enter their quantified values;
- run the simulation;
- get the results.

The session would then explore the planning opportunities in a three-step process: updating of project parameters, simulation run and result analysis.

It is clear that, while the simulation is performed by SPICE, all the tasks concerning the initialisation and the update of scenario parameters and everything that deals with the analysis of results are carried out by interacting with the user: it is precisely on these tasks that author focused trying to provide planners with a system that would not hinder their creativity, but rather that would foster it actively.

4.1 Effective viability graph input

The first step a planner takes, unless retrieving a previously saved project, is to set a cartographic map as the project graphic reference; all the other elements belonging the scenario will be placed according to the project map, as showed in Figure 3. ULISSE lets planners dimension the map by using a calibration command and then by defining a segment of known length.
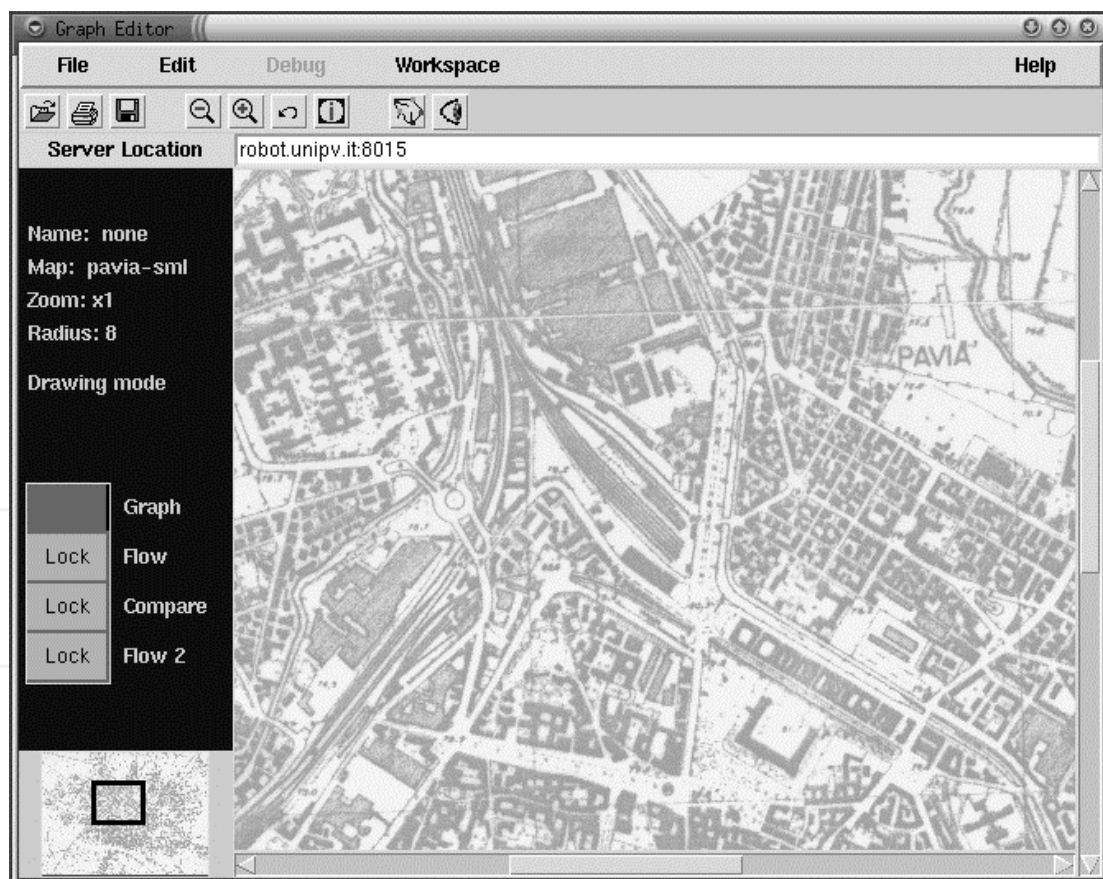
Fig. 3. Screen shot of ULISSE with the map of Pavia loaded

The next steps are the introduction of traffic junctions and branches (nodes and arcs of the urban graph), as shown in Figure 4. Actually, author established that the arcs of the viability graph could only be drawn by connecting existing nodes.

This operational choice in the ULISSE GUI was made in order to speed up all the project graph initialization: ULISSE users are thus free from a mandatory use of the toolbar to switch between arc and node input modes.

Once all the graph data are entered, the network is ready to be simulated and analyzed. Anyway, it is always possible to interact with the scenario by changing any of the graph parameters or by adding or removing nodes and arcs at any time.
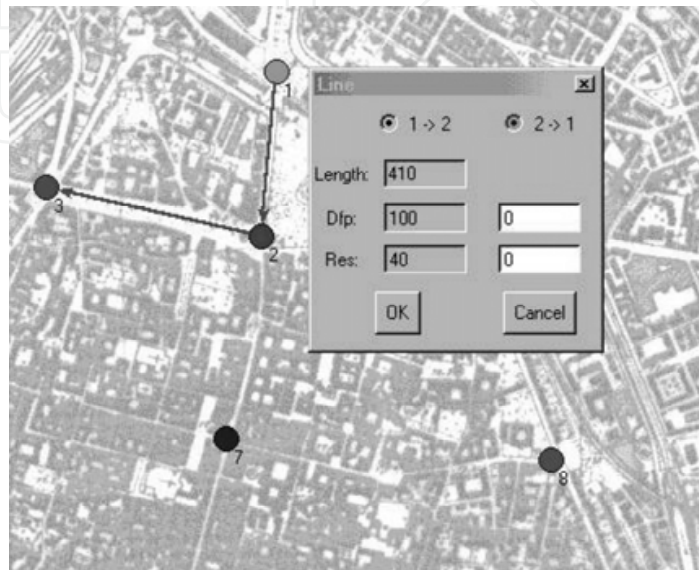

Fig. 4. Net building

5. Result and applications

ULISSE allows urban operators to retrieve a significant number of results, such as the influence area of each service site, the degree of utilization of each service, the induced traffic flow increment on each road, the total cost of any given service location.

Moreover, other relevant information can be obtained: the minimum path matrix for all the nodes of the network; the distribution of traffic due to a given origin-destination matrix.

These are typical results of an accessibility model, and ULISSE permits also to face many other urban subjects such as environmental sustainability of settled scenarios, minimum level of efficiency of public mobility services, localisation of emergency services. Applications of the system given in this paper concern the city of Pavia, in which interesting problems regard the reuse of ex-industrial areas and mobility in the centre of the city - related to its specific morphology and to the distribution of services, which is concentrated in this part of the town.

With reference to official traffic data (Urban Mobility Plan, Municipality of Pavia, 2008), in order to face different matters, the examples pertain two mobility nets: the first regarding the whole city (with 90 nodes), the latter focused on the centre (62 nodes).

5.1 Environmental impact check
The aim of this application is to verify the pollution effects due to a settled distribution of services located in two ex-industrial areas, now apt to an urban renewal: National Railway goods yard (node 23) and SNIA Viscosa (node 82) as shown in Figure 5.

In these areas residential buildings, public services and commercial ones will take place; ULISSE will check the environmental impact of the additional traffic driven by large retailers. With the optimal distribution of clients, ULISSE discovers critical pollution branches. Pollution index is measured by the traffic flow in a given branch in cars/sec multiplied by its path covered time. The model gives this quantity by the electrical power dissipated in the chosen branch: $P = V{\cdot}I$.
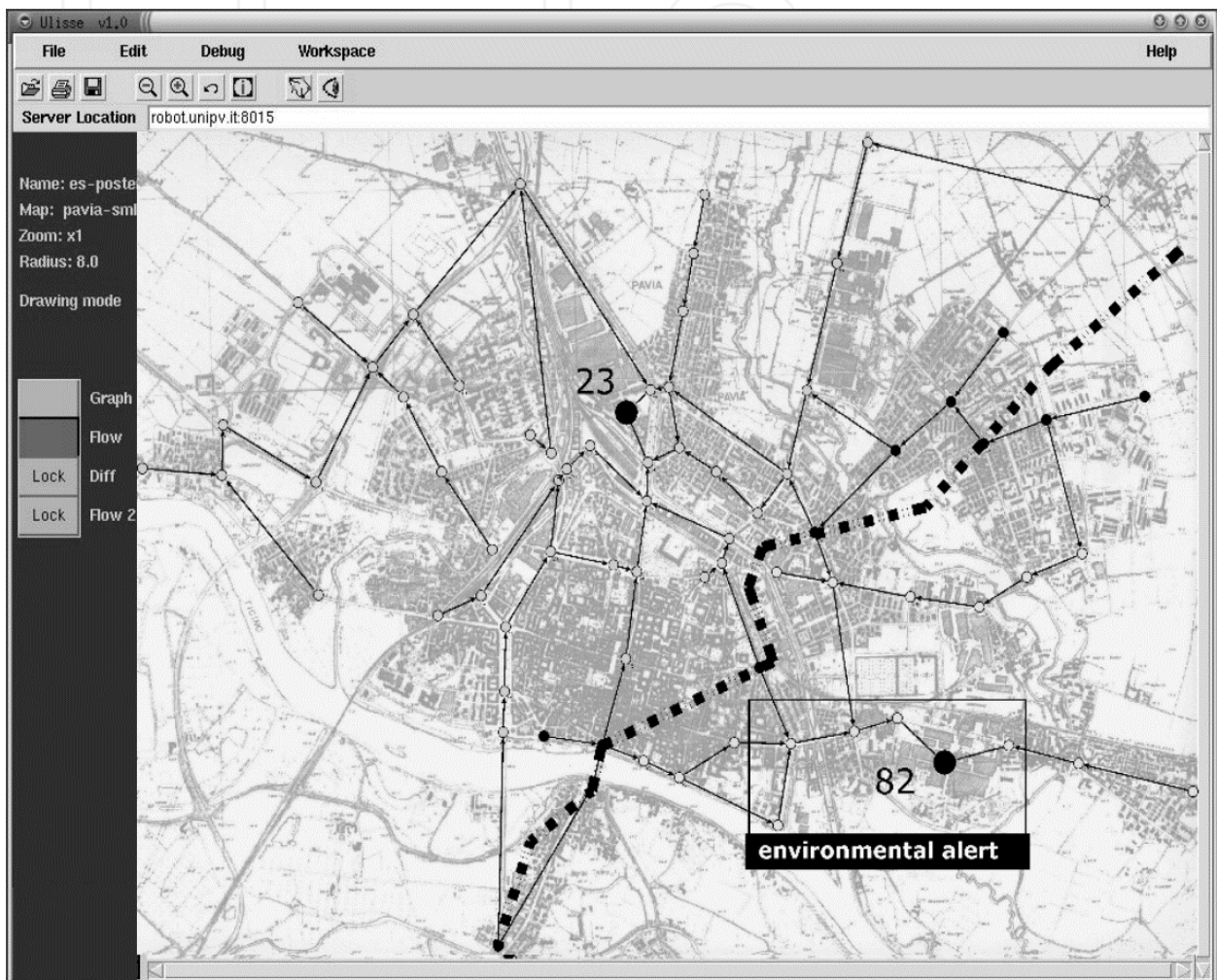

Fig. 5. Net with environment alert around node 82, and the influence zones divided by the ridge line

Figure 5 shows the plan of the city with the considered mobility net, the ex-industrial areas (site of new large retailers) and the distribution of influence areas for each service. The ridge line shows how node 23 receives a larger influence area: this result depends on existing traffic, which is usually dense in the south-east of the city (crossover traffic to east).

The system graphically signs a critical area in the net around node 82 (Figure 5 and 6):

- branch 38-65 (363 meters): pollution index equal to 30 cars – with a density of one car every 12 meters – situation of very dense traffic;
- branch 59-65 (760 meters): pollution index equal to 38 cars – one car every 20 meters;
- branch 65-66 (257 meters): pollution index equal to 27 cars – one car every 9.5 meters, close to complete saturation evaluated in one car every 7 meters (Figure 6).
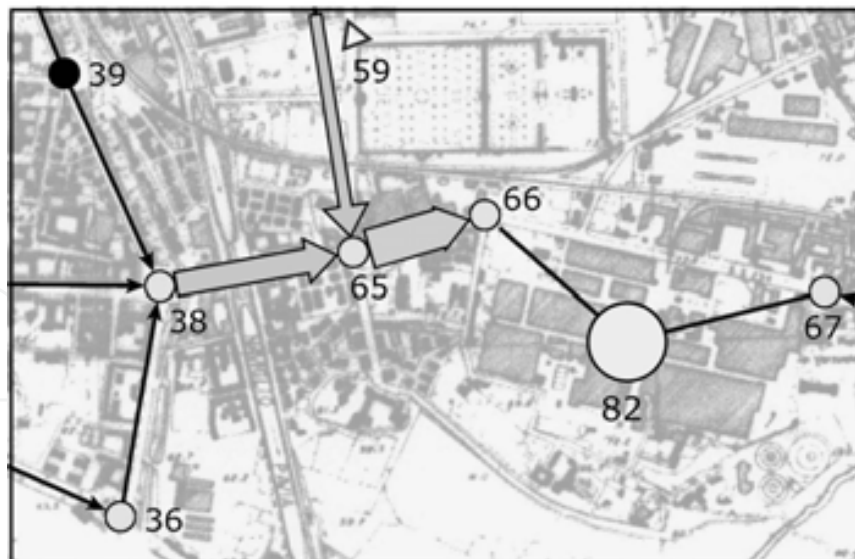
Fig. 6. Thematic zoom on critical branches

Considering the existing traffic, it is easy to have a holdup in branch 65-66, and these traffic conditions last for 25-30 minutes. Environmental consequences of the specific localisation choice are remarkable.

With this results, planners should find different solutions such as: modify of streets fluxes introducing a one-way branches; build new mobility branches (i.e. in the southern area); consider different localisation possibilities in the east part of the city.

5.2 Efficiency of public mobility services

In Pavia, mobility in the centre is critical especially considering the high number of services. Another application of the system is about the multi-modal mobility network, regarding private mobility, public mobility, pedestrians and bicycles. A recent strategy for traffic calming in historical cities is to define pedestrian areas in the city centre, with private movement permission only for inhabitants. Pavia is an archaeological site, and a subway is forbidden: the only feasible public mobility service is on the soil (bus). To reach central services in a reasonable time, bus net must be efficient and needs inter-modal nodes, characterized by parking areas and stations. In ULISSE, multi-modal nodes are considered as services images: destination nodes with positive voltage value (representing the time to reach the real service by bus). Here, this value corresponds to the efficiency of public lines to be minimized.

Taking into account a new net focused on the centre of the city, in which 9 external nodes connect to the remaining real net, 3 services are considered. Two in the centre (S1 and S2) and one further external (S3).

At first step 2 multimodal nodes are assumed, with an equivalent access time equal to 600 seconds each (waits + travels); the resulting total cost is equal to 74.564 second. If the whole net, with the same services, could be used by private cars the result would be equal to 55.545 seconds, and this quantity is considered as reference.

Considering 4 multimodal nodes (b1, b2, b3, b4), with an equivalent access time equal to 600 seconds (wait + travel) the resulting total cost is equal to 69.873 seconds.

Modifying the equivalent access time for each single multimodal node, and verifying the global cost, an acceptable result (global cost close to 60.000 seconds) is for public transport

working at 480 seconds (wait + travel) with 4 multimodal nodes, located as in Figure 7, with influence areas as shown in Figure 8.
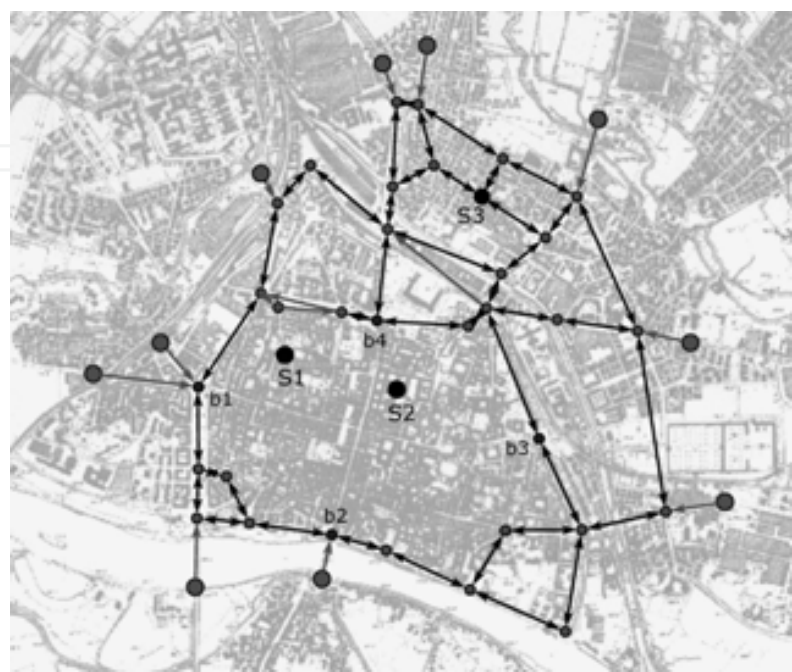

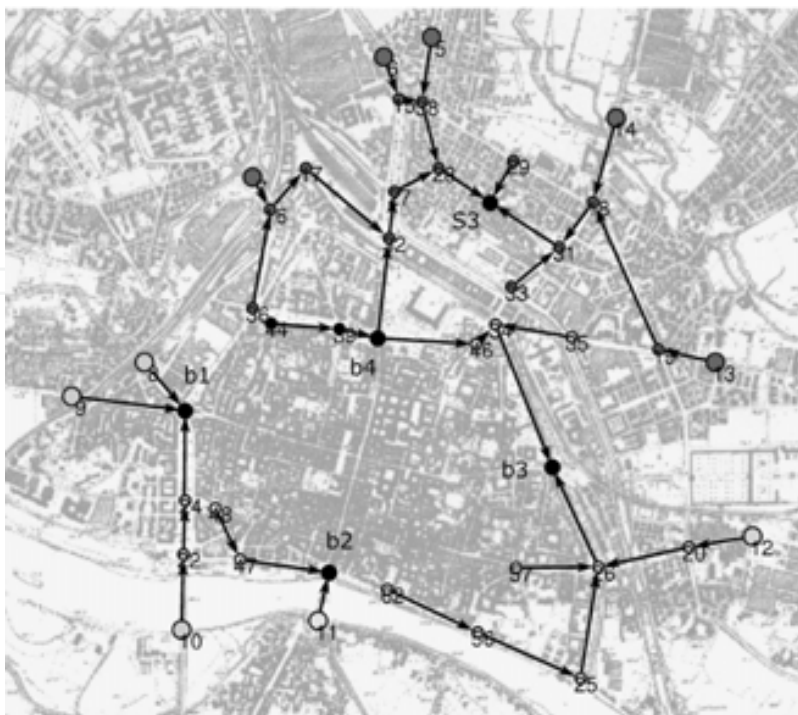Fig. 7. New net with multimodal nodes (bi) and services (Si)

Fig. 8. Influence areas with multimodal mobility net

5.3 Emergency services localization

To obtain the best location for emergency services, such as ambulance basis, the problem is minimizing the access time from each starting point to every possible destination. Compared with the previous nets, it means to change each node from client to service and vice versa. Because of the considered model (electrical analogy), it is possible to consider the net as perfectly symmetrical; in traffic meaning, authors have to consider only existing double sense streets, with similar characteristics for both directions. This simplification is perfectly plausible considering the usual pace of emergency means (acoustic and visual signals ease streets vacation).
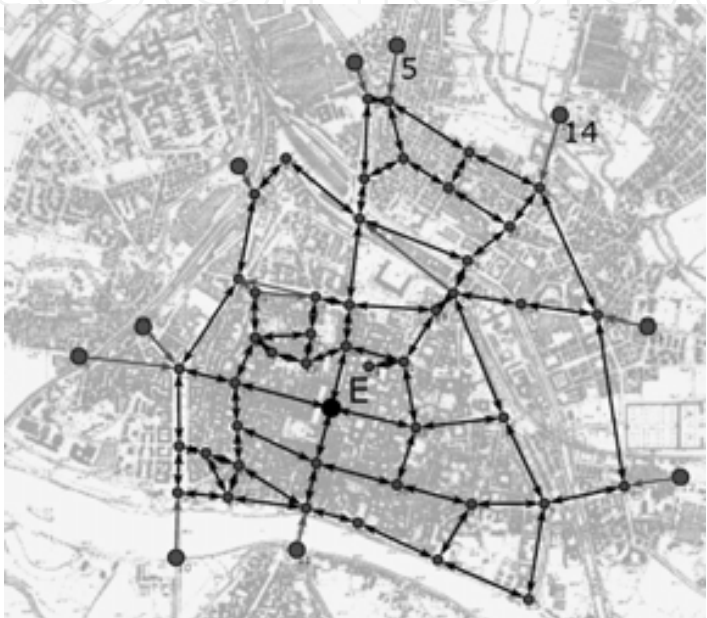
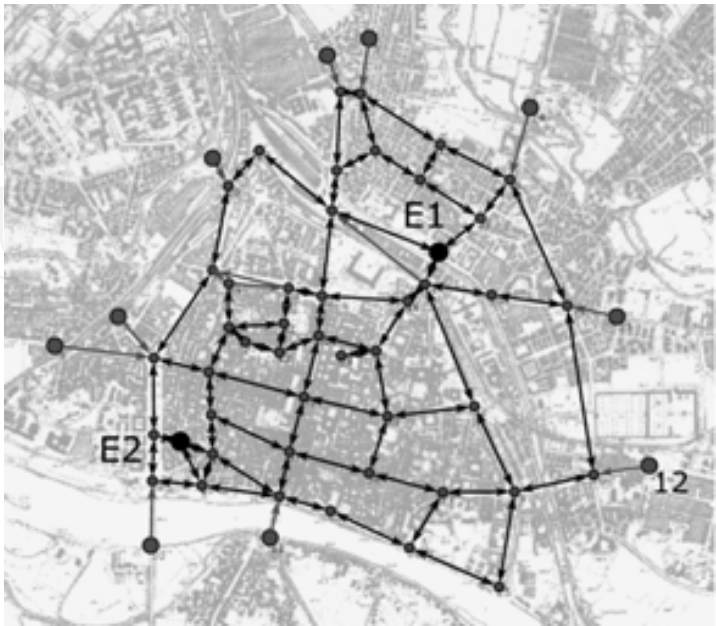Fig. 9. One single emergency base

Fig. 10. Two emergency basis

To test the net, in the first example it is considered one single "ambulance base", located in node E in the centre of the city (Figure 9). The access time is considered on the most distant nodes (net perimeter). In this first case, the maximum access time is at node 14, with 492 seconds, while for node 5 it is 468 seconds.

Then two emergency basis (E1 and E2) have been located (Figure 10). The maximum access time is at node 12, with 358,5 seconds.

Locating 3 basis (E1, E2 and E3), the system gives a general lower access time but, even moving the basis in every suitable place, for the further node it is impossible to decrease the access time lower than 302 seconds. In view of reaching a better result, four bases are situated considering all the possible locations. Comparing the different possibilities, with the best location choice, the maximum access time to node 13 with 220 seconds.
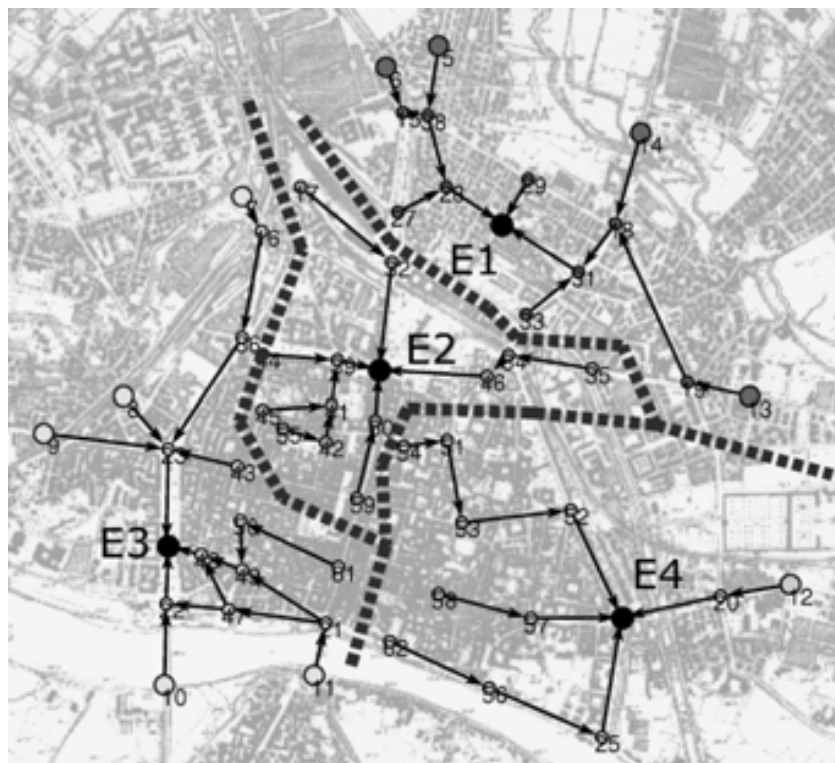

Fig. 11. Four emergency basis - influence areas and ridge lines

6. Discussion

The proposed model is an example of specific technical tools that planners can use to get fast and cheap outputs of localisation hypotheses during the first phases of planning processes. Urban planning process is extremely complex and when planners define the main structure of the plan, they need to verify the order of magnitude of the mass of parameters that are involved in the process. This operation is functional if planners can execute it by themselves. More specific analyses are required in other phases, after the main idea is defined.

ULISSE offers a simple way to calculate the impact on traffic due to location decisions (as well as localisation opportunities with given accessibility requirements) and can be considered as a tool of a comprehensive Decision Support System for urban planning decisions about location problems.

In the paper, urban services localisation is considered in terms of users' access time and of clients' population movement, taking into account the underlying transportation network connecting the various facilities.

Since ULISSE provides a series of standard location like results (such as the influence area of each service site, the degree of utilization of each service, the total cost of any given service location, the minimum path matrix for all the nodes of the network, the distribution of traffic due to a given origin-destination matrix) a significant number of related marks can be determined relying on the proposed model with a friendly interface.

The model has been tested in cities like Pavia, which is a medium city in Italian context; (basis dimensional data are: 70.000 inhabitants, 60 sqKm of Municipality extension, almost 15 sqKm of urbanized area).

Pavia road system is quite simple because there are:

- a clear scheme composed by the main inner circle (ancient walls location) and radial axes;
- a small number of streets (7) that connect the urban area to the external land.

The application of ULISSE in bigger or more complex contexts could provide less satisfactory results.

In fact, ULISSE needs information regarding traffic conditions in every branch of the considered net at the t_0 instant. In a bigger city (or road net), data collecting could be very expensive.

Considering the specific target of the system, which is to give to planner the order of magnitude of accessibility problems, the use of approximate data (taken from statistical elaborations) is acceptable only in limited contexts.

In ULISSE every node and every branch of the net must be entered manually, and for big nets the use of the system is expensive in term of data entry time.

Application of ULISSE in more complex nets could be affected by its simplified scheme of road intersections, which do not consider, in example, specific turns. In particular cases, road intersections can be considered as sub-nets, but in this way the intricacy of the net (and of relative data requirement) increases.

Further steps of development of ULISSE consist on giving to the user the possibility to choose different simulation models, i.e. dynamic models, with the same graphic user interface.

Actual traffic dynamic models require a greater quantity of data in comparison to the static model here presented, but surely can provide more precise outputs and consequently suggest a larger number of possible applications.

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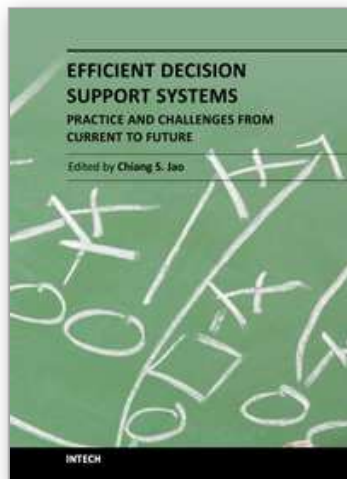
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