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.

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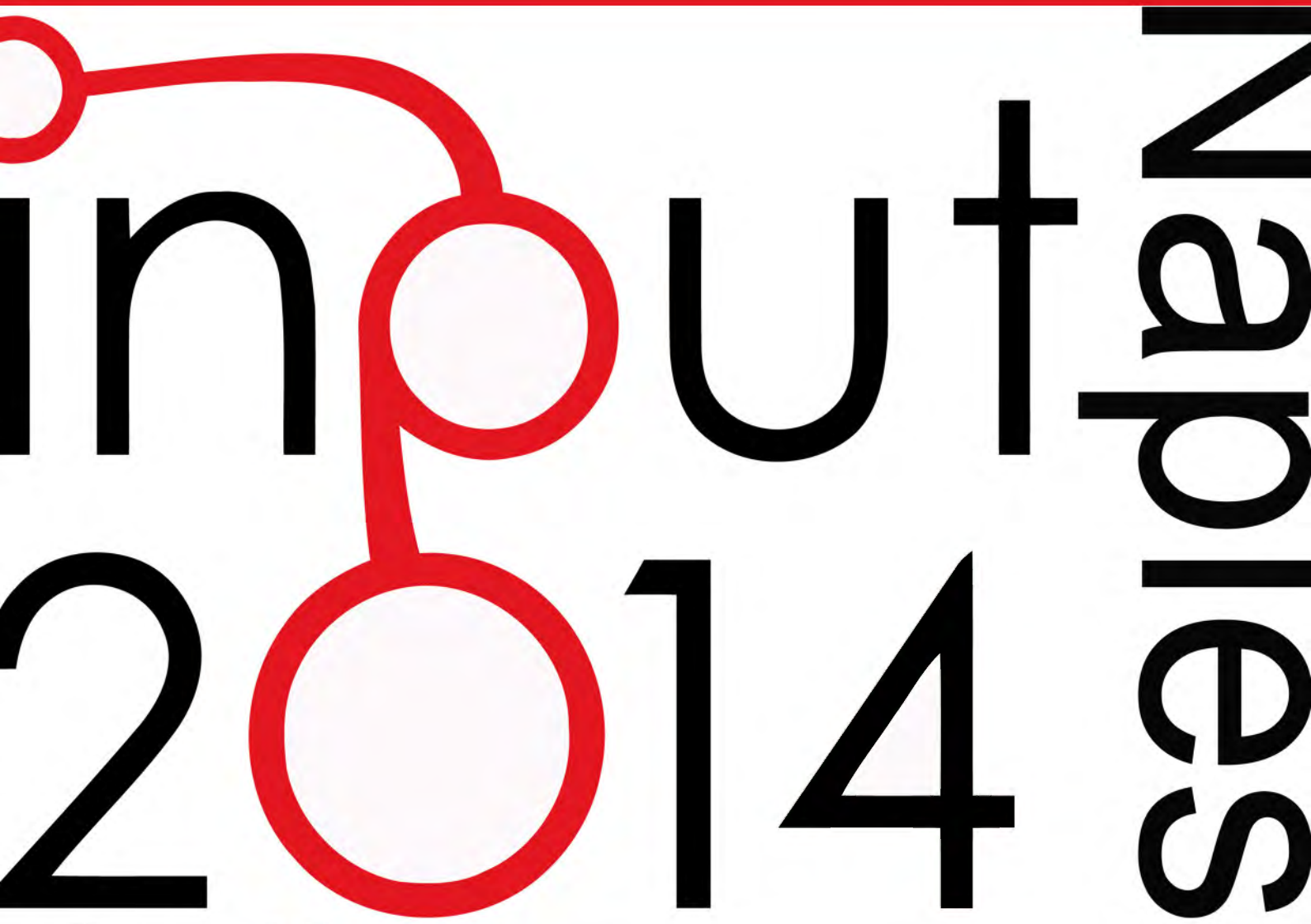

Smart City

planning for energy, transportation and sustainability of the urban system

Special issue, June 2014

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SMART CITY

PLANNING FOR ENERGY, TRANSPORTATION AND SUSTAINABILITY OF THE URBAN SYSTEM

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TeMA Journal of Land Use, Mobility and Environment

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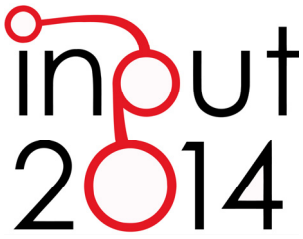
TeMA Journal of Land Use, Mobility and Environment

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

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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 . 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.

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THE MODEL OF VORONOI'S POLYGONS AND DENSITY:

DIAGNOSIS OF SPATIAL DISTRIBUTION OF EDUCATION SERVICES OF EJA IN DIVINÓPOLIS, MINAS GERAIS, BRAZIL.

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ABSTRACT
This paper represents the application of a methodology that supports urban environmental studies to the identification and mapping of areas of influential points or spatial phenomenal occurrences, using the techniques of Multicriterial Analysis and of Voronoi Polygon. It focuses on the use of institutional alphanumeric database transformed into spatial analysis by the use of GIS and models of distribution, to support decision-making regarding allocation strategies and expansion of centers of experimental education called "EJA" (Youth and Adults Education) in Divinópolis, a city in the state of Minas Gerais, Brazil. It describes the process of data that composes information which makes possible to perform urban analyzes and to simulate the scenarios considering the expansion of the system and the review of the allocation of some points.

KEYWORDS
Voronoi Polygon, Multicriterial Analysis, Urban Services Distribution, Spatial Analysis

1 INTRODUCTION

Tools to represent spatial distribution of phenomenon and to analyze the influence of urban entities and occurrences in specific area will be each day more necessary for administrators. The municipal administration is approaching more and more the logic of business. This fact requires increasingly responsible policymaking, reasoned and strategic. In this context, the application of decision support methodologies in urban environmental studies and the identification and mapping of territorial influence of services, represented in punctual spatial occurrences of phenomena, are fundamental to define zoning and administrative segmentations of a territory.

The administration in Divinópolis faces the difficulty of adopting decisions regarding to opening new schools with the Experimental Project EJA (Youth and Adults). To deal with that this study developed a methodology based on Multicriterial Analysis and Voronoi Polygon, in order to give support to such decisions.

According to Moura (2009):

> *The Multicriteria Analysis is a methodological procedure for crossing variables widely accepted in the spatial analysis. It is also known as a result of Decision Tree or Hierarchical Analysis of Weights. The procedure is based on mapping of variables on matrix representation and the definition of the relevance of each variable and each component of the legend to build the final result. The mathematics employed is the simple weighted average and some researchers use fuzzy logic to assign the weights and grades. The Voronoi polygon is an analytical model that allows the studying of areas of influence, from defined locations, considering their relative positions to dataset. The principle is that areas of influence are not composed by simple Euclidean distribution, but are deformed by environmental friction (for example, barriers to urban expansion) and by the mass of its generating points (eg , number of students or vacancies in the schools) .*

1.1 THE CONCEPTUAL BASIS OF THE APPLIED MODELS

A) MULTICRITERIA ANALYSIS

The Multicriteria Analysis had popularized significantly among GIS users, being the model of spatial analysis more used when the objective is the construction of diagnostic and prognostic of a territory, in different scales and with different objectives. There are two reasons for this wide dissemination of the model: the clarity in translating the objectives based on logical analysis in the structuring of the model, and the existence of tools in geoprocessing software, which even if they don´t present the whole model itself, they permit to build the steps needed to the process.

The Multicriteria Analysis can be translated as an algebra of maps, which favors that a problem is subdivided into its main components - the variables that interfere in their behavior - and that they are integrated and combined in order to build a system.

The idea of Multicriteria is not new. It began with Systemic Approach, in the 1950s, from the investigations of the biologist Ludwig von Bertalanffy (1975) who proposed the interdisciplinary studies according to the General Theory of Systems. The reality is seen as juxtaposition and interposition of parties composing a system in which the variables are interdependent and any change results in changes to the hole ensemble.

The idea of Analysis as a process is based on promoting the abstract representation of the phenomena in order to favor their explanation by models which allow their descriptions. In the 1960s, Chorley and Hagget (1967) developed studies of its application to geography, contributing to the understanding of models in spatial analysis.

It is necessary to understand that the Systemic Approach is not only the decomposition into parts and recognition of a phenomenon by its component parts, but it is, above all, the understanding that this decomposition only makes sense if the elements are analyzed in relation to the context in which they are inserted. The elements have characteristics that define them (intensity, mass, age, localization, and so one) and the values of these characteristics mean the states of the elements in a given place at a given time.

A model is the simplification of reality in such a way that it is represented by its essence, eliminating what is not significant for the characterization of the phenomenon and for the purposes of analysis. According to Chorley and Hagget (1967), the models are the formal presentation of a theory the uses the tools of logic, a set theory and mathematics. A model can be a theory, a law, a hypothesis, a structured idea, a relationship, a function, an equation, a synthesis of data or descriptions of the real world. As simplifications of reality they have as important point the selection of the most relevant aspects. The system is studied using a determined purpose, and everything that does not affect this objective is eliminated.

Huggett (1980) explains the process of structuring the model for development of systemic analysis: "By discriminating system parts of sub-systems at different levels of resolution, a complex system is simplified in a logical and realistic way which avoids the bewildering bulk of information at microscopic levels."

Through simplified models, with very initial processes, and based in the logic to decompose to compose, the first more significant application in the area of spatial analysis that followed these principles was the work of Ian MacHarg in "Design with Nature" (1969). The author presents the territory characterized by a series of thematic maps and proposes the identification of appropriate areas for different uses, including preservation and installation of anthropogenic activities. The result is a combination of thematic maps, at that time promoted by simple overlay of maps, which allowed the identification of remarkable places, resulting from the synthesis of variables that best meet the objectives of the analysis. It was the analytical process by decomposition and the synthesis by integration.

By identification of the main components of a system, they can be isolated in information plans or layers. With this ensemble of data, various professionals, with their knowledge and specific objectives, may propose different processes of integration of variables, resulting in a more dynamic interpretation of reality. The descriptions become richer, because they reflect "what", "where" and "how".

Steps on methodological process, according to Moura (2003):

- definition of objectives and applications in the use of the system;
- organization of alphanumeric database and mapping;
- treatment of data for raster analysis and as representation of potential distribution of phenomenon;
- definition of weights and values of the variables;
- integration of the variables in the analysis of multi;
- comparison with the existing reality;
- system calibration and return to the stage of the analysis;
- construction of scenarios (if/then);
- drawing up proposals for intervention, management and restrictions.

According to Anselin (1999) there are steps of understanding the problem, with exploratory analysis, which aims to understand more about the object investigated; and there are steps based on structuring the system and constructing models that represents the reality. Because of these procedures Multicriteria Analysis works, really, as a support to decision making.

After composing the layers of variables, the algebra of maps is structured in Weighted Average:

$$A_{ij} = \sum_{K=1}^{n} (P_k \times N_k)$$

Where:

Aij –The position in the array analysis (line/column), or of a pixel in map

n – Number of maps or layers of variables combined.

Pk – Percentage points or weight assigned to map or layer of variable k in the set of layers.

Nk – Values that means the significance of the degree of relevance of that component of legend for variable k for the final objective

The choice of weights must be very well documented and justified, must be open to revisions, and in most cases is where the system calibrations happen. The different modes of carrying out the choice of weights can be summarized in two groups of procedures: the evaluation guided by data and the assessment guided by specialist knowledge, what Bonham-Carter (1994) denominates "data-driven evaluation" or "knowledge-driven evaluation".

Among the processes of defining weights by "data driven" can be cited the methods that are based on data mining, which seek to identify trends of hierarchy of variables according to what happens in reality, measured by samples chosen in the investigated territory (Castro, 2010).

Among the processes of defining weights by "knowledge driven", consulting the experts, the objective is to receive feedback from those who understand the phenomenon and the reality investigated, and emits its opinions based on the probability and the state-of-the art of the variable. There are different methods to perform this consultation, but the most popular are the Thomas Saaty method and the Delphi method.

The Saaty's method (1980), called "Hierarchical Analysis of Weights", was developed in 1978 at the University of Pennsylvania. It defines the weights of each information plan according to its relative contribution to the ensemble. The goal is to decompose a complex situation in order to make the decisions about what is most important. The method proposes the comparison of variables pair-to-pair and is assigned a criterion of relative importance among them.

The Delphi method was originally proposed in the 1950s by American military industry, the Research and Development (RAND) with the goal to divide responsibilities and get the best solution that was a consensus among people involved. The name comes from the Oracle of Delphi, because the objective is to support the decisions. The argument is that judgments of groups are closer to reality and more accurate than simple individual trials.

According to Dalkey and Helmer (1963) the method is composed of questionnaires applied in rounds to specialists, and these rounds are interspersed with feedback, which aims the convergence of the opinions expressed by the participants. Some authors, as Linstone and Turoff (2002) argue that the number of rounds should be as many are necessary until it reaches the convergence of opinions. But against that we defend that consensus does not exist, and what can be obtained is the maximization of consensus, and because of that, based on a great number of expressive case studies, we made to choice of employing three rounds. In the process described in this paper, the weights were assigned by a small group of experts, who have very good knowledge about the thematic studied and about the city analyzed and, above all, knew about the reality and the conditions of life from young and illiterate adults who require the services of education.

B) VORONOI POLYGONS

The employment of Voronoi polygons as a model of analysis, allows, according to Xavier-da-Silva (2001), prognostic procedures in environmental analysis. The procedure prognosis allows:

> *" ... The proposition is to measure territorial influence of a phenomenon, based on conditions diagnosed and prescribed for a particular territorial extension. It is implicit in the term a foresight, which may be reflected in the overall equation of possible problematic environmental situations for which can be envisaged environmental control measures, through the application of procedures specific to certain geographical areas."*

The author (Xavier-da-Silva, 1999) thus explains the construction of the model:

> *"In computer terms, the model measures the distance of each point in the matrix Amxn until each generator point, being its relevance defined by the lowest of these distances. This relationship can be considered opposite, as the comparisons of all this distances computed shall define, by the shortest distance found, the relevance of polygons in construction. As a result, at the end of the checking of relevancy, all points in Aij matrix will be associated to a generator point from Voronoi Polygons. The plan is subdivided discretized in "k" irregular polygons, that integrates it."*

As part of the applications of SAGA-UFRJ, free software, the application of the Voronoi Polygons were very useful to determine areas of influence of the schools in the city of Divinópolis, what allowed to verify the degree of care to the population, especially in sectors characterized by high population density and high population in social conditions of illiterate. The result characterizes the reality and allows simulating, as a procedure of prognosis, where are the best locations for new future schools or to increase the vacancies in existing schools.

The principle of the Voronoi Polygon is more interesting than the Thiessen method, that is also based on gravitational analysis, because this last one is based on the principle that in the hole territory there are points which are closer to a source, and the result is a polygon whose distances between the source and the point are the lowest possible. The model of Voronoi Polygons is more than simple division of areas, as it also considers the influence of distribution in the territory and the distances from the source, but it´s a more robust model as considers also the mass of the source point and the environmental characteristics that deform the distributions. So, the model is a combination of territorial distribution of sources or generator points, environmental characteristics that work as friction, and the influence of the masses on generator points. This combination of conditions should have the power to organize the space and define the area of influence of each generator point, or to define for each position of the territory which generator point has influence over him, or polarizes it.

In the study of the areas of influence of schools, the model generates results defining which school polarizes each part of the territory in the city. But it is necessary to explain that when a school presents an area of great influence, this does not mean, necessarily, that it has a service so well placed that has great range (resulted from the "mass" applied), but it can mean that there are no other schools in the territory which could cause the subdivision of the area of influence.

With this definition of the methodology, the data collection was performed directly in the field and by bibliographic research. Maps and data where prepared to give support to the development of strategies to improve the EJA Experimental Design and to guide the creation of EJA new poles. This strategy, in this particular educational project, is necessary due to its fundamental principles of flexibility, regarding the profile of the student and specificity of their learning. These educational places must be close to the students' houses, located in positions ease to reach and must be reached by a greater demand of people.

1.2 THE DESIGN OF YOUTH AND ADULT EDUCATION – EJA

Focused to give opportunities to young people and adults who could not complete their studies in their own age, Youth and Adults (EJA) is understood today as a human right, and their own way of education within the Brazilian basic education (according to LDBEN 9394/96), which is characterized by critical dialogue between popular education and school education, and this dialogue, according Paulo Freire's theory, is fundamental to build the basis of EJA, especially the ideas of education considering popular knowledge and social experience of students. (Freire 1999).

Understanding the EJA, from the experiences of popular education, is to organize it so that the study program and courses are the expression of interests, ways of life, the experiences with the students considering formal and non-formal education. Within the system school, EJA must be flexible to the trajectories of these young people and adults, marked by continuing difficulties and exclusions in society.

The EJA is press – well, the collective and democratic construction, requiring participation of teachers and students in defining their times, their rules coexistence in the construction of knowledge, implying the disruption of individualistic and fragmented teaching experience. The EJA has an established curriculum in experiences of its subjects, and therefore requires time for collective planning and continuing teachers' education. The EJA is also understood as continuing education, because youth, adults and seniors should have a solid education in schools and in other areas such as technology centers, leisure and culture. Conceive it as continuing education is affirming the need for public policy of the state towards this type of education, with more resources and expansion of the right subjective to learning for all ages in our county. These were the guidelines indicated in the VI Conference International Adult Education.

According INAF - Indicator of Functional Literacy Institute, Paulo Montenegro Institute and the NGO Action Educational, in 2011 there are still 9 % of the population Brazil (11 million people) uneducated and awesome index 18% (over 23 million people) with incomplete primary education. The table below shows the numbers of population scholarity (table 1):

ILLITERATE	2000 CENSUS		PNAD 2009	
No schooling	10%	10.866.552	9%	11.766.782
Elementary school	30%	32.599.656	18%	23.533.564
Secondary School	28%	30.426.345	24%	31.378.086
High School	24%	26.079.725	35%	45.759.708
Top	8%	8.693.242	14%	18.303.883
total	100%	108.665.519	100%	130.742.024

Tab. 1 Scholarity of the population from 15 to 64 years old in Brazil/IBGE - Source: INAF 2011

In smaller geographic divisions, in the city of Divinópolis / MG, illiteracy and low education data confirm the general dates of education of Brazilian's population. According to the 2010 census realized by IBGE, the population of Divinópolis is 213016 people, and of these, 356 attended young and adults' literacy, 317 at public schools and 39 on private ones. According to the census in Divinópolis there are 84023 people with more than 10 years old who are illiterate, and 60,764 people that are adults above 25 years who has just incompleted elementary education (table 2).

meso, microregions and municipalities	Total	LEVEL OF EDUCATION				
		illiterate and fundamental incomplete	fundamental complete and average incomplete	average complete and upper incomplete	upper complete	not determined

Divinópolis	133600	60764	21837	33580	17222	257

Tab. 2 People that are more than 25 years old Source: IBGE - 2010

The experimental design was established starting from the municipal legislation called "Municipal Organic Law of Divinópolis" which states that primary education should be free and compulsory, even for those who did not have access at the right age. The "Decennial Education Plan of Divinópolis", 2004/2013 (FUNEDI, 2013), presents the chapter "Concerning the Youth and Adults Education", establishing as a goal to eradicate illiteracy and universalize elementary education for youth and adults over fifteen years. The Experimental Design EJA, in seven years of existence, has been serving on average of 400 students per year, in eight public schools, with 32 educators.

2 APPLICATION OF VORONOI'S POLYGONS, MULTICRITERIAL ANALYSIS AND KERNEL'S DENSITY FOR DIAGNOSIS OF TERRITORIAL INFLUENCES IN EJA'S POLES TO DEFINE FUTURE STRATEGIES OF DEPLOYMENTS

Were selected seven municipal schools which receives the EJA project in Divinópolis: CETEPE, E.M. Emílio Ribas, E.M. Professor Darcy Ribeiro, E.M. Professora Veneza Guimarães de Oliveira, E.M. Professora Hermínia Corgozinho, E.M. João Severino de Azevedo e E.M. São Geraldo. The aim of the study was to demarcate the area of influence of such schools, in order to analyze if the location matches the needs of the students from EJA.

The Voronoi's Polygon was applied in the simple and in two complex models. The simple model aimed the understanding of geometric distribution of the areas of influence. The first complex model considered just the mass values on school points, composed by the average between the number of students and the number of teachers, and results in simulation of territorial influence of each point considering spatial arrangement of all points e their mass values. Finally, second complex model of Voronoi's Polygon considers spatial arrangement of all points e their mass values, but also the friction (impedance to spread the influence) along the territory, thus observing spatial variables that interferes in access conditions to the schools with EJA.

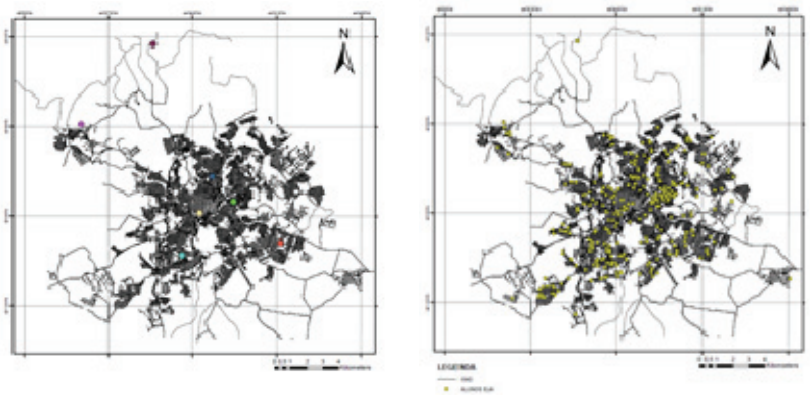
2.1 - METHODOLOGY

Maps and data were collected and organized from various institutions. Initially it was necessary to obtain roads and streets maps from Divinópolis City Hall and provide topological corrections and georeferencing, as they came in cad format.

Alphanumeric tables were organized, presenting data from each school about number of teachers and students, as well as the addresses of students and the location of the school. These data were tabulated, and through the plugin MAPCITE the addresses were converted into geographic coordinates in WGS84 reference, and subsequently converted into SAD69 (Brazilian datum) and resulted in location points of EJA schools and of all the students. (Figure 1).

Because of lack of data, a school which was out of Divinópolis city, in a district in the municipality, was excluded from the analysis. It was not also possible to georreference the addresses of students who live in rural areas, and to deal with this problems they were located in the schools they study, as in this small locations or districts there's just one single school.

To analyze the current situation of concentration of students of EJA'S it was applied the kernel's density, developed from school points and weighted by the number of students in each school. (Figure 1, Figure 2, Figure 3).



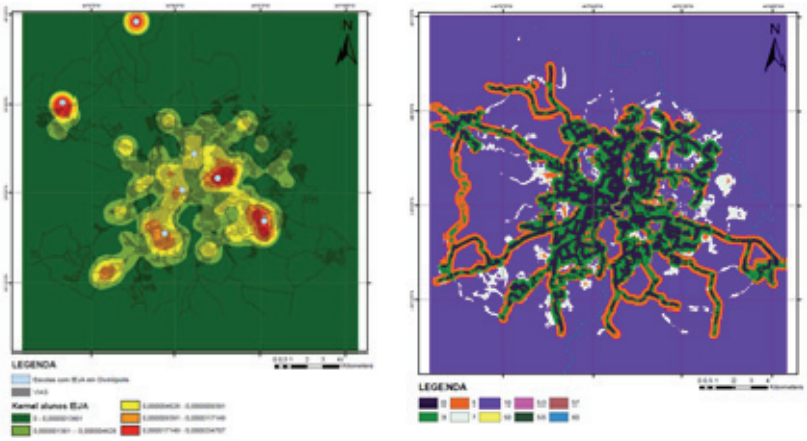
Figg. 1, 2 (1) Distribution of schools. (2) Distribution of students

A map of friction was produced, in order to provide a distribution of difficulties to mobility over the territory. Through literature review and interview with experts, it was decided to take as variable to build this synthesis map the combining of slope; capillary of pathways, the presence of the bus line and the presence of large watercourse which produces barriers in Divinópolis. These variables were combined in Multicriterial Analysis using weighted average according to the importance given by the experts who knows the city and its reality, and this synthesis results in friction map.

The most important map in this synthesis was the route of bus lines, because they are considered the main transport way used by students. It was defined a buffer of 100 meters from the routes, considered the ideal condition, and another buffer of 300 meters, considering an acceptable condition. The second most important map was the capillary of streets and roads, built with kernel's interpolator. It was produced the map of slopes and the map of rivers. Map of friction was generated by grouping all the maps through a Multicriterial Analysis. (Figure 4).

The multicriterial analysis procedure is widely used in advanced geoprocessing because it is based on basic logic building a GIS: selection of key variables that characterize a phenomenon, conducted by a methodological approach for simplifying spatial complexity; representation of reality according to different variables, organized in layers of information; discretization of levels of analysis in space resolutions appropriate for both sources of data but also to the objectives to be achieved; promoting combination of layers of variables, integrated as a system that reflects the complexity of reality; finally, calibration and validation of the system.

It was decided to assign greater value to the presence or absence of buses (50%), capillarity (30%) and the slope (20%). After this first combining, the presence of rivers were considered reducing the condition of mobility, mapping the bridges as areas with conditions and the river line as obstacles.



Figg. 3, 4 (3) Kernel Density of students. (4) Map of friction

Once produced the friction map and other maps, the entire database was transferred to the software SAGA - System for Geo-Environmental Analysis, developed by Prof. Jorge Xavier, the Lageop - UFRJ, where the model Voronoi polygon was applied. The principle of Voronoi's Polygons' is that, considering a territory, there are points that are closer to a generating source than another source, and the result is a polygon whose distances between source and point are as small as possible. The resulting polygons can go beyond simple division of areas and be deformed by environmental characteristics, which are considered friction, and by the influence of mass values applied to the generating points, and the model have the power to organize the space and define the area of influence of the point.

The model developed by Prof. Jorge Xavier and available to use in SAGA software is a more robust model than the Voronoi application presented in others software. It's not only a Thiessen Polygons', but it's a spatial analysis based on gravitational model that combines the spatial distribution conformed by the points of irradiation, the mass points considering factors which give importance or values to origins of the irradiation, and the friction on territory which works as benefits or costs (difficulties or facilities to spread the influence over the space). It applies the mathematical logic:

$$(FZ)Gi = MGi / [(Dx \rightarrow Gi)Ax \rightarrow Gi]$$

Where:

(FZ)Gi = Force of zoning of point Gi;

MGi = Mass value of point Gi ;

$Dx \rightarrow Gi$ = Euclidean distance between each point analyzed and point Gi; e

$Ax \rightarrow Gi = \Sigma Ck$ (from 1 to n)

Where:

n = number of cells (pixels) found in the way between x and Gi;

Ck = value of friction estimated to each cell (pixel) in the way between x and Gi.

In this study, the complex Voronoi proposed by Xavier was used, with mass determined by the composition of the number of students in schools and number of teachers, determining a factor used as mass value, and also taking into account the environmental friction.

Besides the calculation of Voronoi it was provided a map of kernel density considering the interests of population, as in 2012 the Municipal Education Secretary of Divinópolis made a public consult to register the interests on the program, what resulted in a table presenting the number of interested people by neighborhood. This polygons of neighborhoods where converted in centroids which received as mass values

with the number of people who were interested, and a kernel density was applied, to promote the visualization of spatial distribution of concentration of interests in taking part of the program.
To conclude the study, analyzes were performed to identify new areas to promote new places for the project, to verify the adequacy of spatial distribution of schools and to identify areas where the possible students were not well reaching educational services.

2.2 ANALYSIS OF RESULTS

After the model of complex Voronoi was built considering the number of vacancies or possible enrolments in school as mass value and the territorial friction to reach the school point; after constructing the map of students distribution; and after promoting the spatial density analysis of the concentration of possible students registered by the inquiry done by the municipality, they were compared. The goal was to verify the degree of promoting these educational services to the population. The result can provide support in decisions making of new locations of future schools or in the allocation of new vacancies in existing ones.
Analyzing the results, the large influence of a single school does not necessarily mean that it presents a satisfactory broad coverage, but it may means that there is no competition with other school in the same territory in the subdivision of the areas of influence. The large surfaces must be considered negative.
The small territories presented by the areas of influence must also be considered negative, because they mean the spatial concentration of opportunities.
The model allows simulating possible changes. These changes can be, for example, the increasing of mass (number of possible students to be received combined with the increasing of number of teachers) and check the effect of the decision done.
The analysis of friction map allows verifying that worse areas, with grater friction, are in the western part of the city. The best areas, with greater conditions of ways to go from one place to another are the central ones, but in places where the river acts as a barrier it's reduced. (Map 6).

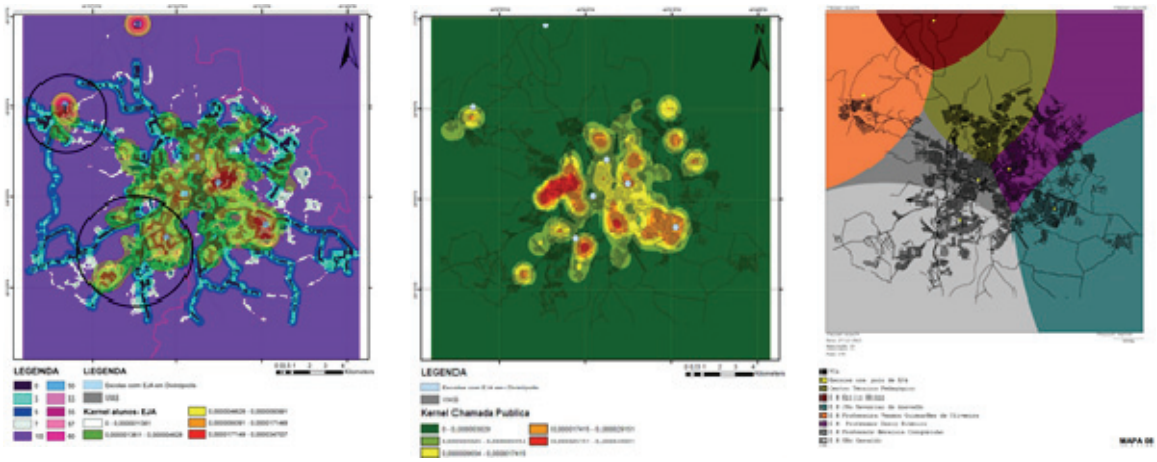


Fig. 5, 6, 7 (5) Combining of students' distribution with friction map. (6) the map of kernel density considering the manifestations of interests registered by the municipality consult. (7) Voronoi with mass factor.

It was promoted the combining of students' distribution with friction map. (Figure 5) The regions marked by the circle shows that the majority of students are in areas of high friction, where the presence of bus ways occurs generally only along avenues, resulting in isolation of these students in their areas of residence.
The map of Kernel density considering the manifestations of interests registered by the municipality consult in 2012 demonstrates that the demand of students who wanted to enroll in adult education are more

concentrated in a different territory from the those where there are already students served by the program. (Figure 6).

The first complex Voronoi models, which takes into account only the mass on points of irradiation, demonstrates that schools with similar mass factor (number of students + number of teachers), but distributed differently the along the territory, have their areas of influence enlarged or reduced, according to the competition with other opportunities. (Figure 7).

At St. Gerard School, for example, there is a large area of influence due to its high mass value (table 3):

NAME	NUMBER OF STUDENTS	NUMBER OF TEACHERS	FACTOR
Centro Técnico Pedagógico	79	3	41
E.M.Emílio Ribas	22	2	12
E. M. Professor Darcy Ribeiro	93	4	49
E.M. Profª Hermínia Corgozinho	92	4	48
E. M. Profª Veneza Guimarães de Oliveira	46	5	26
E.M. São Geraldo (Centro)	113	5	59
EM. Benjamin Constant	16	5	11
E.M. João Severino de Azevedo	75	4	40

Tab. 3 Mass factor

The second complex Voronoi was performed taking into account the factor of mass and the friction of the territory (map 04). The areas of influence decrease/increase according to the degree of difficulty to access the school point, and according to the level of attraction represented by mass values. It was made an overlap between the complex Voronoi (mass + friction) with the map of Kernel density of people interested in taking part of the EJA program, to analyze which schools could be better to receive the students.

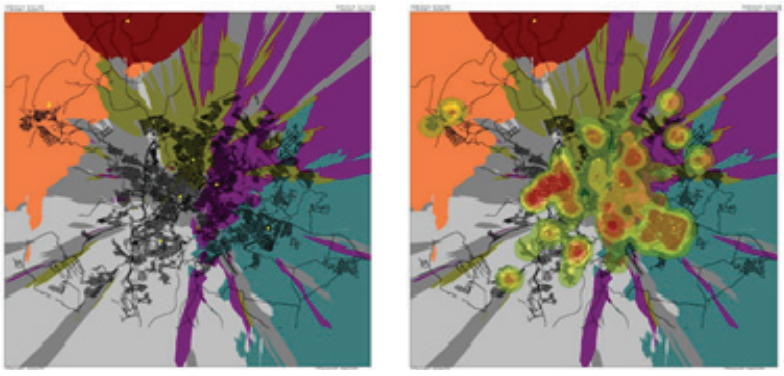


Fig. 8, 9 (8) Voronoi with mass factor and friction. (9) Voronoi with distribution of interest students

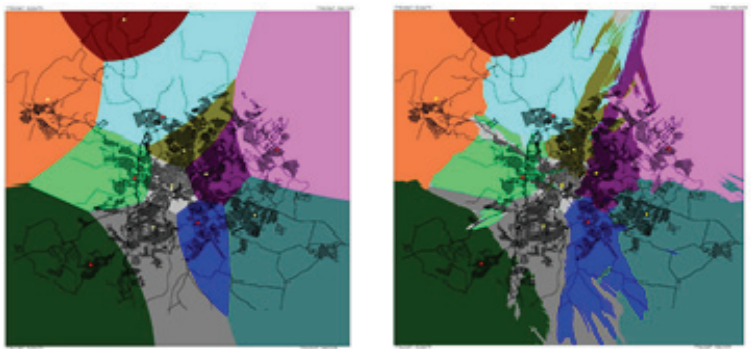
3 CONCLUSIONS

The aim of this paper was to use the Multicriterial Analysis and the Voronoi Polygons in urban studies, to support decision making in the distribution of opportunities of centers called Educação de Jovens e Adultos – EJA (centers of education for youth and mature people) in Divinópolis – MG. After several analyzes, it was conclude that Divinópolis needs a higher number of EJAs. The demand is greater than the number of vacancies at EJA´s. It's also important to observe that there is a deficit in education in Divinópolis, higher than the national average. It's necessary to increase opportunities in number of vacancies and in number of centers, because the program must meet not only people wishing to attend the project, but it is also ensures

that this centers can work according to flexibility and suitability, what means to be integrated in society and in the territory activities. (Figure 10 and Figure 11).

It was observed a spatial location which needs to be more served: São Geraldo and Professora Hermínia Gorgozinho. The first school presents a high demand for new opportunities and has low values of territorial friction. The second school has also a high demand for new opportunities or vacancies and low territorial friction, as it´s placed in a location with good access to public transportation, with high capillarity.

Studying the places to put new schools or to rise the number of students to be received, it is possible to conclude that is necessary to create five new centers, distributed on the follow schools: EM Padre João Bruno/CAIC, EM Joaquim Rodrigues, EM Otávio Olímpio de Oliveira, E.M. Sidney José de Oliveira and E.M. Professor Bahia. These schools were chosen by their proximity to the higher demand of students and to share more areas of influence. To investigate the suggested places, a new Voronoi simulation was performed taking into account the new values projected as sceneries. (Figure 10 and Figure 11).



Figg. 10, 11 (10) Voronoi simulating changes in mass values. (11) Voronoi simulating changes in mass values and considering friction

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IMAGES SOURCES

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