TeMA

Journal of
Land Use, Mobility and
Environment

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
Lycence: Cancelleria del Tribunale di Napoli, n° 6 of 29/01/2008

Editorial correspondence
Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"
Piazzale Tecchio, 80
80125 Naples
web: www.tema.unina.it
e-mail: redazione.tema@unina.it

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.

The Italian National Agency for the Evaluation of Universities and Research Institutes (ANVUR) classified TeMA as scientific journals in the Areas 08. TeMA has also received the Sparc Europe Seal for Open Access Journals released by Scholarly Publishing and Academic Resources Coalition (SPARC Europe) and the Directory of Open Access Journals (DOAJ). TeMA is published under a Creative Commons Attribution 3.0 License and is blind peer reviewed at least by two referees selected among high-profile scientists by their competences. TeMA has been published since 2007 and is indexed in the main bibliographical databases and it is present in the catalogues of hundreds of academic and research libraries worldwide.

TeMA

Journal of
Land Use, Mobility and
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.

TeMA Journal of Land Use, Mobility and Environment

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 . 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). The codex is not present on the pdf version of the papers.

TeMA

Journal of
Land Use, Mobility and
Environment

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

Contents

TeMA Journal of Land Use, Mobility and Environment

TeMA
Journal of
Land Use, Mobility and
Environment

TeMA
Journal of
Land Use, Mobility and
Environment

TeMA

Journal of
Land Use, Mobility and Environment

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

DOI available on the on-line version

SPECIAL ISSUE

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

Naples, 4-6 June 2014

SENSITIVITY ASSESSMENT.

LOCALIZATION OF ROAD TRANSPORT INFRASTRUCTURES IN THE PROVINCE OF LUCCA

LUISA SANTINI [a], SERENA PECORI [b]

[a] DESTEC- University of Pisa
e-mail: luisa.santini@ing.unipi.it

[b] DESTEC- University of Pisa
e-mail: serena.pecori@libero.it

ABSTRACT

The work, result of a research carried out in collaboration with the Chamber of Commerce of Lucca, aims to implement a tool for the evaluation of positive and negative effects arising by the “widening” or “new construction” of road transport infrastructures in the territory. In particular, with respect to the impacts generated by the project actions relating to the construction or widening of roads, the research has produced several sensitivity maps of the studied area and a graphical interface, accessible on the Internet and user friendly, allowing the synthetic evaluation of the impacts and the comparison of different scenarios

The implemented methodology, through the use of advanced tools for data management and processing and for impacts quantification and assessment, has allowed us to define a very detailed database related to all components of study area, both natural and anthropic, and to build a "synthetic sensitivity index", obtained from the combination of thematic information about each component and from the relationships that involve each others. It’s therefore to consider an indispensable support tool for planners and evaluators (eg. SEA procedures), but also for others users (eg organizations representing businesses, consumer associations, etc.). In fact it allows to acquire a deep knowledge of the area (environmental and economic resources), to verify the sensitivity of each part of the area with respect to a series of project actions concerning both the construction of new roads that the widening of the existing ones and finally to evaluate different localization scenarios for the same type of project or different impact scenarios for the same localization

KEYWORDS

Evaluation assessment, impact scenarios, localization scenarios, territorial sensitivity, road construction

1 INTRODUCTION

The present research has been developed within an Agreement between the Department of Civil Engeneering of University of Pisa and Chamber of Commerce of Lucca and is aimed to analyze and evaluate the sensitivity of the area of some municipalities of Province of Lucca with regard to the localization of road transport infrastructures.

The research has been developed by the authors of present paper and others (Claudia Casini, Massimiliano Petri, Diana Poletti, Alessandro Santucci and Diego Guidotti); it has been articulated in four steps, that we describe below.

The first step, named "Analysis", is aimed to individuate the actions related to different phases of construction of road transport infrastructures that can produce some significant impacts (positive or negative) on environmental system, and to create a territorial model through which to be able to develop the following phases of the evaluation: this first step is described in Chapter 2.

The second step, named "Individuation of Environmental Factors", is aimed to identify environmental and social-economic elements and sub-elements susceptible to be modified by the previously identified actions.

The third step, named "Individuation of Impacts", is aimed to identify impacts on environmental and territorial system during the phases of construction and exercise of road transport infrastructures, to quantify each of these impacts in a suitable numerical range and to represent them through georeferenced geographical maps.

Each of these impacts between actions generated in building and environmental elements is represented by a "X" within an "impacts Matrix" and will correspond to a georeferenced geographical map of sensibility of the whole study area, in which to each cell correspond the value (included in the range 0-1) of the impact produced by that action on that environmental factor.

The fourth step, named "software construction", is aimed to built a graphic interface in which, after drawing the layout of a road transport infrastructure, we can visualize, for each environmental factor, a positive or negative index able to quantify the impact of that specific infrastructure on that specific environmental factor: these impact indexes can be calculated considering different points of view, by assigning different weights to the different environmental elements of building actions. The steps 2, 3 and 4 are described in Chapter 3; in Chapter 4 an 5 we describe the analysis related to two specific Environmental Elements, namely "Air" and "Social-economic System".

2 ANALYSIS AND MODELING OF THE STUDY AREA

2.1 KINDS OF INFRASTRUCTURES AND PROJECT ACTIONS

The classification of infrastructures is the same reported between the Ministerial Decree 5/11/2001 "Functional and geometric rules for road infrastructure construction". In particular we consider:

1) highways and main roads presenting an high capacity and checked accesses, with daily flows between 30.000-40.000 vehicles/day;
2) primary roads, urban and not, with same dimensions of roads in 1) but with continuous accesses along the path and daily flows between 20.000-30.000 vehicles/day;
3) secondary roads with smaller dimensions, with daily flows between 10.000-20.000 vehicles/day.

The impacts have been calculated considering two different kinds of works, namely "New construction" of new roads or "Widening" of existing roads: therefore, six typologies of interventions have been considered (3 kinds of roads for 2 kinds of interventions). In order to select project actions related to the two kind of interventions described below, an analysis of all steps (construction, exercise, maintenance) related to the working of road transport infrastructures have been performed, obtaining six specific actions, namely:

- phase of yard: cleaning of the site, excavations or terrain modifications, material provisioning and disposal;
- phase of exercise and maintenance: ground consumption, traffic flows, variation of accessibility.

2.2 THE STUDY AREA

As study area we have considered those territories of Province of Lucca that are interested by a diffuse and massive urbanization, mainly for what concerns industrial, commercial and tourist locations that present relationships in order to the development of activity that can have impacts on traffic an economic systems. The resulting municipalities are: Lucca, Capannori, Montecarlo, Altopascio, Massarosa, Viareggio, Camaiore, Porcari, Pietrasanta, Forte Dei Marmi, Seravezza, Pescaglia, Borgo A Mozzano, Villa Basilica.

2.3 INPUT DATA

Data have been collected mainly within G.I.S. of Regione Toscana, Province of Lucca and Chamber of Commerce of Lucca: for some themes we performed further elaborations, starting from the rough data, such to be able to produce, by integrating different sources, information more suitable for the aim of this research.

In particular, data coming from the Register of enterprises have a very thorough detail and contain information about each single activity located within the study area. They are classified according to the ATECO 2007, that include: Commerce, Industry and Craftsmanship (both Individual Firms and Society) Tertiary, Transports, Tourism and Public Exercises.

2.4 MODELING OF THE STUDY AREA

The different kind and shape of input data has made necessary to perform a preliminary analysis aimed to homogenize them and make them comparable to each others: to this purpose we created the modeling converting all data into the raster format, to make homogeneous data coming from different typologies, scales and geometric primitives.

The conversion has been performed using a reference grid that divides the territory in square cells (10 meters sided): such trial produced in some cases the loss of a part of the information, but considering the high level of resolution (10 meters), such disadvantage can be neglected. The conversion from vector to raster consists of associating to every pixel a value that must be representative of the whole surface of the pixel: the conversion error mainly depends on the pixels that presents a "mixed" information, because their information must be simplified and each of them must be assigned to one single class.

In this research we both used the "Criterion of prevalence" for some information like "land use" (the pixel has been assigned to a class if the majority of the pixel surface reverts in that class) and the "Criterion of preference" in the cases in which the importance of certain uses is clearly superior to that of others (for instance if also only a small part of the pixel is interested from a tie, the whole pixel has been assigned to the class of the tie), in relationship to the importance of the various environmental factors.

2.5 MULTICRITERIA ANALYSIS

Once the database is completed, it is necessary to establish suitable criteria and methods able to quantify the sensitivity of the various parts of the analyzed territory with reference to every possible interactions between environmental elements and project actions.

It is also useful to consider the possibility to vary both points of view and judgment criteria by using "multicriteria Analysis", a comparison procedure based on the modeling of the preferences of a plurality of subjects and points of views that can interfere within the decisional trial. Such a procedure, beginning from a sets of decision-makers that must choose among a set of alternatives, is aimed to reach a greater coherence among the multiple objectives and to define what can be called the "ideal" compromise: this is achieved by defining a set of criteria (relating to social, environmental, economic, etc.) through which you can 'weigh' the various alternatives. In our case, the problem is to identify, among many localization possibilities, those that are preferable, with particular regard to those relating to environmental and economic aspects.

Implementation and use of multi-criteria analysis are proposed in order to provide the user with a tool useful for the evaluation of new infrastructure, in the context of a territorial system in which many changes may occur that may change the weights that various system users, as businesses, citizens, enterprises attribute to different factors at play.

3 CHARACTERIZATION OF ENVIRONMENTAL ELEMENTS AND IMPACTS

The second step has led to the identification of the main components likely to be changed both positively and negatively by the actions related to road infrastructure change. In particular, we analyze separately environmental elements (air, climatic factors, water, soil and subsoil, vegetation and flora, fauna, ecosystems, landscape) from socio-economic ones (socio-economic, demographic and sanitary arrangement, cultural heritage).

Each component has been divided in sub factors, fit to detail the description of the component itself, especially in relationship to the modifications induced by the selected actions: the components considered meaningful for the study area and the relative factors are shown in Table 1.

The third step has the aim of identifying the impacts generated by the various actions on the environmental components mentioned above, and the criteria and indicators in order to quantify these impacts in an appropriate numerical scale and represent them within the study area through geographical georeferenced maps. In order to identify the impact of each project action on each of the factors characterizing the environmental components, a matrix has built with two general revenue (see Figure 1) corresponding to actions/parts of the work and environmental factors: within the matrix are highlighted intersections where it is considered that the specific action could produce an impact on the corresponding environmental factor.

The impacts were quantified by constructing indicators that use variables of different nature, that are often impossible to measure in the conventional manner, such as data derived from the census, pollution levels, the presence of constraints, etc.: each indicator was built on the basis of elements and phenomena considered significant for each factor, derived from the literature and from actually available data.

The matrix of impacts (Figure 1) is essentially the same in the case of construction or renovation/expansion of existing roads, in the sense that the existence or less of the impact does not vary in the two cases: what it is very different is the quantification of the impact with regard to a specific intervention.

However, the innovative element of this work is not related to the construction of indicators related to various factors or to their quantification aspects, but to the fact that each identified impact is "spatialized" in the study area to a very thorough level of detail: in fact, to each squared cell of 10x10 meters is associated a specific value for each impact identified within the matrix. So, to each relevant interaction between design action and environmental factor (impact) is associated a geographic georeferenced map of sensitivity (raster) of the whole study area: in other words, each raster represents the spatial distribution of the considered impact within the study area. Each map, therefore, represents the sensitivity of a single environmental factor with respect to each of the project actions that characterize the infrastructure under consideration. To get the full impact due to all the actions on all the components, synthesized through the '"synthetic index of sensitivity", you must add the single maps of impacts, which, however, are not comparable in the sense that scales and measure units of the attributes are different between them: for this reason, after to the quantification is necessary to proceed to the standardization of the impacts.

COMPONENT	FACTORS	
AIR	F1	Air quality
	F2	Acoustic climate
WATER	F3	Hydrograph / hydrology
	F4	Water quality
SOIL AND SUB SOLI	F5	Geo morphologic dangerousness
	F6	hydraulic dangerousness
	F7	Land use / pedology
	F8	Geology / Geotechnical
FAUNA	F9	Species in soil and subsoil
	F10	Species in water / soil
	F11	Species in air
	F12	Species in the water / air
FLORA	F13	Terrestrial plants
	F14	Habitat
LANDSCAPE	F15	Visual sensitivity of the landscape
	F16	Qualifying elements of the landscape
DEMOGRAPHIC STRUCTURE	F17	Commuting
HYGIENIC- HEALTH STRUCTURE	F18	Health status and well-being of the population
TERRITORIAL STRUCTURE	F19	Infrastructure system
SOCIO-ECONOMIC STRUCTURE	F20	Commercial activities
	F21	Transport companies
	F22	Tertiary sector
	F23	Tourism and public services
	F24	industrial activities
CONSTRAINS	F25	Parks and protected areas
	F26	SCI,SRI, NP
	F27	Wetlands
	F28	Monumental constraint
	F29	Landscape constraint
	F30	hydro geological r constraint
	F31	Areas of respect and others areas

Tab. 1 Factors characterizing environmental and socio-economic components

Standardization is necessary to make comparable and commensurable the different factors through the conversion of the different dimensional scales to a common dimensionless scale, expressed in the range 0-1, where the value "0" corresponds to the minimum sensitivity value within the study area with regard to the localization of road infrastructures (potentially suitable site) and the value "1" to the highest sensitivity (potentially unsuitable site).

After standardization procedure, the final raster, for each environmental component, have been organized into a software that presents a graphical interface through which the user can to interactively calculate the value of the index of sensitivity. The user is actively involved in the process because the quantification of the synthetic sensitivity index is done through a "weighted combination" of the various components that he can drive by assigning a weight in relation to the relative importance that each component assumes in respect of others and by constructing personal evaluation criteria.

		AR	AR	AQ	AQ	SS	SS	SS	SS	FA	FA	FA	FA	FL	FL	PS	PS	AD	AI	AT	ASE	ASE	ASE	ASE	ASE	VL	VL	VL	VL	VL	VL	VL
		F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31
		Air quality	Acoustic climate	Hydrograph / hydrology	Water quality	Geo morphologic dangerousness	hydraulic dangerousness	Land use / pedology	Geology / Geotechnical	Species in soil and subsoil	Species in water / soil	Species in air	Species in the water / air	Terrestrial plants	Habitat	Visual sensitivity of the landscape	Qualifying elements of the landscape	Commuting	Health status and well-being of the population	Infrastructure system	Commercial activities	Transport companies	Tertiary sector	Tourism and public services	industrial activities	Parks and protected areas	SCI,SRI, NP	Wetlands	Monumental constraint	Landscape constraint	hydro geological r constraint	Areas of respect and others areas
A1	Cleaning up of the site					X	X	X		X	X	X	X	X		X	X															
A3	Material handling of the ground			X		X	X		X	X	X	X	X	X																		
A6	Provisioning-disposal of materials	X	X							X	X																					
A7	Presence of the work- land occupation				X	X	X	X	X	X	X				X	X	X									X	X	X	X	X	X	X
A8	Presence of the work- traffic flows	X	X		X					X	X								X	X												
A9	Presence of the work- Changes in accessibility																	X			X	X	X	X	X							

Fig. 1 Impacts matrix

The system also allows to use a preset criterion based on a balanced scenario in which the same importance has been given to all the components.

At the end of the process is possible to see not only the final synthetic index but also get a more detailed form where to each component is assigned a number that quantifies the sensitivity of the territory in relation to the specific drawn path.

A detailed description of all functions of the software and the graphical interface would require a detail that is not possible here and that can be treated and investigated in a subsequent context.

Anyway, it is very useful to describe, in the next two Chapters, the detailed methodology used in relation to two environmental components chosen as an example, namely "Air" and "Socio-economic System".

4 AIR

The "Air" component has been divided in two factors, namely Air Quality and Acoustic Climate.

AIR QUALITY: for the characterization of this factor we used data of traffic flow quantities (coming from various sources), road characteristics (dimensions, conditions) and net and traffic flow characteristics (speed). The pollutants considered are CO (carbon monoxide), VOCs (volatile organic compounds), NOx (nitrogen oxides) and PM10 (Particulate Matter), which were characterized using a methodology that refers to the CORINAIR project (Coordination - INformation - AIR), an European inventory of emission factors from different kinds of production processes and of industrial and domestic energy conversion (website: http://reports.eea.eu.int/EMEPCORINAIR3/en/): we considered the sub model relating to road transport.

The CORINAIR methodology for estimating emissions from road traffic is based on the calculation of emission factors of the major pollutants on the basis of the definitions of the following variables:

- Type of vehicle
- Fuel type
- Displacement (for passenger vehicles and motorcycles)
- Weight (for freight transport vehicles)
- Year of manufacture
- Speed
- Execution of the heating cycle
- Type of road (urban, rural, highway)
- Length of the path
- Air temperature

Some examples of calculation of the issue factor for diesel motorcar:

$$CO\ (g/km) = 0.9337 - 0.0170\ V + 0.0000961\ V^2$$

$$VOC\ (g/km) = 0.1354 - 0.0022\ V + 0.0000113\ V^2$$

$$NOx\ (g/km) = 0.918 - 0.014\ V + 0.000101\ V^2$$

$$PM\ (g/km) = 0.1208 - 0.0277\ V + 0.0000226\ V^2$$

Below are reported some examples of calculation of the emission factor for diesel passenger cars: for the calculation the "Set of Car" of province of Lucca in 2010 has been used. The sensitivity in each cell is given by the sum of:

- Air Quality to the actual state calculated beginning from the existing roads by applying the model Corinair
- Impact of the road, calculated considering the distance of the receptors (buildings): in this case, the value of maximum sensitivity will be assigned to the cell where the receptor is found and will correspond to the eventuality that the infrastructure is realized very near to the receptor itself, while the least (void sensibility) value will be assigned to the cells that are found to a distance greater than the distance of concentration decadence for the examined pollutant.

ACOUSTIC CLIMATE: For the characterization of this factor we consider that the impacts are mainly influenced by the kind of infrastructure and by the distance of each cell, in which some infrastructure can be built, from residential and sensible receptors: so for each cell we consider the distance to the closest receptors (categorized by type according to their sensitivity to noise as residential buildings, public parks, schools, hospitals, etc.) and each cell is associated with a sensitivity value that is directly proportional to the sound pressure level in dB (A) calculated on the receptors. Table 2 reports, for each type of road, the minimum distance decay over which you have no disturbing noise level for the various kinds of receptors (sensitive or residential).

Each receptor is associated with the maximum value of the cell where he is located (assuming that the road can be built in this cell) and progressively lower values to further cells: if a cell is in the range of influence of the more receptors will be assigned a value equal to the sum of the values of sound levels relative to each individual receptor that is located nearby. The sensitivity value in each cell will therefore be greater the smaller will be the distance from the individual receptors and the greater the number of the receptors involved.

Adding up the various cells of the sensitivity of air quality and the Acoustic climate we obtain the overall sensitivity of the air component (Fig. 2).

NOISE SOURCE	EMISSION	DECAY DISTANCE FOR RESIDENTIAL RECEPTORS	DECAY DISTANCE FOR SENSITIVE RECEPTORS
Roads 1)	76 dB(A)	250 m	1000 m
Roads 2)	75 dB(A)	220 m	900 m
Roads 3)	73 dB(A)	85 m	500 m

Tab.2 Distances of decay for various types of road and receptors

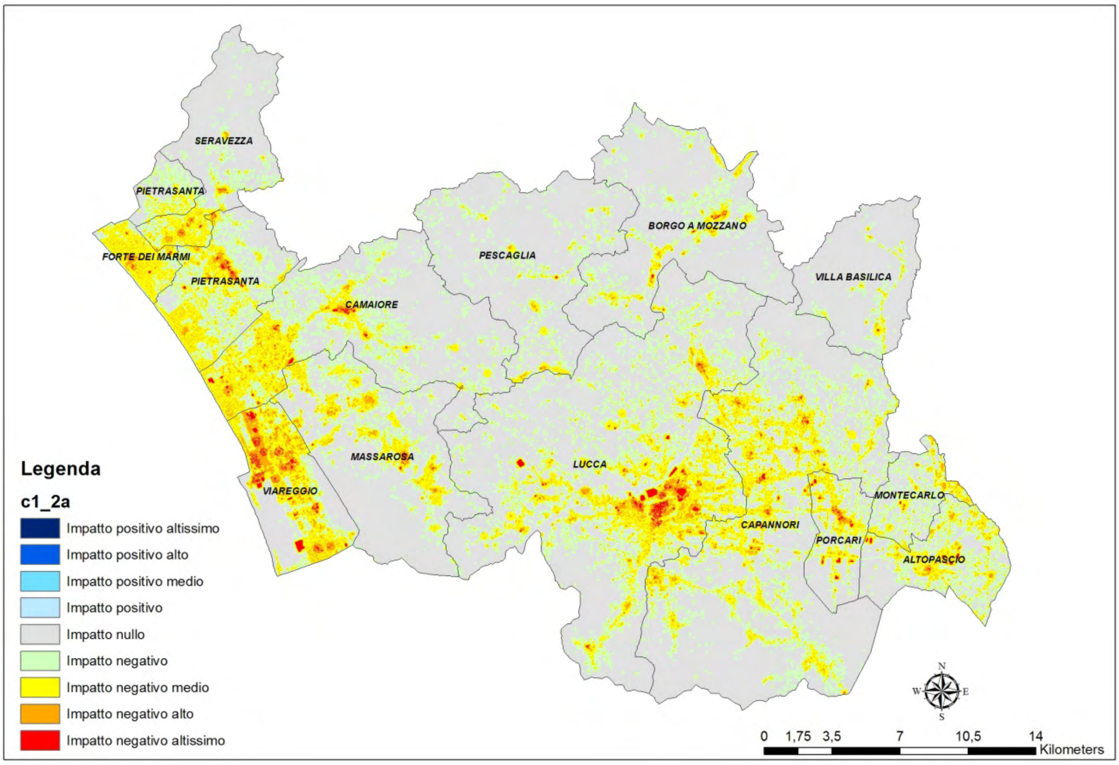

Fig 2 Map of overall sensitivity of the air component

5 SOCIO-ECONOMIC SYSTEM

The most significant impact that the construction or widening of a linear infrastructure causes on the socio-economic system mainly concerns the variation of the accessibility to the various enterprises.

Every economic activity generates and/or attracts a certain amount of traffic that depends on the type of work performed and on the number of employees working within the productive activity: therefore it is assumed that the increase of accessibility that follows the construction of an infrastructure is much more positive, the greater is the amount of traffic generated and/or attracted by the activity itself. In other words, for the same increase of accessibility, will be more favoured (and thus will be associated with a greater positive impact) those productive activities characterized by higher levels of traffic. For the characterization of the socio-economic system component data from the Business Register of the Chamber of Commerce have been used, in which each firm is classified with a code derived from the classification ATECO 2007 adopted by ISTAT as from 1 January 2008, that is the national version of European nomenclature, Nace Rev. 2, published on the Official Journal December 20, 2006 (Regulation (EC) n.1893/2006 of the European Parliament and of the Council of 20/12/2006).

The sensitivity analysis has been developed following the three phases described below.

LOCALIZATION OF ECONOMIC ACTIVITIES: all the economic activities were localized on the territory of the study area (Fig. 3) through a process of geocoding that allows to associate each economic activity with its street number along the infrastructures of the existing road network. The goodness of the result obtained by the process of geocoding depends on the quality of the input address to be processed; if it is in good condition (presence of all the fields, lack of misspellings, etc..) the activities can be georeferenced up to 90-95% of total. In this case the match between the activities and the corresponding street numbers was equal to 92% of the total, but, to improve the quality of the starting data, it was necessary to normalize manually a large number of records: the companies which had been discarded by the automatic procedure was subsequently reinserted manually.

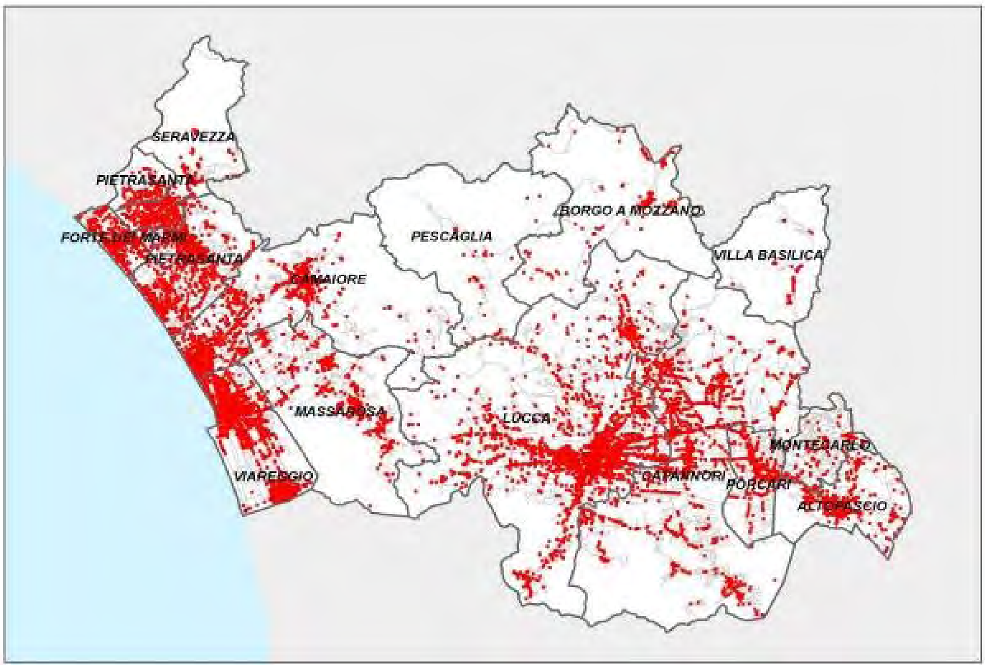

Fig. 3 Georeferencing of activities

CALCULATION OF INDUCED FLOWS: for the calculation of traffic flows, the socio-economic system has been divided into five factors: commercial activities, industrial activities, transportation companies, tertiary, tourism sector and public exercises; each factor was in turn divided into sub factors (Tab. 2) according to flow of traffic generated by each type of activity, calculated using the method Trip Generation. This method represents the most commonly used model for the calculation of the flows attractive potential related to georeferenced activities, ie models of generation of movements: in particular it refers to the american studies contained in the Trip Generation Manual (eighth edition) edited by ITE (Institute of Transportation Engineers), which contains more than 900 classes of activity (Figure. 4) for which are available calibrated models on actual detections of flows attracted from each activity class.

Institutional (Land Uses 500-599)

CODE	LAND USE
501	Military Base
520	Elementary School
522	Middle School/Junior High School
530	High School
534	Private School (K-8)
536	Private School (K-12)
540	Junior/Community College
550	University/College
560	Church
561	Synagogue
565	Day Care Center
566	Cemetery
571	Prison
590	Library
591	Lodge/Fraternal Organization

Medical (Land Uses 600-699)

CODE	LAND USE
610	Hospital
620	Nursing Home
630	Clinic
640	Animal Hospital/Veterinary Clinic

Office (Land Uses 700-799)

CODE	LAND USE
710	General Office Building
714	Corporate Headquarters Building
715	Single Tenant Office Building
720	Medical-Dental Office Building
730	Government Office Building
731	State Motor Vehicles Department
732	United States Post Office
733	Government Office Complex
750	Office Park
760	Research and Development Center
770	Business Park

Fig. 4 Example of codes in the ITE manual

For this purpose are mainly used linear or logarithmic regression models able to predict the number of flows generated and attracted to each category of activity: for each category of activity, flows are modified also on the basis of their size class, represented by independent variable, that may be the number of employees, the surface, the number of beds or other. For this work was therefore necessary to group all the activities within the area, each one characterized by a ATECO code, into homogeneous classes from the point of view of the traffic flows generated, and each identified sub factor was associated with a code of the ITE manual, suitably adapted from the American context to the Italian one. The overall flow induced in each cell was calculated as the sum of the number of employees associated with each activity, multiplied by the unitary flow of each employee.

In Table 3, for each factor are shown the values of the induced traffic calculated by the ITE method, considered in the cell where the activity is localized: the values express the number of vehicles entering / exiting the cell.

FACTOR	SUB FACTOR	INDUCED TRAFFIC FLOW
commercial activities	wholesale trade	15 vehicles/employee
	retail trade - large retailers	87 vehicles/employee
	retail trade - small and medium sized shops	40 vehicles/employee
transportation companies	freight transport	8 vehicles/employee
	maritime transport and Domestic Navigation	8 vehicles/employee
	air transport	8 o vehicles/employee
	management of parking and garages, rental	8 vehicles/employee
industrial activities	heavy Industry	3,8 vehicles/employee
	light Industry	5 vehicles/employee
	manufacturing industry	5,5 vehicles/employee
	warehouses, storage	2,75 vehicles/employee
tourism sector and public exercises	accommodations	20 vehicles/employee
	catering	25 vehicles/employee
	public exercises related to tourismo	60 vehicles/employee
	camping sites	10 vehicles/employee
third sector	office activity not open to the public	4 vehicles/employee
	services provided in public offices	35 vehicles/employee
	commercial services	40 vehicles/employee
	recreation services	53 vehicles/employee

Tab. 3 Values of traffic flows induced in the cell where there is activity by type of activity

Starting from the localization of the individual activities, the values of induced flow decrease depending on the type of road, so that for roads of more relevant size and importance we had a larger radius of influence and vice versa; for existing roads is assumed that the value is, for the same type, half that of the streets of new construction. In each cell the values within all influence radiuses were summed. Figure 5 shows an extract of the map of induced flows in the area near the center of Lucca: the larger circles are associated with the higher values of induced flow and vice versa.

CALCULATION OF ACCESSIBILITY: Calculating the accessibility means to calculate the centrality of the area with respect to the destination or origin elements of the calculation (for example it's possible to speak of accessibility with respect to industrial activities, to health services, to the school system and so on). The calculation consists of the construction of the matrix of distances (measured in travel time on the graph); this matrix shows for each cell “i” “j” the travel time from zone “i” to zone “j”.

The active accessibility is used to understand how an area is accessible as the origin of travel towards some defined objectives; is obtained by calculating the O / D matrix (origin destination) of the travel time from each census section to all the other starting from the assigned road graph, that is that resulting from the regional model.

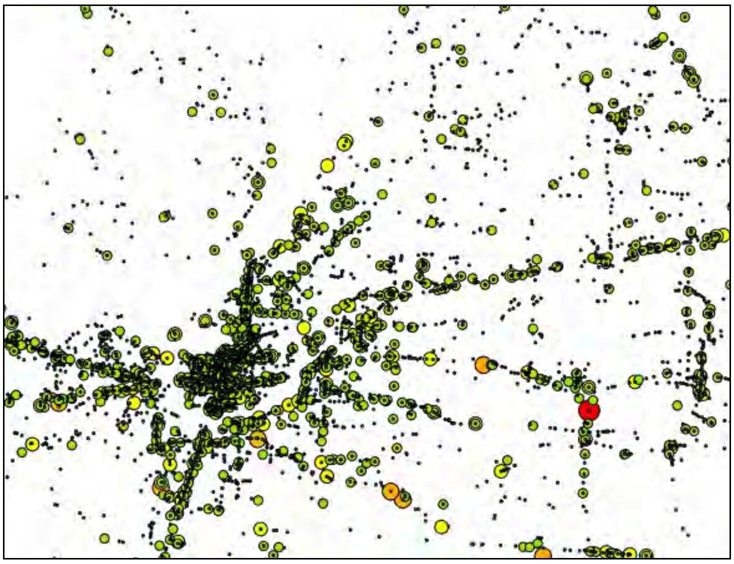

Fig. 5 Detail of the map of induced flows (near Lucca)

The resulting matrix is therefore a square matrix that measures the time it takes to arrive from each section to the others: calculating the marginal row and dividing by the number of zones we get an indicator of the average time to access to the other sections starting from the section of the i-th row.

In this case, the small size of the cell has made it almost impossible to computationally calculate the O/D matrix to the level of disaggregation of each single cell, therefore accessibility active was calculated on the basis of the census sections homogenized for territorial dimension (an aggregation of sections of urban census was carried out to homogenize the territorial dimension of the latter to the average territorial dimension of the suburban sections).

The traffic data used for the calculation are the peak data relating to the time period between 7.00 am and 8.00 am: in this case for all of the census sections of study area starting from all the other sections of the Tuscany Region was calculated the map of accessibility (Figure 6). For the evaluation of the sensitivity of each cell with respect to the construction of new roads were combined, in each cell, the results of the induced flows, in relation to any kind of economic activity, with the data of the accessibility in the current state; to this purpose was used the criterion that the positive sensitivity is greater the greater is the flow indicator associated with each cell, and the lower the accessibility of the cell itself.

By summing the values of the global indicators of the advantage of all cells crossed by the road, the value of which depends on the distance from the firms localized in the area and the value of the flow associated with each firm, is obtained the overall benefit induced by any road layout. The Figure 7 shows the map of the overall sensitivity of the socio-economic system.

6 CONCLUSIONS

Allowing a preliminary analysis and assessment of the environmental and socio-economic benefits of the "widening" or "new construction" of road transport infrastructures, the built instrument constitutes an important tool to support the administrations that deal with analysis and territorial policies.

In fact, on the basis of the sensitivity maps we can evaluate immediately what will be the positive and negative impacts of the proposed road, on each environmental component and, through the composite index, also on the global territorial system

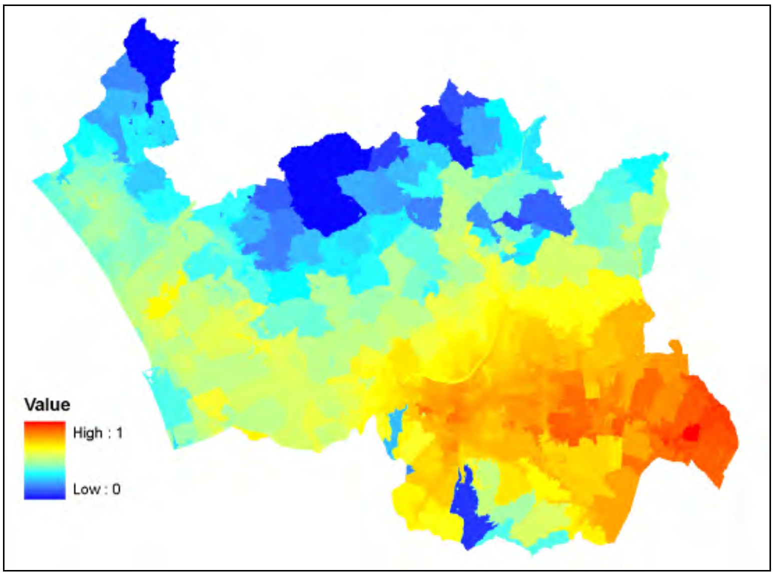

Fig. 6- Map of accessibility

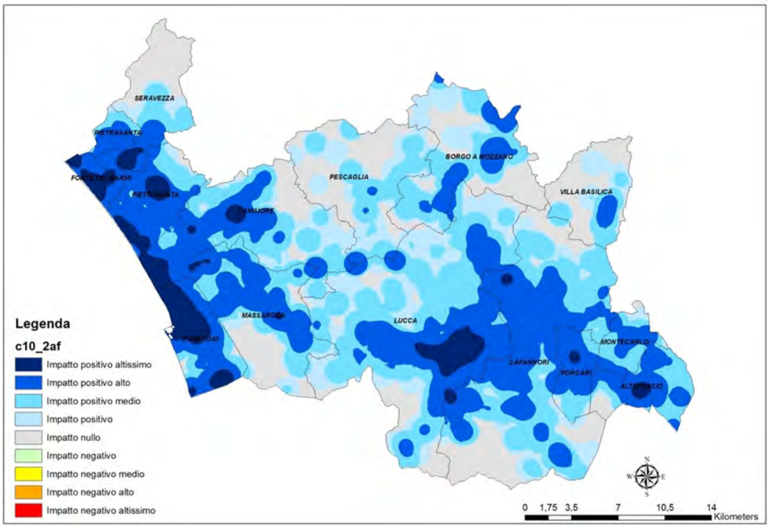

Fig. 7 Overall sensitivity of the socio-economic system

In addition, a graphical interface allows us to trace backwards from the aggregate end result to those relating to the various components and so to investigate the impacts on all of them. In other words, if from the sensitivity analysis related to a particular road project arises an index of high sensitivity, it will be possible, from the consultation of the maps of the individual components, to understand which of them are associated with the critical impacts.

The constructed instrument is also easy to implement and adaptable, depending on further evaluation criteria that might emerge: the scenarios constructed are examples, in fact it is possible to construct, from the same starting maps, endless scenarios by assigning different weights to the various environmental components, according to the needs of the decision makers.

The ability to build scenarios, using a highly differentiated database and the opportunity to assign different weights to the various "local sensitivities" (construction of synthetic sensitivity maps) allows such tool to be used in contests which are highly finalized to the participation of the actors, involved in territorial transformations.

REFERENCES

Bezzi, C. (2007), *Cos'è la valutazione. Un'introduzione ai concetti, le parole chiave e i problemi metodologici*, Angeli, Milano

Camagni, R., Musolino, D. (2002), Verso una metodologia di valutazione di impatto territoriale di politiche, piani e programmi, in: *atti della XXIII Conferenza dell'Associazione Italiana di Scienze Regionali*, ASIRe, Reggio Calabria, 10-12 ottobre.

Franchini, D. (ed.) (2004), *La Valutazione Ambientale di piani e programmi: indirizzi per una pianificazione sostenibile*, Firenze, ARPAT.

Santini, L. (2011), *Valutazione di Sensibilità per la localizzazione di centraline mini-idroelettriche: la valle del Serchio*, Casa Editrice Libria, Melfi.

IMAGES SOURCES

Fig. 1 Impacts matrix.

Fig 2 Map of overall sensitivity of the air component.

Fig. 3 Georeferencing of activities.

Fig. 4. Example of codes in the ITE manual

Fig. 5 Detail of the map of induced flows (near Lucca)

Fig. 6-Map of accessibility

Fig. 7- Overall sensitivity of the socio-economic system

AUTHORS' PROFILE

Luisa Santini

She teaches Urban Planning at the Faculty of Engineering of the University of Pisa. She is an expert in urban and regional planning, urban design, environmental and strategic assessment , decision support tools.

Serena Pecori

She teaches Laboratory of Urban Planning at the Faculty of Engineering of the University of Pisa. She is an expert in environmental and strategic assessment, environmental analysis and noise evaluation.