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LOCATING UNDESIRABLE FACILITIES

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1. Introduction

Traditionally, mathematical models used to solve locating problems for one or more facilities, assuming in most cases that the facilities provide a desirable service. This is, for example, the case of public service centres, like hospitals or police stations, or the case of warehouses or branch-houses for a business. In such instances usually the interaction between the facility and customers involves the travel problem. Assuming travelling costs directly related to the travel distance, the problem is then to find a location for a new facility (or new facilities), so that some functions of the distance (and, consequently, of the costs of the service) are minimised ([1], [2]).

However, this is not necessarily true for every type of facility. For example, in the case of landfills or waste incinerators, or in many other cases, the minimisation of distance between the facility and customers is not desirable for various reasons: in such cases we denote such facilities as "undesirable". A facility can be defined as "undesirable" when, although it is useful or necessary for the society, it brings some disadvantages for the population living nearby, as, for example, for the production of frequent and bothersome noise, like in case of an airport, or for the emission of smoke or others substances, dangerous or not, by a factory funnel. Other plants, although normally safe, can be dangerous for the surrounding area and its population because they involve the use of some hazardous materials. Another complication related to the problems in this general field is that the risks and benefits associated with the choice of a site can be shared in different parts among different groups of people, which brings out the matter of equity of that choice.

Beside this, as the life conditions in more industrialised countries have been improving, public has become more attentive to environmental and ecological problems, and citizens show a decreasing tolerance towards real or perceived threats concerning safety, health or just lifestyle for themselves and for their families ([3]). This social phenomenon explains the strong opposition met by every project for the installation of a new facility that might be defined as "undesirable". Problems related to location of undesirable facilities have taken a highly determining and conditioning role in many fields, and for this reason many researchers have spent much work attempting to solve them. The first models of location of undesirable facilities were mostly single objective models as well as in case of desirable facilities.

However, a location decision for an undesirable facility usually involves achieving multiplicity of objectives so that the latest analytical models proposed to support this type of choice are mostly multiobjective models that try to address different aspects of the problem.

The most prominent objectives, taken in account in a wide variety of models, seem to be minimisation of costs, minimisation of risks (real risks or perceived risks, which reflect opposition of people), and maximisation of equity (intended as equity in the risk distribution).

E. Erkut and S. Neumann ([4]) presented a multiobjective model for locating one or more undesirable facilities, which should service a particular region, and selecting their sizes. We developed this model taking it as a starting point for implementation of a computer program that can be used by the decision-maker as a support in the final locating choice.

The objectives of the model are:

- Minimise total costs;
- Minimise total opposition shown by the citizens towards the plants;
- Maximise equity.

We will now explain the model and highline the upgrade we made.

2. Starting Model

We assume that the region requires some specified level of considered service and this need must be filled by installing the plants in a combination of different sizes.

Firstly we assume that a number of candidate sites has already been selected because there is usually a lot of ties upon the location choice imposed by natural barriers as lakes or forests, as well as by protected zones, private properties and so on, so that former selection of candidate sites is often needed.

Regarding population centres, we assume that for every one of them the annual demand of the service is known and that the population is considered to be concentrated in the centre of the populated area.

Regarding facility sizes (which means their capacity to provide the service), we assume that, as a result of probable technological ties, only a small number of different sizes can be considered.

The first objective of the model is minimisation of total costs consisting of total costs of the plant plus the transportation costs. We consider as known the total costs of the plant in each candidate site and for every alternative size we can make a choice in that site. These total costs include annual operating costs and annualised investment costs. Investment costs can include purchase money for the land and building-up costs, as well as possible compensation for the people living nearby, or costs of preventive studies on the environmental impact, or cleaning costs after the activity is finished.

Total costs of the plant will change with the plant size, but the fact that bigger plants can be cheaper because of scale economies must be taken into consideration.

Transportation costs related to service providing are taken equal to the product of the amount of transportation for the distance between the facility and the population centre, and the unitary transportation cost that is supposed to be known.

The second objective is minimisation of total opposition of people which is considered the same as the risk perception of people. This objective is based upon the definition of the "disutility" function, by means of which we can express the risk perception for a citizen living in the population centre j due to the facility of size a_k located in the site i, with the Euclidean distance d_{ij} from population centre j, as:

$$(d_{ij})^{-p} \cdot (a_k)^q \qquad const. p, q > 0 \tag{1}$$

Hence, we assume that disutility is a decreasing function of the Euclidean distance between a population centre and a facility, and an increasing function of the facility size. Parameters p and q should be determined with empirical studies: they depend especially on the nature of the facility and on position of residents of the region towards the facility.

Total disutility for a single citizen is calculated as the sum of the disutilities due to all the facilities of the proposed system. Opposition of a population centre is calculated as a sum of all individual disutilities of the residents, and total opposition towards the proposed system is calculated as a sum of oppositions of all population centres.

The last objective is maximisation of equity. As we suppose that no citizen supports a disproportional amount of burdens, a suitable measure for equity has to assure that smaller population centres are not disadvantaged against the bigger ones. As a measure of equity (or, better, unequity) we take the maximum individual disutility calculated as explained above. The third objective is hence minimising maximum individual disutility associated with the proposed system of facilities.

3. Conflicts Among Objectives

We can identify some conflicts that come out among all components of the considered objectives.

Total costs are given by sum of the facility costs (investment and operating costs) and transportation costs. These two components collides with each other: in fact, few big plants will be needed in order to reduce investment costs (scale economy), but it would be necessary to have many facilities in order to reduce transportation costs and they should be consequently smaller in order to distribute the service over the region in a better way.

The opposition objective collides with the reduction of transportation costs: in order to minimise them, we should in fact locate the facilities as close as possible to the demand centres, but in order to minimise the opposition of people, the contrary should be done.

The equity objective fights the investment costs reduction, because these costs can be reduced by locating less plants as possible, and to maximise the equity the highest possible number of plants must be located.

Finally, there's a conflict between equity and opposition objectives: high number of small plants can increase equity, but, nevertheless, opposition can be increase.

4. Model Formulation

We will describe the notation adopted for the model now and then the model formulation will be shown.

Indices:

i .... index for candidate sites ($i = 1, ..., m$);
j .... index for population centres ($j = 1, ..., n$);
k... index for facility sizes ($k = 1, ...,K$).

Decision variables:

y_{ik} = 1 if a facility of size k is located at the site i, 0 otherwise;
x_{ij} = amount of annual demand of population centre j covered by facility located at site i.

Parameters:

D_j .... annual demand of population centre j;
w_j .... dimension (number of inhabitants) of population centre j;
a_k .... annual capacity of a plant of size k;
c_{ik} .... total annual costs of a plant of size k located at site i;
tc_{ij} .... unitary transportation costs from site i to population centre j;

d_{ij} .... Euclidean distance between candidate site i and population centre j;

p, q .... parameters of the individual disutility function.

Objectives:

$$\min G(X,Y) = [g_1(X,Y), g_2(X), g_3(Y)] \tag{2}$$

$$g_1(X,Y) = \sum_{i=1}^{m}\sum_{k=1}^{K} c_{ik} \cdot y_{ik} + \sum_{i=1}^{m}\sum_{j=1}^{n} tc_{ij} \cdot x_{ij} \tag{3}$$

$$g_2(Y) = \sum_{i=1}^{m}\sum_{j=1}^{n} w_j \cdot (d_{ij})^{-p} \cdot \sum_{k=1}^{K} (a_k \cdot y_{ik})^q \tag{4}$$

$$g_3(Y) = \max_{1 \le j \le n} [\sum_{i=1}^{m} (d_{ij})^{-p} \cdot \sum_{k=1}^{K} (a_k \cdot y_{ik})^q] \tag{5}$$

Constraints:

$$\sum_{i=1}^{m}\sum_{k=1}^{K} a_k \cdot y_{ik} - \sum_{k=1}^{K} a_k \cdot y_{tk} < \sum_{j=1}^{n} D_j \qquad for\ t = 1, 2, ..., m \tag{6}$$

$$\sum_{i=1}^{m} x_{ij} = D_j \qquad for\ j = 1, 2, ..., n \tag{7}$$

$$\sum_{j=1}^{n} x_{ij} \le \sum_{k=1}^{K} a_k \cdot y_{ik} \qquad for\ i = 1, 2, ..., m \tag{8}$$

$$\sum_{k=1}^{K} y_{ik} \le 1 \qquad for\ i = 1, 2, ..., m \tag{9}$$

$$y_{ik} = 0 \quad or \quad 1 \qquad for\ i = 1, 2, ..., m, \quad k = 1, 2, ..., K \tag{10}$$

$$x_{ij} \ge 0 \qquad for\ i = 1, 2, ..., m, \quad j = 1, 2, ..., n \tag{11}$$

$$\sum_{i=1}^{m} (d_{ij})^{-p} \cdot \sum_{k=1}^{K} (a_k \cdot y_{ik})^q \ge 0 \qquad j = 1, 2, ..., n \tag{12}$$

The constraint (6) corresponds to the formulation of a non-redundancy hypothesis, which imposes that if one of selected sites is excluded from any solution the total demand cannot be met by that solution. In fact, due to the nature of the facilities we are considering, we assume that the decision-maker would not be interested in a solution with redundant facility, hence we will exclude this type of solutions.

The constraint (7) assures that the demand of each population centre is satisfied and the constraint (8) imposes that the amount of the service provided by the site i does not exceed the capacity of the plant located in that site. Finally, constraint (9) imposes that only one of possible capacities can be chosen for every plant.

5. Implementation of the Model

We implemented a computer program based on the model we have described above that is applicable to location problems with the hypothesis stated above.

The discrete nature of the problem (discrete set of candidate sites and discrete set of possible capacities for the plants) suggests the implementation of an enumeration procedure that generates all the possible solutions that fill total demand without any redundant facility.

In our algorithm, each level of the enumeration tree corresponds to a candidate site. At every node of the tree we decide what capacity the facility installed in that site will have, considering zero value if the site is not selected. Then we go to the subsequent level (the next site), where the choice is repeated, so that for enumeration we generate all possible combinations of candidate sites with available sizes. Due to the combinatorial nature of the problem, maximum number of possible solutions is $(k+1)^m$. This is because there are m candidate sites, and for each of them any of the k alternative capacities can be taken, considering zero capacity (the (k+1) alternative) if the site is not selected.

For all these combinations, it must be verified whether total demand (sum of demands of all population centres) is not greater than sum of capacities of all the plants in that combination. This condition descends directly from the constraints (7) and (8) (but they also need to be verified individually) and allows us to eliminate all combinations that do not meet total demand of the service for the considered region.

Imposing the constraint (6), we then eliminate combinations with redundant plants. This is carried out by alternatively eliminating every plant in the combination and checking every time whether the capacity of remaining plants exceeds total demand.

To make the data elaboration more efficient, in the enumeration procedure we implemented, for each node we checked whether demand is filled, and in such case we have a solution; otherwise, the node is fathomed. A node can be fathomed even if the demand is met, but there is a redundant plant. If there is no redundant plant, then the search of solutions over that node must be continued even if a solution was found.

At the end of this procedure, we have a set of all applicable solutions that must be reduced using the optimisation criteria given in the model. For each configuration of the facility system that has been generated by the enumeration algorithm we must calculate the objective function values: total costs, opposition, and maximum individual disutility.

6. The Transportation Problem

For a given configuration of plants, total costs depend on the costs of the transportation activity associated with that configuration. These transportation costs depend themselves on the way the demand of each population centre is divided among all undesirable facilities; namely it depends on the set of unknown parameters x_{ij}. Hence, the set of values x_{ij} that minimises transportation costs must be found, and this is required for every configuration of the system generated by the enumeration algorithm.

Therefore, we need to solve transportation problem. It is a particular case of linear programming problems.

7. Calculation of Efficient Solutions

The transportation problem is solved for each of the enumerated configurations − feasible solutions, and consequently the value of three objective functions is calculated based on expressions (3), (4) and (5).

The best solutions − efficient solutions are then selected as a result of comparison. To start the comparison, the first feasible solution is selected and inserted into a set of efficient solutions. Each feasible solution considered successively is then compared to all the solutions selected as efficient and it is eliminated if it has all values of objective functions higher than any other selected solution has.

When all objective function values have been calculated and the selective comparison has been carried out for all the "feasible" solutions, we get the complete set of "efficient" solutions. For each of them, values of total costs, total opposition, maximum individual disutility, facility costs, transportation costs and the matrix of the demand distribution of the population centres upon the facilities are stored.

However, we cannot state that one of these solutions is the "best" solution without referring to some specific evaluation criteria. In fact, if we compare any two of these solutions we will always find that in general a solution is more advantageous than another one in one of three objectives, and disadvantageous in a different objective: hence, we have now to solve the problem of how to interpret these results.

8. Output Data Representation

To simplify the result presentation, the program calculates normalised values for objective functions, making the best value to correspond to 0 and the worst to 1. The intermediate values are found by linear interpolation between 0 and 1. Once these scores are generated, we can choose whether to arrange them by costs, by opposition or by maximum individual disutility. In fact, due to the intrinsic conflicts among the objectives, each solution can reach totally different scores and take different positions in three classifications.

To compare these solutions better (considering all three objectives at the same time), we need to define some particular aggregation criteria of the three scores we get so that it is possible to determine a "compromise solution".

For instance, if we refer to normalised values, we can consider an ideal solution that scores the zero value in all three objective functions. Clearly, this solution cannot be feasible and will not be comprised in our set of efficient solutions (in fact, if it was so, we should have deleted all the other solutions by comparing them with this one). We will then denote it “utopian solution”.

In a three-dimensions space in which every dimension corresponds to an objective function, with some given metrics to evaluate distances between the solutions, we can then find the solution of our set that is the closest to the utopian solution (0, 0, 0). The compromise solution we find will change depending on the metric adopted, because when the metric changes, the distance values change, too. Our program can automatically arrange efficient solutions by rectilinear distance or by Euclidean distance from the solution (0, 0, 0).

Another way of evaluating these results is to use weighted sum of three normalised values of the objective functions. Given a set of weights w1, w2 and w3 (the sum being 1), we can identify the solution with lower value of the following function

$$F(X,Y) = w_1 \cdot g_1(X,Y) + w_2 \cdot g_2(Y) + w_3 \cdot g_3(Y) \qquad (13)$$

Of course, if we vary w1, w2 and w3, the compromise solution will vary, too. Choice of these weights depends on political, economical, social and moral considerations of the responsible subject of the project. We can provide some visual information which can help the decision-maker in the data interpretation by representing the definition space of the weights w1, w2 and w3. This space will be triangular because we have three objectives and, consequently, three weights. In each corner of the triangle one of the weights is equal to 1 and the others are 0. In the centre of the triangle all weights are equal to 1/3. It is possible to share the triangle in convex polygons where one of the solutions dominates the others. Our program can automatically generate this representation by assigning the colour that corresponds to the solution that ranks the minimum value of the weighted sum of the scores of three objective functions to each pixel that is inside a triangular area of the screen.

9. Example

Now we will refer to a simple example to illustrate how the program works.

In this example we have 10 population centres (n = 10), 4 candidate sites (m = 4) and 3 possible facility sizes for each site (K = 4, with the fourth capacity being zero if the site is not selected).

The input data are shown in Chart 1. Note that the demand D_j is set to be equal to the population of the population centre j.

Note also that the unitary transportation costs values are randomly taken from the range between the values of the Euclidean distance and of the rectilinear distance between the candidate site and the population centre. This is because, in a particular problem, the unitary transportation costs can be proportional to the real travel distance.

The number of dispositions with repetition of the K considered capacities in m candidate sites is $K^m = 4^4 = 256$. As a result of the calculation we see that only 57 solutions of these 256 satisfy the demand of the service without redundant plants.

Chart 1 *Input data for the example considered*

Coordinates of population centres:

1.	[12.1; 31.2]	6.	[21.0; 14.9]
2.	[27.2; 26.3]	7.	[25.3; 12.5]
3.	[18.3; 24.6]	8.	[7.3; 11.0]
4.	[14.7; 21.3]	9.	[16.2; 7.9]
5.	[21.5; 18.6]	10.	[25.8; 8.7]

Coordinates of candidate sites:

A	[20.3; 27.5]
B	[6.2; 25.3]
C	[23.8; 18.2]
D	[14.3; 13.7]

Population and demand of the service for all population centres:

Popul. centre:	1	2	3	4	5	6	7	8	9	10	Total
Population:	7.9	18.5	3.7	2.2	2.8	6.7	1.2	1.3	2.4	1.1	47.8
Demand:	7.9	18.5	3.7	2.2	2.8	6.7	1.2	1.3	2.4	1.1	47.8

Possible facility capacities: 0, 10, 15, 27

Investment costs for candidate sites:

Candidate site:	A	B	C	D
No facility:	0	0	0	0
Facility of size 10:	80	100	150	140
Facility of size 15:	120	150	180	210
Facility of size 27:	180	225	270	315

Unitary transportation costs from sites A-D to population centres 1-10:

	1	2	3	4	5	6	7	8	9	10
A	10.90	7.10	4.40	10.80	9.10	12.30	19.00	26.50	21.70	22.30
B	10.80	20.50	11.50	11.00	20.00	23.20	28.90	14.30	25.90	34.20
C	22.70	10.50	10.90	11.20	2.50	5.90	6.70	21.70	16.90	10.50
D	17.90	23.50	13.90	7.20	10.90	7.00	11.20	9.10	6.90	15.40

Disutility function parameters: q = 1.70; p = 1.40

For each of these solutions our program solves the transportation problem and calculates the effective and normalised values of three objective functions. Comparison of these last three values results in 7 of 57 feasible solutions that can be selected as efficient. For these 7 solutions the distance from the utopian solution is calculated both in rectilinear and Euclidean distances. Chart 2 shows the final data for these solutions.

Chart 2 *Efficient solutions with normalised values of the objective functions and distance from the utopian solution (0, 0, 0)*

Sol. No.	Capacity at the site				Costs	Opposition	Max Indiv. Disutility	Rectilinear Distance	Euclidean Distance
	A	B	C	D					
1	27	10	15	0	0.000	1.000	1.000	2.000	1.414
2	27	10	0	15	0.134	0.706	0.945	1.785	1.187
3	27	15	0	10	0.145	0.660	0.942	1.747	1.159
4	15	10	15	10	0.336	0.292	0.556	1.184	0.712
5	15	15	10	10	0.525	0.100	0.126	0.750	0.549
6	10	15	10	15	0.848	0.000	0.128	0.976	0.858
7	10	27	0	15	1.000	0.058	0.000	1.058	1.002

Now we can decide whether to show the results ordering the efficient solutions by increasing costs, opposition, maximal individual disutility or distance from the utopian solution.

Fig. 1 shows the disposal and the capacity of the plants for each efficient solution. Furthermore, the program provides other useful data as real investment and transportation costs and a matrix of the demand distribution for each solution.

10. Discussion of Example Results

We can now refer to the data shown in order to interpret the program output.

Regarding costs, the best solution is the number one, which has lower investment costs as well as small transportation costs due to installation of a bigger facility in site A that is the nearest to bigger population centres. For the same reason, however, this solution ranks the worst in the opposition objective. In fact there is an intrinsic conflict between transportation costs and opposition: in order to decrease opposition, we should locate bigger facilities far from bigger population centres, but this results in an increase of transportation costs. The first solution is the worst one even from the equity (maximum individual disutility) point of view because of a very small distance between the big plant at site A and the population centre 3.

The solution with minimum opposition is the number 6, where two smaller facilities are located closer to bigger population centres and two medium-sized facilities are located in an area of low population density. However, this solution involves high total costs, primarily because of building a facility in all candidate sites, which results in high investment costs. Transportation costs are also high, because bigger facilities are located in slightly populated areas.

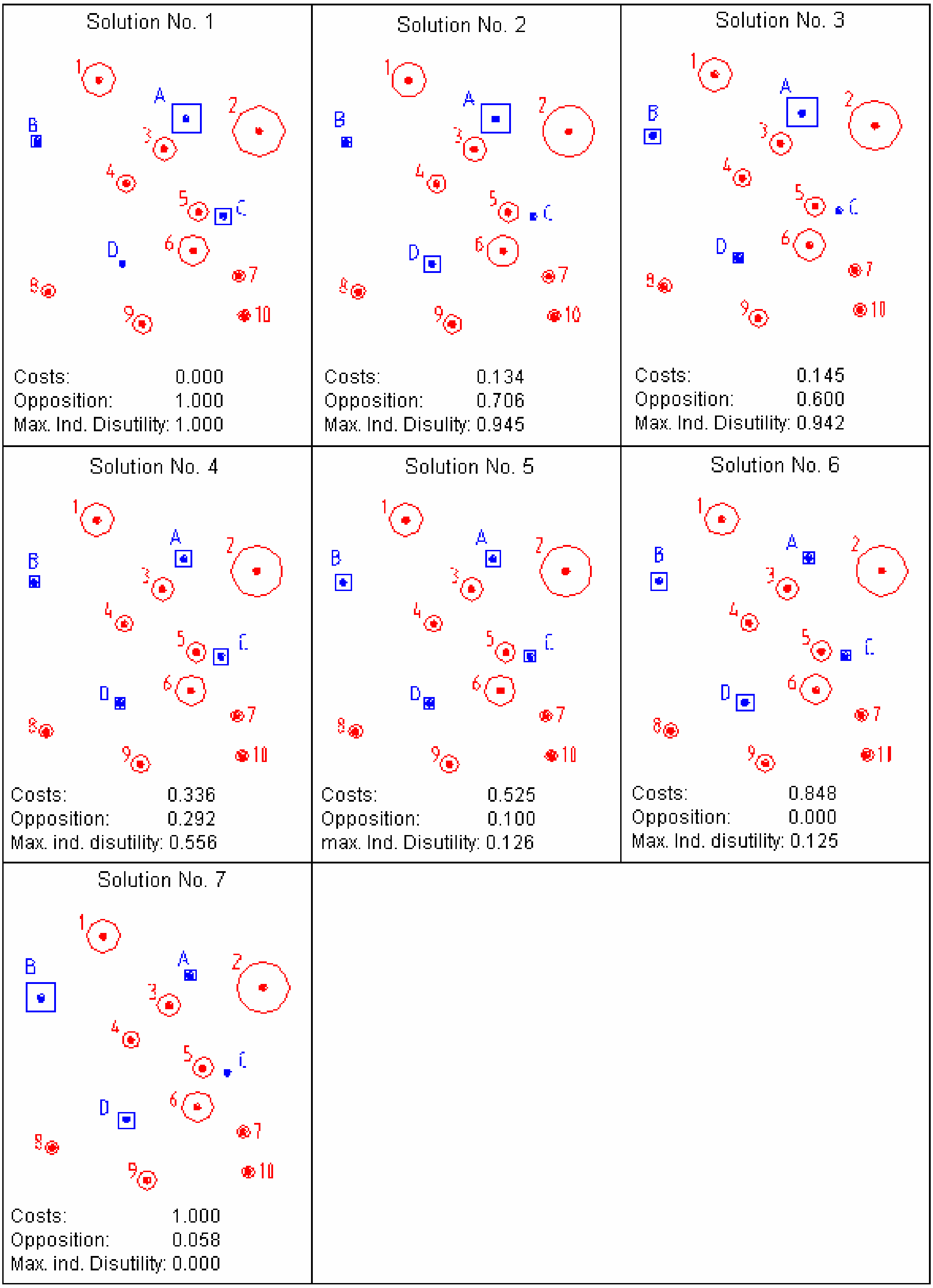

***Fig. 1** Efficient solutions*

The solution that ranks the maximum in equity is the number 7, because in the sites A and C, which are very close to population centres 3 and 5, only one small-sized plant is located. However, transportation costs and, hence, total costs, are the highest of the solution set because the largest facility is located in an area of low population density.

The conflict among the cost objective and the maximum individual disutility and opposition objectives becomes obvious if we consider that when we want to sort the solution by decreasing costs, we sort them even by increasing opposition as well as by decreasing maximum individual disutility. Only in the solution number 6 we can recognise a conflict between the maximum individual disutility and the opposition objective, due to the selection of site C, very close to population centre 5, which makes maximum individual disutility to increase even if the opposition is minimised.

This discussion makes clear that is impossible to choose from the solution set a single solution that we can deliver to the decision-makers: because of intrinsic conflicts among three objectives and their components, each solution we choose in the end must be a compromise solution. However, this is not a fault of the model, but it is an unavoidable consequence of the complexity of the real world situation that we are trying to represent with the model. Anyway, the output data provided by the program can support the decision-maker in evaluating and comparing different solutions and allow him to be more aware of the final choice to be made.

In addition, more intuitive representation of the results we got can be very useful. We can refer to the distance from the utopian solution or to the weighted sum of the objective functions.

If we sort the solution by the distance from the utopian solution (0, 0, 0), the solution number 5 results in the best compromise solution both in rectilinear and Euclidean distance. In this solution we have in fact small or medium-sized facilities in each candidate site, so the opposition and the maximal individual disutility are quite low even if the investment costs are increased by this circumstance. Beside that, higher investment costs are balanced by lower transportation costs due to good distribution of the plants over the region.

Note that it is possible to have different compromise solutions for different metrics, even though the best solution is the same for the metrics considered in this example.

Finally, we can use an additive aggregation of weighted values of three objective functions. The triangle in Fig. 2 is divided into six convex regions where one of the solutions ranks the minimum for the aggregation function.

The figure provides a visual information about the program output. For example, if the weight that is associated with the cost objective is less than 1/3, the decision-maker should concentrate on the solutions 5, 6 and 7. Note that the best solutions in three classifications by costs, opposition and uquity (maximum individual disutility) dominate in a region that is close to the corresponding vertex, while the compromise solution 5 dominates in the middle of the triangle. Besides, the rectilinear distance is actually an additive aggregation with all unitary coefficients, and in the centre of the triangle all the weights are equal, so the results must be the same.

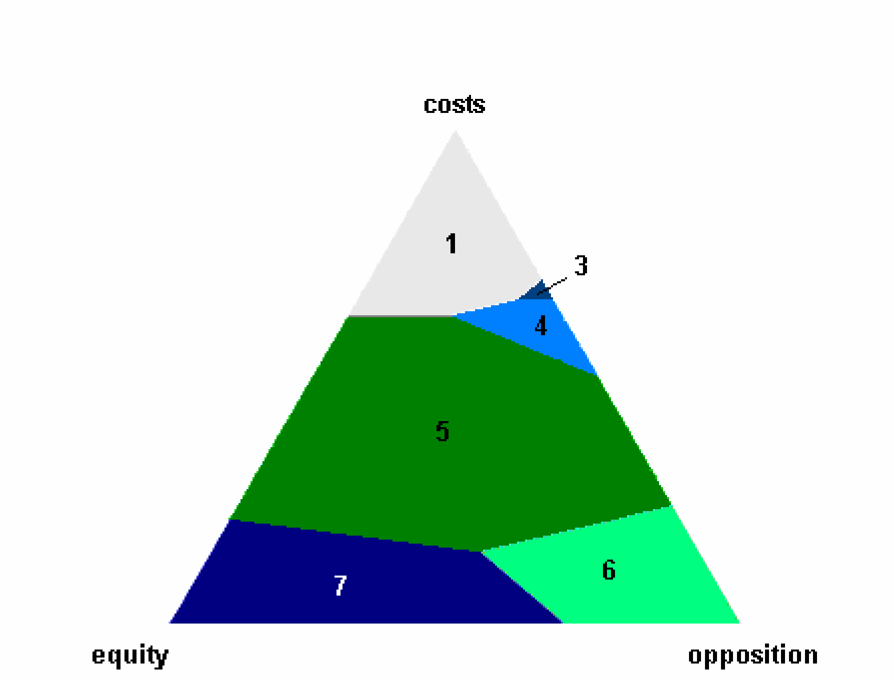

Fig. 2 *Triangle of weights*

Note also that the solution number 2 is not shown in the triangle, which means that the solution is convex, dominated by the other solutions, and hence this solution can never reach the minimum value of the weighted sum for each value of the three weights. This does not mean that this solution is worse than the others, and it should still be considered.

11. Conclusions and Suggestions for Further Work

Further development for the model could be the consideration of pre-existing undesirable facilities that are not related to the service demanded by the region, for example when evaluating maximum individual disutility (i. e. considering chemical plants when planning incinerators). This is to avoid, for example, the installation of an incinerator near the same population centre that bears the presence of a nuclear power plant. Of course, these pre-existing plants would contribute to the demand satisfaction in any way and the number of feasible solutions would not change, hence the number of efficient solutions would not be affected. The only inconvenience would be the growth of the number difficulties in data collecting and input.

An interesting extension of the model could be assigned to a particular case of an integrated system with different types of facilities, particularly a system of incinerators and landfills for municipal solid wastes. In fact, although the incinerator is for many reasons the more desirable way to manage solid wastes, the landfill is always a necessary step in the treatment process, as there always is a “waste of the waste” that must be sent to the landfill. After enumerating all possible combinations of incinerators that fill the total demand, for each of them we should enumerate all the possible combinations of landfills that can treat the residues left by the incinerators. For each of these solutions (combinations of incinerators and landfills) the problem would be then to solve two different editions of the transportation problem: between incinerators and population centres and between landfills and incinerators, seen in the second case as demand centres. Of course, the set of candidate sites for the incinerators and for the landfills should be different (for instance, some particular characteristics of the site may be required for a landfill but not for an incinerator), but some sites may be shared between two sets (namely sites that are suitable for both types of plants). For this reason, efficient solutions with two types of plants located in the same site may be selected.

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Resumé

ROZMÍSŤOVÁNÍ NEŽÁDOUCÍCH OBJEKTŮ

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Při činnosti různých institucí se často setkáváme s potřebou rozhodnout v rámci regionu (státu, kraje, obce, městské části apod.) v otázkách spojených s rozmísťováním, budováním a provozem *obslužných středisek*, která mají zabezpečovat určité služby pro obyvatele regionu. Tato střediska však kromě žádaných služeb mohou mít i nežádoucí vliv jak na kvalitu života obyvatel regionu, tak i na složky životního prostředí. Může se jednat např. o skládky a spalovny odpadů, chemické provozy, asanační střediska, sklady chemikálií nebo pohonných hmot, vojenské objekty, velkogaráže, letiště, elektrárny, televizní vysílače aj).

Mnohé z těchto objektů jsou pro společnost zejména z ekonomických důvodů nezbytné, ale pro jedince, kteří bydlí resp. dlouhodobě se zdržují v jejich blízkosti, jsou z různých důvodů nežádoucí (hluk a vibrace, škodlivé exhaláty, elektromagnetický smog, obtěžující zápach, vznik

alergií u citlivých jedinců atd.). Jejich škodlivé či nevhodné působení může způsobovat kromě přímých poškození zdraví např. i pokles ceny nemovitostí v jejich blízkosti, nezájem spotřebitelů o zemědělské produkty z takto zatížených oblastí, zhoršení životních podmínek (znepříjemňování bydlení, rušení spánku).

Na začátku rozhodovacího procesu zpravidla vzniká ve veřejnosti odpor (opozice), kdy sice občané obecně uznávají nutnost zřízení střediska z hlediska poskytovaných služeb (i jim osobně), brání se však umístění konkrétního střediska do své blízkosti. Tento odpor vzniká právě kvůli možným škodlivým nebo nepříjemným účinkům střediska. Velikost opozice závisí na výběru konkrétní lokality, na velikosti a charakteru střediska i na řadě sociálně-politických aspektů (stav legislativy, zájmy sousedících regionů, informovanost obyvatel regionu a jejich ochota k veřejné angažovanosti).

Proto rozhodnutí o umístění objektů s možnými nežádoucími účinky, která mnohdy mají i politický charakter, musejí nejen vycházet z primárních ekonomických údajů, ale i brát v úvahu také sociální, hygienické a psychologické aspekty této problematiky. Je třeba uvažovat jak jejich vliv na člověka, tak na ostatní živou i neživou přírodu i na kulturní památky. Problémem je rovněž skutečnost, že příslušná rozhodnutí nejsou jen záležitostí odborníků, ale mnohdy spíše orgánů státní správy. Dopad těchto rozhodnutí se přitom mnohdy projeví až za mnoho let, kdy již budou na příslušných místech zcela jiní lidé.

V příspěvkuje popsan tříkriterální model pro rozmísťování obslužných středisek s možnými nežádoucími učinky na životní prostředí.

První kritériem je minimalizace celkových nákladů obslužných středisek. Jedná se o investiční a provozní náklady související s činností obslužných středisek.

Návrh dalších dvou kritérií vychází z pojmu "neužitečnost" obslužného střediska, který zahrnuje veškeré jeho možné negativní účinky na životní prostředí (zdravotní závadnost, hluk, zápach, neestetičnost aj.). V navrhovaném modelu se předpokládá, že tato neužitečnost závisí na velikosti obslužného střediska a na jeho přímé (eukleidovské) vzdálenosti od obsluhovaných míst. Vzhledem k tomu, že je obtížné tuto neužitečnost vyjádřit kvantitativně, navrhují autoři modelovat ji jako spojitou nerostoucí funkci vzdálenosti (jdoucí k nule, jestliže se vzdálenost blíží k nekonečnu) a spojitou neklesající funkci kapacity obslužného střediska.

Druhým kritériem je minimalizace odporu veřejnosti proti zřízení a provozu obslužných středisek ("celková opozice“, kterou se rozumí se jí součet opozic jednotlivých obyvatel ve všech obsluhovaných místech). Velikost opozice konkrétního obyvatele jednoho obslužného místa je funkcí vzdálenosti od obslužného střediska a velikosti obslužného střediska.

Třetí kritérium je založeno na myšlence "spravedlnosti". Mělo by zabezpečit, aby nedošlo k nadměrnému zatížení konkrétního obyvatele resp. malé skupiny obyvatel možnými nežádoucími účinky obslužných středisek, tj. aby nebyly zvýhodněny větší skupiny obyvatel obsluhovaných míst na úkor menších. "Neužitečnost" působící na jednoho obyvatele obsluhovaného místa vypočteme jako součet "neužitečností" jednotlivých obslužných středisek. Třetím kritériem je pak minimalizace maximální neužitečnosti snášenou obyvatelem nejvíce zatíženého obsluhovaného místa.

Jednotlivá kritéria jsou tvořena složkami, které si mohou navzájem odporovat. U prvního kritéria se celkové náklady skládají ze dvou složek – z místních nákladů (tj. investičních a provozních nákladů na vybudování, provoz a likvidaci středisek) a z přepravních nákladů (souvisejících se zabezpečením obsluhy v obsluhovaných místech). Je zřejmá jejich protichůdnost: místní náklady jsou menší pro malý počet velkokapacitních středisek (a naopak přepravní náklady v tomto případě rostou). Naproti tomu při větším počtu malých obslužných středisek se přepravní náklady snižují, ale jsou nutné vyšší náklady místní.

Podobně minimalizace celkové opozice v druhém kritériu je v rozporu s přepravními náklady: abychom minimalizovali celkovou opozici, musíme obslužná střediska umísťovat co nejdále od obsluhovaných míst, což vede k nárůstu přepravních nákladů a naopak. Spravedlnost ve smyslu třetího kritéria je v rozporu s místními náklady, protože místní náklady jsou minimalizovány při rozmístění co možná nejmenšího počtu obslužných středisek, zatímco maximální spravedlnost vyžaduje umístění co možná největšího počtu středisek. Protichůdně působí i druhé a třetí kritérium: příliš velký počet (byť malých) obslužných středisek ve snaze dosáhnout maximální spravedlnosti může vyvolat velkou celkovou opozici.

Při návrhu modelu je možno uvažovat rovněž problém tzv. nadbytečných středisek; takovými středisky rozumíme střediska, jejichž odstranění ještě nevede k tomu, že zbývající obslužná střediska již nejsou schopna uspokojit všechny požadavky obsluhovaných míst. V dalším textu se uvazžují pouze řešení, která neobsahují nadbytečná střediska.

V příspěvku je popsána matematická formulace vícekriteriálního modelu a jeho inplementace na počítači PC. Hlavní pozornost je věnována interpretaci výsledků získaných výpočtem na počítači.

Summary

LOCATING UNDESIRABLE FACILITIES

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The paper presents a way of solving the problem of locating facilities with possible undesirable effects on environment. The problem is transformed into a task of looking for solutions that are minimum based on three points of view: total costs, opposition of inhabitants, maximum individual disutility (equity). A model was established in order to achieve this and a computer program was implemented. The results are presented in this paper.

Zusammenfassung

VERTEILUNG DER UNERWÜNSCHTEN OBJEKTE

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Dieser Artikel befasst sich mit der Lösung des Problems der Veteilug der Objekte, die unerwünschte Wirkungen an die Umwelt haben können. Das Problem ist in die Aufgabe der Multikriterialminimalisation (erstes Kriterium der Gesamtkosten, zweites Kriterium der Einwohneropposition und drittes Kriterium des Maximums der individuelle Unnützlichkeit) transformiert. Auf Grund des dargestellten Models war ein Programm für PC implementiert. Die Ergebnisse sind im diesen Beitrag gezeigt.