Evaluation of environmental impact caused by new residential areas in the Bucharest Metropolitan Area

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***Abstract*—** Residential areas had already became the most important modeller for human settlements that are aggressed at qualitative and quantitative level by inadequate insertions, gas emissions, wastewater discharging, green spaces destruction, waste production, consumption of energy, water and other resources. The diversity of environmental impacts generated by residential areas requires a complex methodology application, able to emphasis the resources consumption and the generated problems. In the Bucharest Metropolitan Area the tendency of residential areas expansion is very active, on both large scale residential projects and isolated private initiatives. In order to evaluate the environmental impact caused by residential surfaces, multi-criteria assessment was used, which took into account various criteria related to their specific impact: location characteristics, amount of consumed resources and external impacts characteristics. The method can be used in classifying residential areas according to their potential impact on environmental quality. However, this method cannot provide a dimension for the processes of environmental degradation.

***Keywords* —** Bucharest metropolitan area, environmental impact assessment**,** multi-criteria assessment, residential areas.

I. Introduction

THE residential areas are now household degradation sources [1] responsible for many environmental problems found at local, regional and global level (global climate changes, environmental acidification, ozone layer depletion, biodiversity degradation, poor management of hazardous products) being considered in developed countries as different sources when the environmental quality is evaluated in a certain space [2].

Manuscript received July 31, 2011. This work was supported in part by the UEFISCDI under Grant 92014/2008 (Partnership Program) Environmental management in residential areas from urban areas under recent environmental changes.

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The complexity of their approach comes from:

- ***diversity,*** that appears in population (numerical distribution, behaviours; influenced by education, social and economic level, traditions and customs, age, gender; differential access to infrastructure and public or private services; housing models) and in urban structures level (location of residential areas in geographical, social, economic, cultural, historical and urban context);
- ***high fragmentation***, household sources being highly dissipated and random structures in terms of aggressiveness;
- ***impossibility of controlling environmental risks*** only by preventive actions (for example, banning the use of certain substances or products and limiting their appearance in households) and general safety actions (especially informational, educational and awareness actions);
- ***limited resources of administrative institutions,*** placed in a position to solve with priority social and economic problems;
- ***networking with other existing problems in society*** (conflicts, social segregation, economic difficulties, ease of access to a true dwelling or to infrastructures and public services) [3].

Residential spaces through their structure and functions contribute to environmental aggression [4]. Thus, the structure of residential areas is a significant consumer of territorial resources (especially space, construction materials, energy resources, human and technological capital), and a generator of problems during their construction and operation (changes in geomorphologic, climatic, hydrological, hydrogeology and biotic level, affecting environmental properties) [5].

Among the most common urban mistakes relating to residential areas are included:

- unplanned development without taking into account the support capacity and equilibrium of human ecosystems;
- destruction or degradation of open areas;
- chaotic reconversion of restructured areas;
- expansion of structural and functional outskirts;
- failure to adapt urban functions to changes in urban consumption models;
- acceptance of some urban functions incompatible

with current urban structure (large commercial areas, warehouses) [3].

The evaluation of environmental impacts caused by residential areas can be achieved using very different methods, of which the multi–criteria assessment is a representative one [8]. This method has the advantage that takes into account the diversity of problems that residential areas generate upon the environment.

The main objective of the paper is to select the best alternative in terms of environmental quality for location of a new residential area using multi-criteria assessment.

II. Study area

The Bucharest-Ilfov Development Region overlaps on the central – southern part of the Romanian Plain, characterized by the presence of loess and alluvial deposits, elevations of 50-150 m, flat surfaces, temperate continental climate (9.8–11.2^{0}C annual average temperature, precipitations of 500-600 mm), and an environment with a high degree of human transformations expressed by the reduced percents of aquatic (3.4%) and forestry (14.2%) surfaces [6]. The total surface of the region is 182,115 ha (13% Bucharest). The land use is mainly agricultural (60.2%, respectively 109,605 ha), constructed surfaces representing 17.46% of the region's total surface. The resident population consists of 2,208,368 inhabitants, of which 87% are in Bucharest [7].

The economic profile of the Bucharest-Ilfov Development Region is dominated by real estate transactions and services activities (21%), followed by industry (20.4%), trade (18%) and agricultural activities (0.7%) [7], [9].

The region's heterogeneity allows the delimitation of a southern Bucharest area characterized by an agricultural and industrial decline, with new real estate projects designed to attract important investments for these areas with location advantages: European Road E70 towards Giurgiu, the banks of Danube and the potential for cross-border collaboration [10].

In the Bucharest-Ilfov Development Region the residential project Green City (103 ha, started in 2008) was evaluated in terms of its environmental impact characteristics. It is located in the village 1 Decembrie (Table 1).

Table 1
Characteristic elements for incompatibilities analysis in the 1 Decembrie village

Location	% of total LAU 2	Distance from forests (m)	Distance from rivers (m)	Residents no. of entire residential project
Arges River Meadow	3.4%	20	500	3168

The residential project Green City is located in the Argeș-Sabar floodplain, in an area with moisture excess in the substratum and a shallow depth of groundwater (2 m). The previous function of this land was agriculture, in this area functioning a complex of vegetable greenhouses.

III. Methodology

The analysis included 10 representative criteria and 4 development alternatives. Based on the results of statistical analysis, criteria were selected in order to describe direct environmental impact of residential areas (1, 2), the use of green alternatives (4), the problems of location (3, 5), economic (6), social (7, 8), environmental impacts, and safety on location (9, 10). The criteria are:

1. Monthly quantity of wastewater, calculated considering an index of 4 m³/person;
2. Monthly quantity of waste, calculated considering an average index of waste production of 24 kg/inhabitant;
3. The weight of project area near degradation sources was calculated using Buffer and Clip functions of ArcGis 9.3 software, considering buffer zones of 15 m and 50 m around the industrial and agricultural units;
4. The energy weight produced with polluting technologies. Only for green alternative was estimated to be 87.97% (100% - 12.03%*) *for projects that use energy from national system (eea.europa.eu) and project characteristic value for green alternatives;
5. Surface of soils contaminated with pesticides which overlaps the area where greenhouses were;
6. Land surface removed from agricultural circuit, was extracted from aerial images 1:5000;
7. Weight of land surfaces with crime risks was calculated according to dwellings nearness of sensitive areas (peri-urban forest, River Argeș) and to isolated areas that can receive crime. With the help of Buffer and Clip functions was created a buffer area (50 m) around these sensitive areas, then through cutting were obtained the land surfaces with crime risks;
8. Number of employees was estimated according to size and capacity of trade and provide services units for each project alternative;
9. The contamination risk of groundwater was calculated according to constructed area surface for each project alternative. Final value was the weight reported to total alternatives area;
10. The fire risk was calculated according to houses weight located near forest and industrial units and to occupied area by industrial and agricultural units. The Buffer and Clip functions allowed identifying the size of these fire risk areas. The final value was weighted according to total surface for each alternative.

The 4 options were:

A alternative: Building a residential project with 2770 dwellings, GF3 and a total built area of 103 ha;

B alternative: Building a sustainable residential project by creating 315 green dwellings with alternative energy sources, GF1 and total built area of 8.6 ha;

C alternative: Keeping the initial land state;

D alternative: Building a recreational centre.

Data homogeneity was ensured using Mathematical Programming [8], as they were transformed into percents, considering the maximum value with the highest environmental impact equal to 100%. The intermediary homogenous values per alternative were determined using percents from the best value.

Using Analytical Hierarchy Process [11] the weight of each of the 10 criteria (g_i) was established, considering the sum of all weights to be equal to 1.

By multiplying the weight of each criterion with the normalized values eight partial scores were obtained. The final score (S) for each alternative was obtained by aggregating the partial scores according to the formula:

$$S = \sum_{i=1}^{10} (g_i * f(t_i))$$

The second method used a GIS component named *Model Builder*. As a result were identified suitable areas for building Green City Residence. *Model Builder* is an application for creation and running models based on a flow of operations and tools. The model components are: input, output and processes. The model for identification of suitable constructing areas was based on the following criteria: distance from the swampy area (it is not allowed to build less than 15 m from this area); distance from the National Road, DN5 (interdiction of building to less than 50 m from the National Road); distance from forest (interdiction of building in the protection zone of 50 m); distance from greenhouses (interdiction of building less than 15 m from greenhouses) [12] and initial land use, according to aerial images from 2005.

To build the model were used: Euclidean Distance, to calculate with vectors helps (water bodies, forest, greenhouses and DN5) the straight line distance; Reclassify, for raster reclassification resulted from distance calculation, with 0 and 1 values (0 represents the banned area of building according to criteria distances and 1 represents the area beyond building activities are allowed). With Single Output Map Algebra function, an expression was created for overlapping the resulted raster from the reclassification with 0 and 1 values. Thus the final raster resulted with the overlapping of all areas which fulfilled condition 1 (suitable areas for building the residential project) and all areas which fulfilled condition 0 (areas where building activities are forbidden) (ArcGis Desktop 9.3 Help).

IV. RESULTS

In terms of environmental impact size, the high score 85 (the highest environmental impact) was obtained for A alternative, followed by score obtained by C alternative (60), represented by initial land state.

High impact of initial land state can be explained by the previous function of land which was dominant agricultural and industrial (39.19 ha of constructions and yards for agricultural and industrial activities) (Table 2).

The score obtained shows that there are significant differences between alternatives: sustainable dwellings in the residential project (31) and building of recreational centre with swimming place and sport areas (35) (Table 3).

Criteria with the great weight (0.2090, 0.1474, and 1.138) are related to the most important environmental impacts caused by residential project.

Table 2
Criteria for each project alternative

Criteria	A	B	C	D	U M
Environment					
Monthly quantity of wastewater	132960	4212	252	2240	m^3
Monthly quantity of waste	26.59	0.84	0.05	0.44	t
Weight of surface located to 15 m or 50 m near degradation sources	0.31	0	7.77	0	%
Energy weight produced with polluting technologies	100	87.97	100	100	%
Soils surface contaminated with pesticides	15.31	0	12.72	0	ha
Economy					
Land surface removed from agriculture	25.4	25.4	0	7.02	ha
Social					
Weight of land surfaces with crime risks	38.8	18.67	18.67	1.75	%
Number of employees	240	45	500	60	no.
Risk					
Contamination risk of groundwater	8.9	0	29.34	33.2	%
Fire risk	63.78	43	40.38	10.7	%

Calculation of land surfaces where building is permitted provides an analysis of suitable area for dwellings location. Of the total area, 40.84% represents areas where building is permitted, and 59.16% represent areas with building is banned. So, building of Green City Residence (103 ha) should overlap on the area allowed for construction activities (78.28 ha).

Forest (36.89 ha), greenhouses (12.72 ha), DN5 (5.18) and swampy area (29.3) and protection distances from General Urban Plan of 1 Decembrie village and laws [12] overlaps on areas banned for construction.

Overlapping the resulted model with the Zonal Urban Plan of 1 Decembrie village (Fig. 1) highlights malfunctions areas. Thus from 63.3% (total housing area), according to resulted analysis only 41% is integrated in area where residential buildings are allowed.

Table 3.
Criteria weight for each project alternative

Criteria	Weight	A	B	C	D
Environment					
Monthly quantity of wastewater	0.059	5.9	0.17	0	0.11
Monthly quantity of waste	0.077	7.7	0.23	0	0.15
Weight of surface located to 15 m or 50 m near degradation sources.	0.1474	14.74	1.62	14.7	14.7
Energy weight produced with polluting technologies	0.0363	0.43	3.63	0.43	0.43
Soils surface contaminated with pesticides	0.128	12.8	0	10.6	0
Economy					
Land surface removed from agriculture	0.0461	4.61	4.61	0	1.29
Social					
Weight of land surfaces with crime risks	0.1352	13.52	6.48	6.48	0.67
Number of employees	0.024	1.15	0.216	2.4	0.28
Risc					
Contamination risk of groundwater	0.138	3.72	0	12.1	13.8
Fire risk	0.2090	20.9	14	13.2	3.55
Total score	1	**85**	**31**	**60**	**35**

V. Discussions

The tendency of agriculture revitalization and abandonment [6] characterized the area where Green City Residence is located. Removing crops from agricultural circuit and abandoning greenhouses produced were associated with transformation of agricultural areas into residential areas.

The productivity of former agricultural activities depended on pests and diseases elimination that could affect plants and by maintaining nutrients in soils. Therefore nitrogen fertilizers and pesticides were used [13]. Pesticides used in agriculture can be the most ubiquitous environmental contaminants [14]. Currently, Green City Residence experiences the influence of pesticides and nitrogen fertilizers past use.

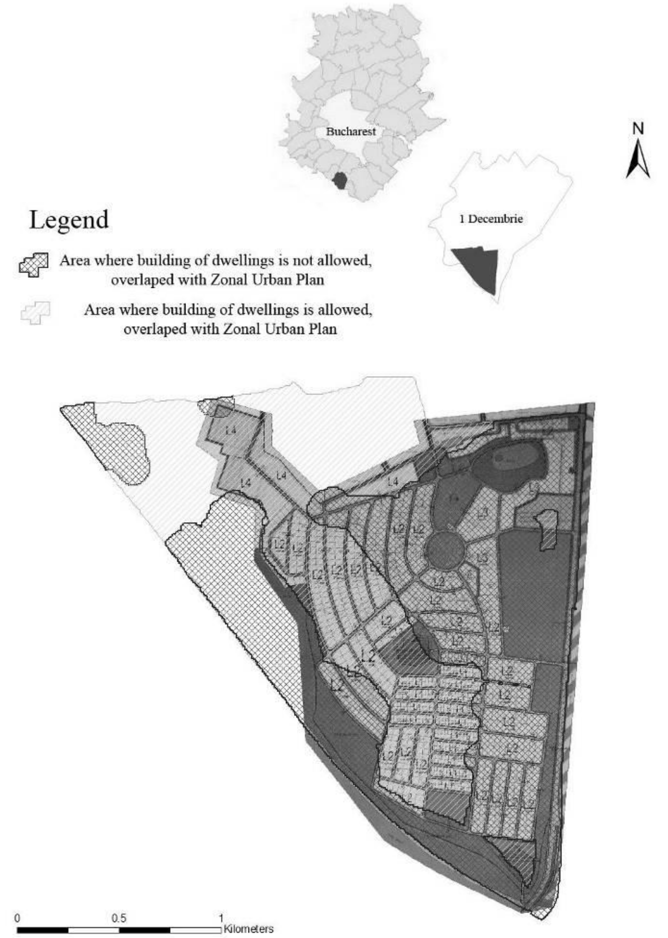

Fig. 1 – Permission/Forbidden surfaces for building residential areas in the Green City Residence perimeter

Greenhouses from Green City Residence show various environmental problems caused by resulted organic waste (some of the waste is reused as fertilizer for flowers and some go as uncontrolled waste discharges, polluting the area) and by the manner how they are heating (stoves that work by burning wood, with negative effects on air quality through pollution with toxic organic matters) (Fig. 2).

Other influence factors, responsible for environmental quality problems intercepted by Green City Residence are the natural background and neighbourhoods.

Concerning natural background, Green City Residence is located in a floodplain area, of the Argeș River. Thus, groundwater is situated near the surface, measures of consolidation and waterproof to prevent water bogging and infrastructure damage being necessary.

Fig. 2 – Greenhouses proximity to the residential area of Green City Residence

Green City Residence has as neighbourhoods: north - Liviu Rebreanu St. and the village cemetery; east – E70 – Bucharest – Giurgiu; south and west – Argeș River. Industrial unit RDS Romanian Drink Service (Garrone residence) is located within Green City Residence, affecting environmental quality and public health because of traffic attracted by this industrial and commercial area (Fig. 3). This industrial unit can represent a fire risk due to inflammable substances.

Fig. 3 - RDS Romanian Drink Service (Garrone residence) proximity to residential areas

The cemetery situated in the north of Green City represents another type of incompatible neighbourhood for residential areas. Cemeteries create problems by its function: environmental, health, hygiene [15] and psychological [16] problems.

Annexation of Green City with the sensitive forest area caused deforestation and forest vegetation aggression, so there is a loss of land for urbanization [17]. The results lie in reduced life forms and extinction of plant species through changes in substratum moisture conditions. Besides the establishment of background near natural conditions where it is created a harmony between nature and residential areas, forests generate conflicts mainly due to presence of unwanted animals (dogs, crows, insects), disparate waste warehouses and insecurity.

High environmental impact exerted by the Green City Residence is caused by certain influence factors. The main problems are air, water and soil quality.

Interior roads made for an easy access in the residential district, parking for cars which are located near residential areas and also regular events attract a permanent flow of vehicles, so exhaust gases fill the air with pollutants (carbon monoxide, nitrogen oxides, volatile organic compounds and lead emissions) and affect public health.

Another source of air pollution is represented by greenhouses from households as their heating is based on burning fossil fuels. Through burning wood, air is contaminated with suspended particles (solid aerosol) and carcinogenic compound of polycyclic aromatic hydrocarbons – PAH (benzopyrene) [18].

Regarding water quality, groundwater can be affected because its level is close to the surface (2 m), with the possibility of pollutants infiltrating during long rains. These pollutants can come from oil losses on the traffic roads and parking areas, from uncontrolled discharging of building materials with toxic substances (paints, varnishes for interior arrangement, adhesives). For wastewater problems the management of Green City Residence has invested in building an wastewater treatment plant according to European standards.

Soil quality is mainly affected because of past land use (agriculture - greenhouses) and greenhouses presence inside residential district. First, past agricultural activities required the use of pesticides and nitrogen fertilizers. Thus, the nitrites presence in soils can cause problems regarding green and aquatic areas maintenance.

Waste is another environmental problem for Green City Residence. Wastes with environmental impact are those resulted from the dwellings construction, predominantly construction materials waste (rubble, excavated soils), package waste (pasteboard, plastic), bulky waste (from demolition), municipal waste (glass, waste from street cleaning, organic waste: wood, leaves, gardening waste). These are often uncontrolled discharged in building area, affecting environment natural components (uncontrolled discharging of these in forest reduces its capacity of growing and regenerating) and decreasing the aesthetic value of the landscape.

The health state of Green City inhabitants is unbalanced by risk factors represented by past use of pesticides and nitrogen fertilizers, and also by presence use of these for the existing greenhouses. The contact between residential areas and greenhouses is obvious; the proximity of the two different functions has a strong potential impact on public health. In this context it is important to maintain toxic substances concentrations under the maximum allowable concentrations [19].

VI. CONCLUSION

Residential areas need a detailed evaluation of their environmental aggression since the plan phase. Many aspects of the relationship with environment and neighbourhoods are very difficult to be corrected and modelled in the project's operating phase. Multi-criteria assessment allows the possibility of environmental problems notification and solving. At the same time it is a tool that can be used in prioritizing environmental quality in residential areas.

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