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SPATIAL DATABASES FOR WIND PARKS

Abstract. *This paper identifies the characteristics of a wind farm and the influence factors for these, grouped by the objective function, the input parameters, the nature of parameters and the criteria they apply for, i.e. the objective function, the input parameters, the optimal value, the nature of parameters and the criteria. It proposes an algorithm for calculating the performance indicators of wind power plants that can be included in a GIS (geographic information system) prototype for wind power plants.*

From entities that we identified in wind farms in Romania, and from studies and analysis made, we built a conceptual database schema. It contains tables, for each table the proper fields, including spatial fields, and the relationship between tables. The subprograms are developed in Oracle PL/SQL programming language and the database is stored in Oracle Spatial.

Key words: wind farms, spatial database, algorithm, shadow effect, noise, velocity.

JEL Classification: C02, O52, C230.

1. Analysis of influence factors in formalizing algorithms

GIS functionalities can be easily distributed in services in a Service Oriented Architecture (SOA). Such services can be determining the most proper areas for installing new wind farms, generating the efficiency of a power plant etc. Nisioiu (2009) analyzes the requirements, design approaches and use of SOA for Romania and Mircea (2011) recommends using SOA in a Cloud Computing environment. The developed GIS takes into account these kind of architectures.

In developing a spatial database applications for wind farms there are more algorithms to be taken into consideration for implementing the various factors affecting the proper functioning of the wind farms. These factors are wind energy produced by plants, noise produced by wind plants, shadow effect, areas of conflict for wind farms, pollution, visibility, protected areas, wind direction and wind speed as shown by Intermediate Energy Infobook (2011) etc. Some of the algorithms associated with these characteristics will be considered in the next paragraph, based on those described by Nielsen (2006). Other algorithms are discussed by Shahan (2011) or Richard (2011).

The energy produced by a wind turbine

An accurate wind speed distribution is very important because wind energy increases with the wind speed value to the power of three. The energy obtained from a wind power plant is calculated with the following equation:

$$E = ½ * \rho * w^3 * A * C_e \ \ (W/s) \quad (1)$$

where: ρ = air density = 1.125 kg/m3
w = wind speed
A = range of action for turbine blades
C_e = efficiency of wind power plants

Noise

Noise produced by wind power plants (in decibels - dB) is important because it can influence the placement of wind farms outside noise sensitive areas. The international standard that describes how to calculate the noise buffer zone is ISO 9613-2 called *Attenuation of sound during propagation outdoors*, Part 2. G*eneral method of calculation* is presented below:

$$L_{AT}(DW) = L_{WA} + D_C - A - C_{met} \quad (2)$$

where: $L_{AT}(DW)$ = noise level for each source
L_{WA} = noise source
A = amortization
C_{met} = meteorological correction factor
D_C = directional correction factor

$$\mathbf{D_C = D_\Omega - D_E} \quad (3)$$

where: D_Ω = reflection coefficient of ground
D_E =directional effect, usually is 0

$$D_\Omega = 10 \lg\{1 + [d_p^2 + (h_s - h_r)^2] / [d_p^2 + (h_s + h_r)^2]\} \quad (4)$$

where: h_s = height at which the noise source is located
h_r = height at which the noise receiver is located, typically 5 m
d_p = distance between noise source and its receiver, projected from the ground

$$d_p = \sqrt{[(x_s - x_r)^2 + (y_s - y_r)^2]} \quad (5)$$

where: (x_s,y_s) = noise source coordinates

(x_r,y_r) = receiver coordinates

Depreciation of the noise source and noise critical point has several components, as follows:

$$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc} \qquad (6)$$

where: A_{div} = amortization due to the geometry

A_{atm} = amortization due to the air absorption

A_{gr} = amortization of land

A_{bar} = amortization due to protection from noise is usually 0

A_{misc} = amortization due to other effects (vegetation, buildings, industry) is usually 0

$$A_{div} = 20 \lg(d/1m) + 11 \text{ dB} \qquad (7)$$

where: d = distance between noise source and receiver

$$A_{atm} = \alpha_{500}\, d / 1000 \qquad (8)$$

where: α_{500} = coefficient of air absorption = 1.9 dB / km (for optimum conditions of 10˚C temperature and 70% atmospheric humidity)

$$A_{gr} = 4{,}8 - (2h_m / d)[17 + (300 / d)] \qquad (9)$$

If $A_{gr} < 0$, then it is approximated to 0 and h_m is:

$$hm = (hs + hr) /2 \qquad (10)$$

$C_{met} = 0$, if $d_p < 10(h_s + h_r)$, and $C_{met} = C0[1\text{-}10(h_s + h_r)/d_p]$, if $d_p > 10$, where C0 is a factor that depends on weather conditions and takes values between 0 and 5 dB.

The effect of shadowing

Shading effect occurs around wind farms in certain time and certain surfaces. The parameters this effect depends on are:

- D, diameter of the sun is 1,390,000 km;
- d, the distance from the sun is 150,000,000 km;
- angle of action is 0.531 degrees.

Theoretically, these parameters would cause a shading effect up to 4.8 km around a turbine with blades of 45 meters in diameter. In fact, the effect of shading never achieve the theoretical maximum value because of weather conditions. When the sun is too close to the horizon, the shadow dissipates before reaching the ground or the receiver. The maximum wind shadow around wind power stations is calculated as:

Max_dist = (5*w*d) / 1,097,780 (11)

where: w = average width of turbine blades
the value 1,097,780 is derived from the diameter of the sun, reduced by a factor of compensation, because the sun is a circle not a square.

Defining the areas of conflict

There are several protected areas that are influenced by human factor or areas that are just soundproofed. Whatever type of protection they need, this should be considered before placing wind farms in their vicinity. Conflict areas may be considered those areas that might be affected by the placement of wind farms in the vicinity, but also those areas, which in turn, may affect the proper functioning of wind power stations, by distorting winds or causing pollution. The most important characteristics to be specified are their exact location and number of miles around the insulation required. The most common areas of conflict for wind farms are:

- Other wind farms;
- Archaeological sites;
- Churches;
- Villages and cities;
- Pools of water;
- Factories;
- Forests;
- Nature reserves;
- Road;
- Railroads;
- Rivers and lakes;
- Military sites;
- Airports.

2. Defining an algorithm

After analyzing the influence factors presented in the previous paragraph, we can create an algorithm that takes them into account. First we synthesized a table of influence factors, their objective function, input parameters, the nature of parameters and the criteria on which they stand.

Table 1 - Influence factors for wind farms – 1st version

No.	Influence factors for wind farms	Objective function	Input parameters	Nature of parameters	Criteria
1	Produced energy	Maximize	Wind speed	Depends on natural causes	Location criteria
			Blade area	Depends on manufacturer	Performance criteria
			Farm efficiency	Depends on manufacturer	Performance criteria

2	Produced noise	Minimize	Source noise	Depends on manufacturer	Performance criteria
			Directional correction factor	Is obtained from calculations	Is obtained from calculations
			Amortization	Is obtained from calculations	Is obtained from calculations
			Meteorological correction factor	Is obtained from calculations	Is obtained from calculations
3	Produced shading effect	Minimize	Blade width	Depends on manufacturer	Location criteria Performance criteria
4	Conflict areas for wind farms that interact	Position outside the location of plants	Protected areas	Depends on natural/human causes	Location criteria

It is noticed that, from the four factors, only the last presented, namely the conflict areas, is not dependent on how plants are built or how they work. The fourth factor of influence is important only for plant location. In a more detailed analysis, we can take into account the noise produced or the shadow effect in correlation with conflict areas.

The algorithm that we propose will take into account only the fulfillment of the objective function, without correlating the effect of the four factors considered. The main reason is lack of real data, applied in Romania, for all possible conflict areas and also the way the noise or shading effect would affect each type or class of areas previously defined as conflict areas.

The table above will be commented after applying the algorithm, which will simplify or transform the parameters. Finally, based on this algorithm we will establish the performance criteria and location of wind farms.

The algorithm has as starting point the achievement of the four objective functions. The first factor of influence is intended to maximize the energy obtained as follows:

First factor of influence

$Max (E) = (1/2)*\rho*\omega^3*A*C_e$

The relations between the equation's components are directly proportional to the energy produced, which means that energy maximization involves obtaining a high value for wind speed, range of action for the blades and plant efficiency. Air density is constant at 1125 kg/m^3. Wind is a natural factor, uninfluenced, and the range of action for the blades and plant efficiency depend on the manufacturer. Substituting into the equation we obtain:

$Max (E) = 0.5625* \omega^3*A*C_e$

Second factor of influence

The noise function obtained for a wind farm is the most complex, its parameters being decomposed at several levels.

$$\text{Min}(L_{AT}) = L_{Aw} + D_C - A - C_{met}$$

Some function components are proportional related to it (source noise and directional correlation factor), while the remaining components, amortization and meteorological correlation factor draw a negative effect on function. The aim is to achieve a low source noise (depending on the manufacturer) and a low directional correlation factor (which in turn depends on the coefficient of reflection from the ground and directional effect) and to obtain a high level of damping source noise (which has five components, shown in equation 6) and of meteorological correlation factor (resulting from calculations).

Using the equations 4 – 10, taking into consideration the standard values D_E=0, h_r=5, A_{bar}=0, A_{misc}=0, α_{500}=1.9 and replacing into the objective function several times, we have obtained:

$$\text{Min}(L_{AT}) = L_{Aw} + D_\Omega - D_E - (A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc}) - C_{met}$$

$$\text{Min}(L_{AT}) = L_{Aw} + 10*\lg\{1 + [d_p^2 + (h_s - h_r)^2]\} - (20*\lg(d) + 11 + \alpha_{500}*d/100 + A_{gr}) - C_{met}$$

$$\text{Min}(L_{AT}) = L_{Aw} + 10*\lg\{1 + [(x_s - x_r)^2 + (y_s - y_r)^2 + (h_s - 5)^2]/ [(x_s - x_r)^2 + (y_s - y_r)^2 + (h_s + 5)^2]\} - (20*\lg(d) + 11 + 1.9*10^3*d/10^2 + A_{gr}) - C_{met}$$

$$\text{Min}(L_{AT}) = L_{Aw} + 10*\lg\{1 + [(x_s - x_r)^2 + (y_s - y_r)^2 + (h_s - 5)^2]/ [(x_s - x_r)^2 + (y_s - y_r)^2 + (h_s + 5)^2]\} - (20*\lg(d) + 19*d + 11 + A_{gr}) - C_{met}$$

Considering x_s = latitude, y_s = longitude, $x_r \approx x_s$, $y_r \approx y_s$, $h_s = h_r$, and the distance between source of noise and receiver equal to 1 meter, the objective function becomes:

$$\text{Min}(L_{AT}) = L_{Aw} + 10*\lg[1 + (h_s - 5)^2/(h_s + 5)^2] - (20*\lg(1) + 19 + 11 + A_{gr}) - C_{met}$$

According to equation 9 and replacing the values for d and h_m, we have obtained $A_{gr} = 4.8 - (2*h_s)*(17 + 300) = 4.8 - 634*h_s$

If $h_s > 0$, then $A_{gr} < 0$. Therefore A_{gr} is considered to be 0 and the objective function becomes:

$$\text{Min}(L_{AT}) = L_{Aw} + 10*\lg[1 + (h_s - 5)^2/(h_s + 5)^2] - (0 + 30 + 0) - C_{met}$$

$$\text{Min}(L_{AT}) = L_{Aw} + 10*\lg[1 + \frac{(hs - 5)2}{(hs + 5)2}] - 30 - C_{met}$$

As the meteorological correction factor depends on the distance between the source of the noise and receiver, and $x_r \approx x_s$, $y_r \approx y_s$, then d_p tends to 0 and C_{met} may be considerate equal to 0. The objective function becomes:

$$\text{Min}(L_{AT}) = L_{Aw} + 10*\lg[1 + \frac{(hs - 5)2}{(hs + 5)2}] - 30$$

Reconsidering the new objective function obtained, we see that the parameters on which it depends are source noise (desired value is as minimal) and plant heights.

We have consider the function $f(h) = 10*lg[1 + \frac{(h-5)2}{(h+5)2}] - 30$, for which we calculated the extreme points, in order to achieve the optimum height for the placement of wind farms. For this we calculated the derivative of order 1:

$$f'(h) = 10*lg(e)* [1 + \frac{(h-5)2}{(h+5)2}]' / [1 + \frac{(h-5)2}{(h+5)2}]$$

$$[1 + \frac{(h-5)2}{(h+5)2}]' = 2*\frac{h-5}{h+5}*(\frac{h-5}{h+5})' = 20*(h - 5)/(h+5)^3$$

$$f'(h) = 10*lg(e)*\frac{20*(h-5)/(h+5)3}{1+(h-5)2/(h+5)2}$$

$$f'(h) = 10*lg(e)*\frac{20*(h-5)/(h+5)3}{(h2+10*h+25+h2-10*h+25)/(h+5)2}$$

$$f'(h) = 10*lg(e)*\frac{20*(h-5)/(h+5)}{2*(h2+25)}$$

The extreme points are solutions to equation $f'(h) = 0$. Therefore we considered:

$$10*lg(e)*\frac{10*(h-5)}{(h+5)*(h2+25)} = 0$$

The only real solution of the equation is h = 5 and represents the extreme point. To determine whether the point found is a maximum or minimum value of function *f*, we must calculate the function values for the point 5 and other points in its neighborhood.

$$f(5) = -30 \text{ and } lg[1 + \frac{(h-5)2}{(h+5)2}] > 0. \text{ Therefore } f(h) > 30 = f(5), \forall\ h \neq 5, h > 0.$$

It follows that h = 5 is the minimum value for the function *f*, and extrapolating for the objective function Min (L_{AT}) = L_{Aw} + f(h_s), we noted that optimal values are a noise level for the source as low and a height of the plants as close to 5 meters.

Third factor of influence

Shading effect can be represented by an objective function as follows:

Min (max_dist) = (5*w*d)/1,097,780

Since the distance to the sun is $15*10^{10}$ meters, then:

Min (max_dist) = $(75*10^{10}*w)/1,097,780 \approx 683197*w$

Therefore, in order to obtain a shading effect as small, turbine blades need to have the width as small.

Fourth factor of influence

Conflict areas for possible location of a wind farm can be quantified only as total area reserved. It is desirable that these areas do not intersect with areas with high wind potential.

Given the new parameters calculated, Table 1 can now be reconsidered as follows:

Table 2 - Influence factors for wind farms – 2nd version

No.	Influence factors for the wind farms	Objective function	Input parameters	Optimal value	Nature of parameters	Criteria
1	Produced energy	Maximize	Wind speed	Maximum value	Depends on natural causes	Location criteria
			Blade area	Maximum value	Depends on manufacturer	Performance criteria
			Farm efficiency	Maximum value	Depends on manufacturer	Performance criteria
2	Produced noise	Minimize	Noise source	Minimum value	Depends on manufacturer	Performance criteria
			Plant height	5 meters	Depends on manufacturer	Performance criteria
3	Produced shading effect	Minimize	Blade width	Minimum value	Depends on manufacturer	Location criteria Performance criteria
4	Conflict areas for wind farms that interact	Position outside the location of plants	Protected areas		Depends on natural/human causes	Location criteria

We can observe that depreciation, directional and meteorological correction factors were eliminated by entering the height parameter. Also, by attending the four components of the algorithm we determined the optimal values of parameters.

Based on these calculations, we can determine the criteria for judging the performance of a wind farm, and also the criteria for finding the optimal location for a new wind farm.

Performance criteria depend on the technical characteristics of the wind power plants offered by manufacturers and the natural wind velocity, as follows:

- wind speed – maximum;
- blade area – maximum;

- blade width – minimum;
- wind farm efficiency – maximum;
- noise source – minimum;
- plant height – 5 meters.

Location criteria should consider the following factors:

- wind speed – maximum;
- conflict areas – intersection of the desired location of the wind farm and a certain distance around protected areas should be null;
- shading effect – intersection of the maximum shaded area and protected areas should be null.

The performance criteria may be applied before installing a wind plant and they assume choosing a particular model based on its technical characteristics. Also, they can be applied to already installed plants, in that case taking into account the current wind speed in order to determine their instant performance. In this situation it is desirable that the technical parameters to be updated if they change over time. For example, farm efficiency may decrease due to temporary or permanent technical failures.

Considering these aspects we defined the technical performance of the plant *i* (Pt_i), which is recommended to be determined before buying a farm wind, and the actual performance (Pa_i), calculated at any time. The application that we developed calculates the actual performance using a database trigger that occurs whenever one of the technical characteristics of the plant it is updated in the database.

$Pt_i = 80\%*P_{Ei1} + 15\%*P_{Ni} + 5\%*P_{Si}$

We considered that the most important factor for a wind farm is the performance obtained by wind power production of energy (P_{Ei1}), while the performance in terms of noise level (P_{Ni}) and the performance in terms of produced shading effect (P_{Si}) are less significant. Each of the three components of Pt_i, are composed of the parameters discussed above. Thus, depending on how they participate in the algorithm described above, the performances are:

$$P_{Ei1} = 50\%*\frac{blade\_area_i}{Max\ j=1,n\{blade\_area_j\}} + 50\%*\frac{efficiency_i}{Max\ j=1,n\{efficiency_j\}}$$

$$P_{Ni} = 60\%*\frac{Min\ j=1,n\{noise_j\}}{noise_i} + 40\%*\frac{5}{5+|5-height_i|}$$

$$P_{Si} = \frac{Min\ j=1,n\{blade\_length_j\}}{blade\_length_i}$$

Performance components are calculated relative to the maximum value (for parameters that must be maximized) and minimum (for the parameters to be minimized) for the *n* farms analyzed. The only exception is the *height* component, which is relative to the optimal value of 5 meters.

Similarly, $Pa_i = 80\%*P_{Ei2} + 15\%*P_{Ni} + 5\%*P_{Si}$

In this case, the component that differs is the performance obtained by wind power production of energy (P_{Ei2}), for which we propose the following calculation formula (considering that for calculating the energy produced by a wind plant, the wind velocity is to the 3rd power):

$$P_{Ei2} = 60\% * \frac{area_i}{5} + 20\%*\frac{blade\_area_i}{Max\ j=1,n\{blade\_area_j\}} + 20\%*\frac{efficiency_i}{Max\ j=1,n\{efficiency_j\}}$$

In Romania, the wind parameter can be classified into five zones, depending on the average number of hours per year the wind blows. Wind speed is in strict connection with these areas. Depending on these areas, the wind farms will have associated a share, as follows:

- for values up to 1500 hours / year, the share is equal to 1;
- for values between 1500 and 2500 hours / year, the share is equal to 2;
- for values between 2500 and 4000 hours / year, the share is equal to 3;
- for values between 4000 and 5000 hours / year, the share is equal to 4;
- for values over 5000 hours / year, the share is equal to 5.

Unlike the performance criteria, the placement criteria are eliminatory. Depending on them, we can make the decision to build or not to build a wind farm in a certain area. Thus, if the location where we want to build the wind farm has not the share 3, 4 or 5, then it is advisable to consider another place. The same happens if the area is declared a conflict area or if the effect of shading affects large agricultural areas, private sectors etc.

In the application developed based on these algorithms, we determined the potential areas that may the right place to develop new wind farms, according to performance criteria.

Using the described criteria and the algorithms for calculating various indicators, we can compare performance of various farms and we can determine the optimal location or the values of objective functions.

If we consider the wind farms already located, we recommend calculating the objective functions for influence factors and comparing performance against the criteria described above. For exploration of potential areas for wind farms, it is useful to use the criteria of location, and for choosing a wind farm offer of producers we suggest determining the technical performance. These are just some examples in which the algorithms and criteria discussed in this paragraph may be implemented.

3. Conceptual schema of the database

The entities that we identified for wind plants domain and the work study and analysis, helped us build a conceptual database schema. It contains the tables, for each table its fields, including spatial fields, and the relationship between tables.

Conceptual schema includes the tables: CENTRALE (spatial table for wind plants), STATII (regular table for points of collecting the energy produced by power plants), ZONE_VANT (spatial table for wind areas), ZONE_CONFLICT (spatial table for conflict areas), ZONE_CONFLICT_VANT (spatial table for conflict areas split by wind areas) and PRODUCATORI (regular table for producers of the wind turbines), with the following links between them (expressed by primary keys):

- a collecting station refers to several plants, while a wind plant can belong to a single central station;
- a plant is produced by one company and a manufacturer can make many power plants;
- a power plant is located on a single area of wind and a wind zone includes several power plants;
- an area of wind may include several areas of intersection between surfaces defined by the specific wind areas and the declared conflict areas, while these areas may be located on a single area of wind;
- a conflict zone may include several areas of intersection between surfaces defined by the specific wind areas and the declared conflict areas, while these areas may include part of one area of conflict.

Each table contains one primary key, foreign keys if necessarily, a spatial field for the spatial tables and other descriptive data fields.

In CENTRALE table the fields are de name of the plant, the village and the region where it is placed, its latitude and longitude, the installed power, in MW, the date of the contract and the provider.

For STATII table the information stored is: voltage - U measured in kV, registration number and other comments on how to make connection to the national electricity grid.

ZONE_VANT contains information on wind activity in Romania, which is defined by velocity (in m / s) and wind area, with values between 1 and 5, 5 being the areas with the highest wind potential and 1 the areas where wind seldom blows.

PRODUCATORI table contains the producers' name and technical specifications of the plants that depend on producers, such as energy efficiency, noise (in dB), blade width (in cm), the range of the blades (in cm^2), plant height (expressed in m).

ZONE_CONFLICT table stores data about areas of conflict defined by name, number of kilometers to be affected to isolate them, spatial location.

ZONE_CONFLICT_VANT is the intersection table between ZONE_CONFLICT and ZONE_VANT, containing in addition to primary key and foreign keys to referenced tables, the location of this area.

For all these tables the data, which comes as text, XML files, Excel files etc., should be loaded and processed in a spatial relational database (e.g. Oracle). Ways to obtain performance in such a process are revealed by Lungu (2010).

4. Creating procedures

The main sub-procedures that are used in the application are *alg1* (for calculating the performance), *alg2* (for determining the areas with potential for placing new wind farms), *alg3* (used for a trigger) and trigger named *performance* (for updating the plant performance). All of them are shown below.

In order to implement the performance calculating algorithm, we used the following stored procedure. It contains several main modules:

- defining the memory variables (latime_min, zgomot_min, aria_max, eficienta_max, e, lg, l, dist_max, vant_var, zona_var, p_en, p_z, p_u, p_tot);
- defining explicit cursor c1;
- executing the algorithm for calculating the performance (initializing the variables, loading values from the cursor, calculating the maximum efficiency, maximum area, minimum width, minimum noise, showing extreme values, calculating and displaying the performance indicators).

```
      create or replace procedure alg1
      is
      -- defining the memory variables
      latime_min number(6,2);
      zgomot_min number(5);
      aria_max number(6,2);
      eficienta_max number(6,2);
      e number(14,4);
      lg number(10,2);
      l number(10,2);
      dist_max number(20,2);
      vant_var number(10,2);
      zona_var number(1);
      p_en number(20,2);
      p_z number(20,2);
      p_u number(20,2);
      p_tot number(20,2);
      -- defining the explicit cursor c1
      cursor c1 is select id_centrala, centrale.denumire
as den, localitate, eficienta, zgomot, inaltime,
latime_palete, aria_act_palete from centrale,
producatori where
centrale.id_producator=producatori.id_producator;
      -- executing the algorithm for calculating the
performances
      Begin
```

```
      --initializing the variables
      latime_min :=1000;
      zgomot_min :=1000;
      aria_max :=0;
      eficienta_max:=0;
      -- loading the values from the cursor
      for i in c1 loop
      select vant into vant_var from zone_vant, centrale
where centrale.id_vant=zone_vant.id_zona and
id_centrala=i.id_centrala;
      e:=0.5625*power(vant_var,3)*i.aria_act_palete*i.ef
icienta;
      lg:=log(10,1+power(i.inaltime-
5,2)/power(i.inaltime+5,2));
      l:=i.zgomot+10*lg-30;
      dist_max:=683197*i.latime_palete;
      --calculating the maximum area
      if aria_max<i.aria_act_palete then
      aria_max:=i.aria_act_palete;
      end if;
      --calculating the maximum efficiency
      if eficienta_max<i.eficienta then
      eficienta_max:=i.eficienta;
      end if;
      -- calculating the minimum length
      if latime_min>i.latime_palete then
      latime_min:=i.latime_palete;
      end if;
      -- calculating the minimum noise
      if zgomot_min>i.zgomot then
      zgomot_min:=i.zgomot;
      end if;
      -- displaying the extreme values
      dbms_output.put_line('Energia produsa de centrala
'||i.id_centrala||' '||i.den||' din localitatea
'||i.localitate||' este: '||e);
      dbms_output.put_line('Zgomotul produs de centrala
'||i.id_centrala||' '||i.den||' din localitatea
'||i.localitate||' este: '||l);
      dbms_output.put_line('Efectul maxim de umbrire
produs de centrala '||i.id_centrala||' '||i.den||' din
localitatea '||i.localitate||' este: '||dist_max);
      end loop;
      for i in c1 loop
      -- calculating the performance indicators
```

```
      select zona into zona_var from zone_vant, centrale
where centrale.id_vant=zone_vant.id_zona and
id_centrala=i.id_centrala;
      p_en:=0.6*zona_var/5+0.2*i.aria_act_palete/aria_ma
x+0.2*i.eficienta/eficienta_max;
      p_z:=0.6*zgomot_min/i.zgomot+0.4*5/(5+abs(5-
i.inaltime));
      p_u:=latime_min/i.latime_palete;
      p_tot:=p_en+p_z+p_u;
      -- displaying the performance indicators
dbms_output.put_line('Performanta energiei centralei
'||i.id_centrala||' '||i.den||' din localitatea
'||i.localitate||' este: '||p_en);
      dbms_output.put_line('Performanta nivelului de
zgomot al centralei '||i.id_centrala||' '||i.den||' din
localitatea '||i.localitate||' este: '||p_z);
      dbms_output.put_line('Performanta dpdv al efectul
maxim de umbrire produs de centrala '||i.id_centrala||'
'||i.den||' din localitatea '||i.localitate||' este:
'||p_u);
      dbms_output.put_line('Performanta totala a
centralei '||i.id_centrala||' '||i.den||' din
localitatea '||i.localitate||' este: '||p_tot);
      end loop;
      end;
```

The second algorithm for determining areas with wind potential was implemented by creating two virtual tables and a stored procedure. Virtual tables include the wind power plants and the buffer zones around them according to the shadow effect produced by each, respectively the spatial intersection of these buffer zones and the conflict areas situated in areas with high wind intensity.

```
      create view view1 as select id_centrala,
sdo_geom.sdo_buffer(geom,683197*latime_palete,0.005) as
buff from centrale c, producatori p where
c.id_producator=p.id_producator
      create view view2 as select
sdo_geom.sdo_intersection(amplasare, buff, 0.005) as
intersectia from zone_conflict_vant z1, zone_vant z2,
view1 where z1.id_vant=z2.id_zona and zona in (3,4,5)
```

The stored procedure *alg2* creates a table called *rezultat* in which inserts the values obtained from the spatial difference applied to the areas from the virtual table previously created and 3, 4 or 5 wind zones.

```
      create or replace procedure alg2
      is
      j number;
```

```
      cursor c1 is select
sdo_geom.sdo_difference(amplasare,intersectia,0.005) as
zona from zone_vant z, view2 where z.zona in (3,4,5);
      begin
      --execute immediate 'drop table rezultat';
      execute immediate 'create table rezultat(id number
primary key, zona sdo_geometry)';
      commit;
      j:=1;
      for i in c1 loop
      execute immediate 'insert into rezultat
values(j,i.zona)';
      j:=j+1;
      end loop;
      end;
```

We also created a trigger to update the performance of the plants whenever one or more technical features are modified in the PRODUCATORI table. Initially we have created PERFORMANTE table, which has a relation type 1-1 with CENTRALE table.

```
      create table performante(id_centrala number
primary key references centrale, performanta number);
```

The trigger calls *alg3* stored procedure having the field *id_producator* as parameter for the producer of the plant which has modified characteristics. The algorithm is actually a modified version of *alg1*, to which we added an input parameter and which also contains a modifying command.

```
      create or replace procedure alg3(id_prod
producatori.id_producator%type)
      is
      -- defining the variables
      latime_min number(6,2);
      zgomot_min number(5);
      aria_max number(6,2);
      eficienta_max number(6,2);
      e number(14,4);
      lg number(10,2);
      l number(10,2);
      dist_max number(20,2);
      vant_var number(10,2);
      zona_var number(1);
      p_en number(20,2);
      p_z number(20,2);
```

```
      p_u number(20,2);
      p_tot number(20,2);
      -- defining c1 explicit cursor
      cursor c1 is select id_centrala, centrale.denumire
as den, localitate, eficienta, zgomot, inaltime,
latime_palete, aria_act_palete from centrale,
producatori where
centrale.id_producator=producatori.id_producator and
producatori.id_producator=id_prod;
      -- executing the algorithm for calculating the
performances
      Begin
      latime_min :=1000;
      zgomot_min :=1000;
      aria_max :=0;
      eficienta_max:=0;
      for i in c1 loop
      select vant into vant_var from zone_vant, centrale
where centrale.id_vant=zone_vant.id_zona and
id_centrala=i.id_centrala;
      e:=0.5625*power(vant_var,3)*i.aria_act_palete*i.ef
icienta;
      lg:=log(10,1+power(i.inaltime-
5,2)/power(i.inaltime+5,2));
      l:=i.zgomot+10*lg-30;
      dist_max:=683197*i.latime_palete;
      -- calculating the maximum area
      if aria_max<i.aria_act_palete then
      aria_max:=i.aria_act_palete;
      end if;
      -- calculating the maximum efficiency
      if eficienta_max<i.eficienta then
      eficienta_max:=i.eficienta;
      end if;
      -- calculating the minimum length
      if latime_min>i.latime_palete then
      latime_min:=i.latime_palete;
      end if;
      -- calculating the minimum noise level
      if zgomot_min>i.zgomot then
      zgomot_min:=i.zgomot;
      end if;
      end loop;
      -- calculating the performance factors
      for i in c1 loop
```

```
      select zona into zona_var from zone_vant, centrale
where centrale.id_vant=zone_vant.id_zona and
id_centrala=i.id_centrala;
      p_en:=0.6*zona_var/5+0.2*i.aria_act_palete/aria_ma
x+0.2*i.eficienta/eficienta_max;
      p_z:=0.6*zgomot_min/i.zgomot+0.4*5/(5+abs(5-
i.inaltime));
      p_u:=latime_min/i.latime_palete;
      p_tot:=p_en+p_z+p_u;
      -- updating PERFORMANTE table
      update performante set performanta=p_tot where
id_centrala=i.id_centrala;
      end loop;
      end;
```

The code for creating the trigger is:

```
      create or replace trigger performance after update
on producatori
      for each row
      begin
      alg3(:old.id_producator);
      end;
```

5. Conclusions

The influence factors for wind farms analyzed in Table 2 are the parameters in the proposed algorithms. Each of them may be a point of interest for different owners of a wind farm (electric companies, government, farmers, families). For example the noise factor can be very important for families that have wind farms on their property and less important for electric companies that place their farms on isolated areas. Also the produced energy is most important for electric companies. In each specific case mathematical programming can be used in addition to the algorithms described above for optimal decision making. Popescu (2011) gives example of mathematical programming.

The database can be stored using different spatial database management systems and then processed using programming languages. This article proposes an implementation using Oracle products as Oracle Spatial Database and PL/SQL.

Acknowledgements

This paper presents some results of the research project PN II, TE Program, Code 332: "Informatics Solutions for decision making support in the uncertain and unpredictable environments in order to integrate them within a grid network", financed within the framework of People research program.

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