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Ireneusz Wyczałek

Division of Surveying
Department of Land Engineering
Poznań University of Technology
(61-138 Poznań, ul. Piotrowo 5)

The cartographic development of the decision charts technique*

Among methods of solving decision matters the technique of decision charts has been presented in this paper and the idea of their cartographic development has been proposed. The problem has been described on the base of real application that concern of choosing a place on water intake for new arisen housing estate. The technique of colour scale for visualization of choice criteria and logical operations on colour images has been proposed in order to find the place which meet earlier formulated conditions in the best way. The results has been colected in modified decision chart. Next possibilities of development of the method have been indicated.

INTRODUCTION

The visualisation of spatially localized objects and phenomena, and some relations between them, is one of the basic tasks of cartography in the field of decision analyses. Kraak and Ormeling [2] as the examples of decision applications of cartography indicate methods which are based on drawing conclusions from the analysis of a few types of maps referring to the same area. Andrienko and Andrienko [1] are occupied in developing explorative methods of searching out and processing data obtained from the external bases and also cartographic visualisation methods of the results of the analyses of these data. Malczewski [3] presents solution, which essence is the visualisation of the results of analyses derived from the decision making theory.

This work is based on the experiences in the field of creation and using decision charts, one of the popular tools that arrange and improve work of clerks, whose some often routine activities are dependent on certain explicitly defined external factors. The school-bookish example of profits deriving from the application of decision chart is the work of secretarial staff of a firm as far as sending letters or parcels that require a choice of decision like the way of sending postal matters in dependence on its weight, size, value, price, localisation of the receiver etc. [5]. In case of objects or processes localised spatially conditional decisions many a time are taken up in the local administration of commune councils (town-planning or communication departments) in institutions or land developing offices and also in life saving and other spheres of public life. One of the factors which influence taking up a decision is a localisation of an object in relation to other terrain objects or phenomena taking place in the

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area of interest. In this work there was presented a project of cartographic solution of spatially localised decision issues which idea is developed on the basis of real, but fictional example of its application as the development of methods of decision chart creation.

1. *The essence of decision charts*

The aim of decision rules creation is subordination of certain actions to each possible condition that may appear. So that in order to take up certain decision there are necessary conditions and actions and decision rules relating them, which in traditional sense can be arranged in a form of a text, graph or a chart.

We omit textual and graphic forms as unnecessary from a cartographic point of view and concentrate our mind on a construction of a decision charts. They consist of four parts:

– blocks of conditions and their factors, that create conditional part of a chart,

– blocks of actions and action factors, creating action part.

Conditions and actions are the text part of a chart and factors of conditions and actions create part with rules.

The factors of conditions often have the form limited as far as its fulfilment is concerned *Y* or impossible to be *N* but they can be extended by signs <, >, =, numbers or texts. The sign „×„ or „+" in the field of action factors expresses an agreement for taking up an activity, and „–" the lack of agreement. Between decision rules there is the relation of the type *„or...or..."* what we call the exclusive alternative. Only one rule is assigned to each considered case. Quite different is the inclusive alternative in which we can refer several rules to the same condition often realised in a definite order. In more extended decision issues it is admitted to use enlarged factors or group conditions in sequences of a type *"if...and...or..."* or actions in sequences *"do it...do not do it..."*. In more complicated cases we can divide charts creating system of relations and mutual conditions. A few charts can be organized in order to create ranks, branches, loops or to indent one another. Let's present an example illustrating simple application of a decision chart. It will be developed in order to illustrate the suggested cartographic method.

2. *A practical example*

Let's assume that in the nearest neighbourhood of new arisen housing estate (Fig. 1), which consists of some of blocks of flats, we have to localize drinking water intake because during negotiation with the operator of the nearest water supply system there was stated too high costs of a solution. The housing estate is localized on a private property surrounded by public forest, the roads and the cemetery.

In order to analyse the problem of finding a place for a well several conditions were formulated which simultaneous fulfilment constitutes positive answer as for as its localization is concerned:

A. Water intake must fulfil geological and hydrological conditions;

B. It should be placed on the site belonging to the investor, but not farther than 100 m from the borders of the designed housing estate;

C. It should not be closer than 50 m from cemetery;

D. It should not be closer than 20 m from buildings – the further the better;

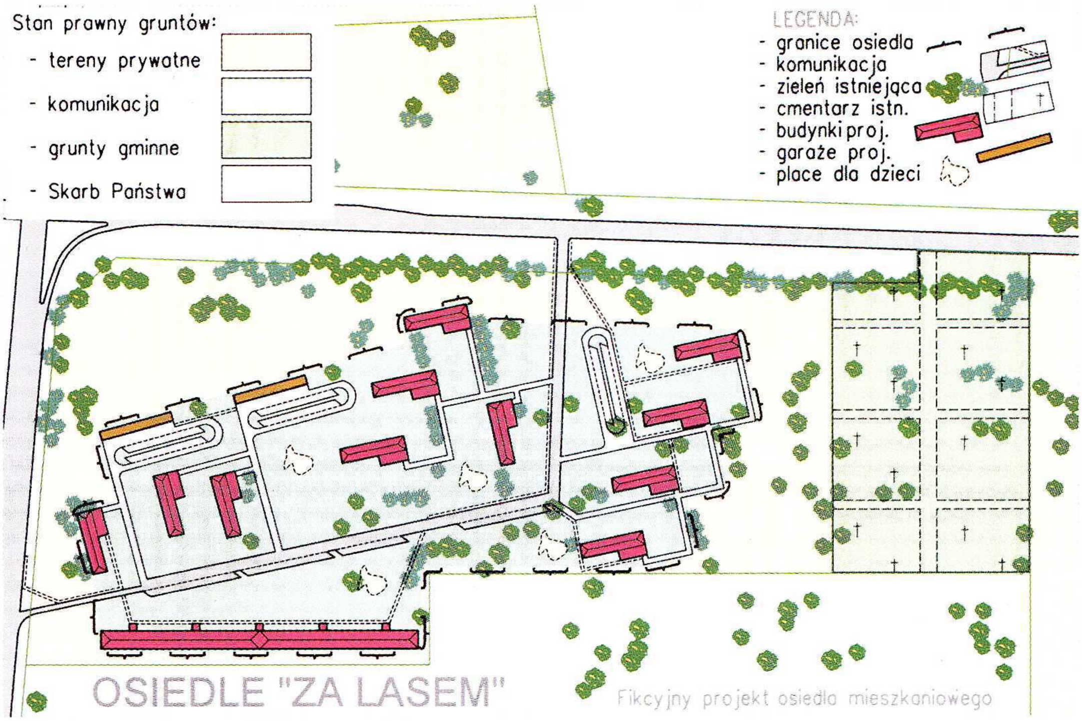

Fig. 1. The fictional design of a housing estate - the basis for the development of the presented method

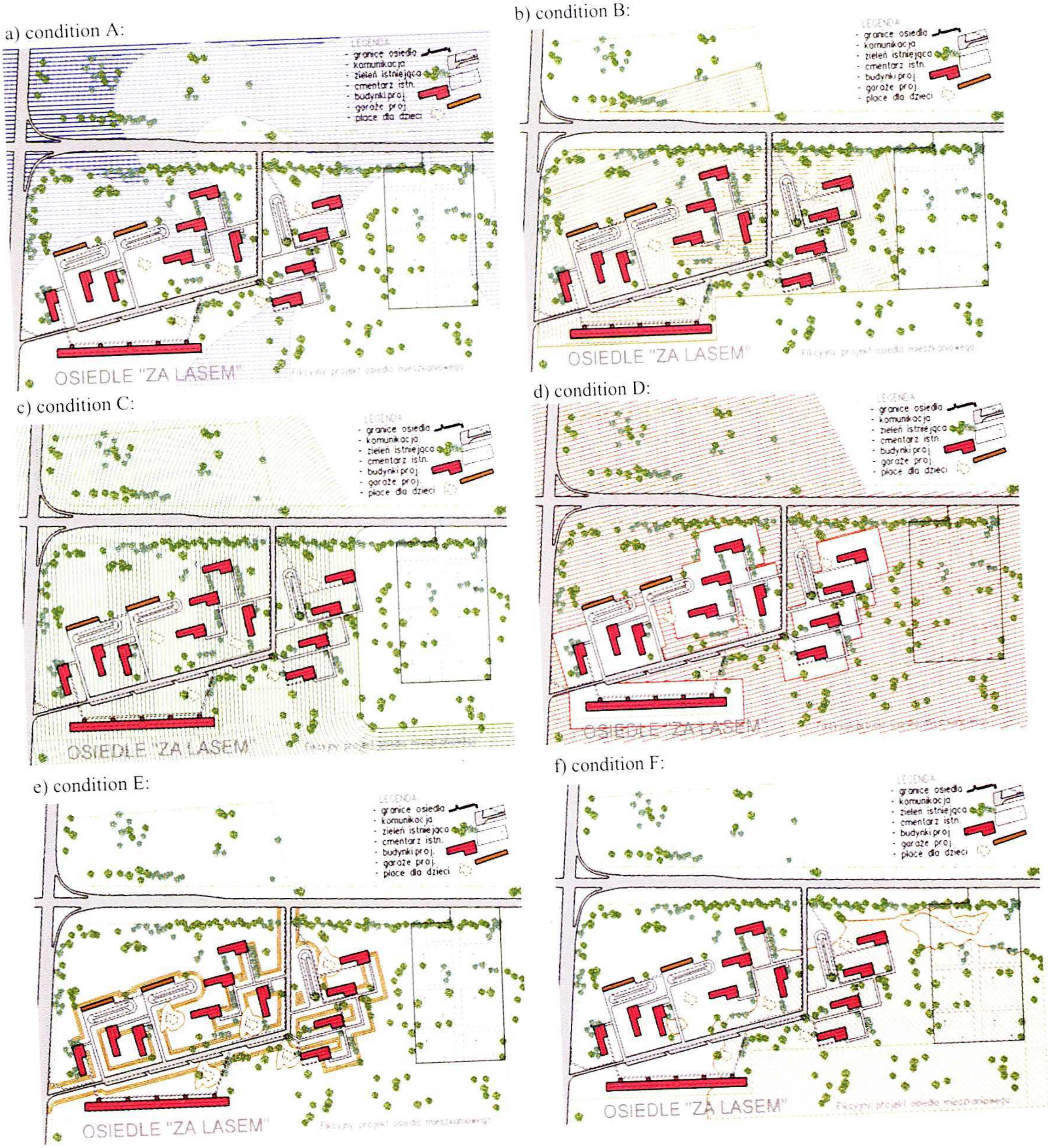

Fig. 2. The maps illustrating individual conditions for water intake localization (A to F)

E. It should be placed neither on internal communication areas, such car parks, access to garages, pavements, bicycle ways, playgrounds, nor in the vicinity of those areas smaller than 6 m, but it should be direct way to the well (6–10 m from the road);
F. It should not be absolutely localised just near public roads and in such a distance from them where soil contamination with fumes exceeds permissible norms.

This example we illustrate on separate maps on which places fulfilling certain conditions are presented by hatching.

A chart fulfilling all variations of mentioned conditions would consist of 2^6 that is 64 columns. The number of columns we can limit by excluding contrary conditions, repeating or unreal ones, or by grouping some conditions. We join conditions B∩C (logical *and*) or D∩E and carry out analysis referring to the areas fulfilling necessary soil conditions (fulfilled conditions A and F).

The decision chart will take a shape:

Table 1

	conditions B∩C	*Y*	*Y*	*Y*	*Y*	*N*	*N*	*N*	*N*
	conditions D∩E	*Y*	*Y*	*N*	*N*	*Y*	*Y*	*N*	*N*
	conditions A∩F	*Y*	*N*	*Y*	*N*	*Y*	*N*	*Y*	*N*
1	good localization	+	–	–	–	–	–	–	–
2	wrong localization	–	+	+	+	+	+	+	+

Figure 3 presents maps created from the conditions joined in pairs as in a chart. The last map comes from the overlapping of the first three.

The constructed decision chart gives only one positive answer – only when all the conditions are fulfilled. On the map of a housing estate which comes from the superposition conditions, there is not such a place. It means the necessity of looking for further solutions.

Let's assume the solution requiring further localizations of accompanying invention which is based on:

a) the construction of a road of access when the price of it will not exceed limits of break-even point which is adequate to build of 40 m of a road,
b) the construction of filter screens of spreading fumes on condition that the well may be localized at a distance from the public road equal to 1/5 of a width of a screen and assumption that the price of 25 m of a screen equals to the price of 10 m of a road.

These plans must fulfil formal requirements which make possible taking out the road of access to the well from the public road and limiting the length of a screen to 100 m. It would be possible to combine the two solutions, but under consideration that the total price will not exceed a break-even point.

In order to modify the decision chart we have to add actions which reflect these additional invention projects. But first let's notice that action 2 in the chart 1 is completely useless because it is a simple contradiction (logical *not*) of action number 1. So that in place of action 2 we will write down actions describing the two inventions (new actions 2 and 3) and also two hypothetical mixed solutions (actions 4 and 5):

Table 2

	conditions B∩C	*Y*	*Y*	*Y*	*Y*	*N*	*N*	*N*	*N*
	conditions D∩E	*Y*	*Y*	*N*	*N*	*Y*	*Y*	*N*	*N*
	conditions A∩F	*Y*	*N*	*Y*	*N*	*Y*	*N*	*Y*	*N*
1	to build water intake in selected place	+	–	–	–	–	–	–	–
2	to build water intake and up to 40 m of a road of access	–	–	+	–	–	–	–	–
3	to build water intake and up to 100 m of a screen	–	+	–	–	–	–	–	–
4	to build water intake and up to 50 m of a screen and up to 20 m of a road of access	–	–	–	+	–	–	–	–
5	to build water intake and up 25 m of a screen and up to 30 m of a road of access	–	–	–	+	–	–	–	–

Combinations used in description of actions 4 and 5 are characterized by mathematical relation which may be expressed by inequality:

$$d_d \cdot k_d + d_e \cdot k_e \leq k_{\text{dop.}}$$

in which:

d_d, k_d – the length and price of a road of access,
d_e, k_e – the length and price of a screen,
$k_{\text{dop.}}$ – admissible price of an accompanying invention,

where

$$k_e = (10/25)k_d$$

or

$$k_d = 2.5k_e$$

therefore

$$(2.5d_d + d_e)k_e \leq k_{\text{dop.}}$$

and finally

$$2.5d_d + d_e \leq k_{\text{dop.}}/k_e.$$

We should replace the last two verses of a chart 2 by this complex description of an action. Let's notice that if not fulfilling conditions B∩C each action is estimated in a negative way. In such a way we can join the last 4 columns using symbol *Y/N* for values of the conditions of one's choice. Let's add another row which suggests the action for the situation and this way we will get final shape of a decision chart.

Table 3

	conditions B∩C	*Y*	*Y*	*Y*	*Y*	*N*
	conditions D∩E	*Y*	*Y*	*N*	*N*	*Y/N*
	conditions A∩F	*Y*	*N*	*Y*	*N*	*Y/N*
1	to build of water intake in selected place	+	–	–	–	–
2	to build water intake and up to 40 m of a road of access	–	–	+	–	–
3	to build water intake and up to 100 m of a screen	–	+	–	–	–
4	take up complex invention which fulfils relation $2.5 \cdot d_d + d_e \leq k_{\text{dop.}}/k_e$	–	–	–	+	–
5	to connect to the distant water supply system	–	–	–	–	+

When we want to interpret of our chart we can start reading it, as any other decision chart, successively: action→conditions (from bottom to top) or conditions→action (top to bottom). The first case we can read as looking for localisation for which certain invention should be undertaken (to build water intake and – in case of need – a road, screen or these two). The second way is to check what conditions fulfils the chosen place and to conclude from the chart what invention should then be undertaken.

The use of the chart is only possible in the case when we would like to check earlier chosen localisation. We have to state that in this situation using the chart only we were made to grope in the dark. In order to made complex analyses of the whole area we need help of cartographic tools. Let's repeat the Figure 3 complemented by the variant fulfilling action 2 which consequence is broadening an access to internal roads up to 40 m.

This way we got a field of verification of a sequence of various solutions fulfilled particular assumptions. The decision taken on the basis of chart 3 and a map guarantees of a proper choice of water intake localisation. Unfortunately on the summary map for action 2 we still can't find satisfactory solution. Similarly we can illustrate extension of a map for action 1 by the influence of actions 3 and 4 with hope to find the place we look for. In order to improve our search, and broaden its range, let's find other method of visualization and cartographic analyses.

3. *The metod of spatial decision analyses with the use of colour scale*

Looking at the maps for the particular conditions, and also looking at the summary maps we can notice that using of the typical graphic solutions for the used range method in them (hatching, but also the use of different graphic filling symbols) limits possibilities of cartographic transfer. On the one hand it is difficult to deliver features of spatially variable values, for example in order to illustrate continuous changes of soil contamination. It is also difficult to avoid loss of the map readability, because of the overlapping of too many conditions (separate symbols). In the simple application it is enough to apply logical products (the common part), but for the presentation of spatially changing phenomena or in order to differentiate weights for the particular conditions such a solution is not useful. It will be presented a solution, that uses colour which saturation will correspond to the intensity of the presented phenomena.

Let's assume that each decision criterion is represented on the separate layer of the map by colour filling. Colour is defined by a certain number describing its saturation. As the basic colour we can assume red (usually associated with the prohibition or denial), green (which marks agreement or acknowledgement) or any other.

Let's suppose here lightening (white colour) as described with value 1, the most intensive red colour as 0, and all intermediate values described by the decimal fraction from range from 0 to 1. Referring to a decision chart 0 will be an equivalent of a negation (in a chart 3 a sign „–" in the part of conditions of an action) and 1 will be an equivalent of permission (a sign „+"). As we noticed earlier not all the answers are explicitly defined. When we have to decide about a way of sending the parcel mentioned in the beginning we always get an explicit answer. But looking for localization of an object in the site where take place such phenomena as spreading of fumes or other contaminations we will be exposed for their further concentration in the direct neighbourhood of the source which intensity decreases with the distance coming across of screening obstacles. In these cases particular concentration of fumes can be described with different values of intensity of colour on a map (in a chart we can describe it with the number from the chosen range). In our example we might formulate condition F in such a way in order to expect the least influence of contamination on the place of water intake, what we can illustrate on the map as colour intensity. Then the picture 2f) would take following appearance (the picture taken from: Muller and others, [4]).

In the similar way we can interpret building of screens but also to differentiate buffer zones around buildings (condition D) and excluded housing estate areas (condition E). In order to illustrate these issues let's introduce contours for condition A (soil-water) and F (contamination) or tonal description for the decrease of values of particular buffer conditions according to particular assumptions:

A) soil-water conditions take values from 0.5 to 0.9 (this mean the lack of areas which have definitely bad features and features remarkably friendly),
B) border buffer changes linearly from value 1 along the border to 0.2 in the places in a distance 100 m, and 0 in other parts,
C) 50 meters isolated zone around the cemetery which takes value 0,
D) values in a buffer around buildings increase linearly from 0 to 1 in a distance 25 m,
E) buffers around isolated housing estate areas change their values from 1 to 0 in a zone of a distance from 6 to 10 m, and 0 in other places,
F) the contamination of an environment with fumes is estimated according to the model of spreading of gas fumes, taking values from 0 just near a road to 1 in the best covered areas.

These maps illustrate pairs of particular conditions, the same as on the picture 3, but now we use the red-white scale.

The map 6d is an answer for the asked question for the best localization of water intake. The map is intensely red on the most of its area what exclude these places from taking into account. The lack of white places confirm the conclusion about the lack of places explicitly useful. But there are some places intensely lightened. On the picture 7 there is presented the enlarged output map with optically marked lightened places. Looking at the values of colour intensity in these places we will estimate their usefulness.

Fig. 5. The modified map of the communication contamination of the localization of a well

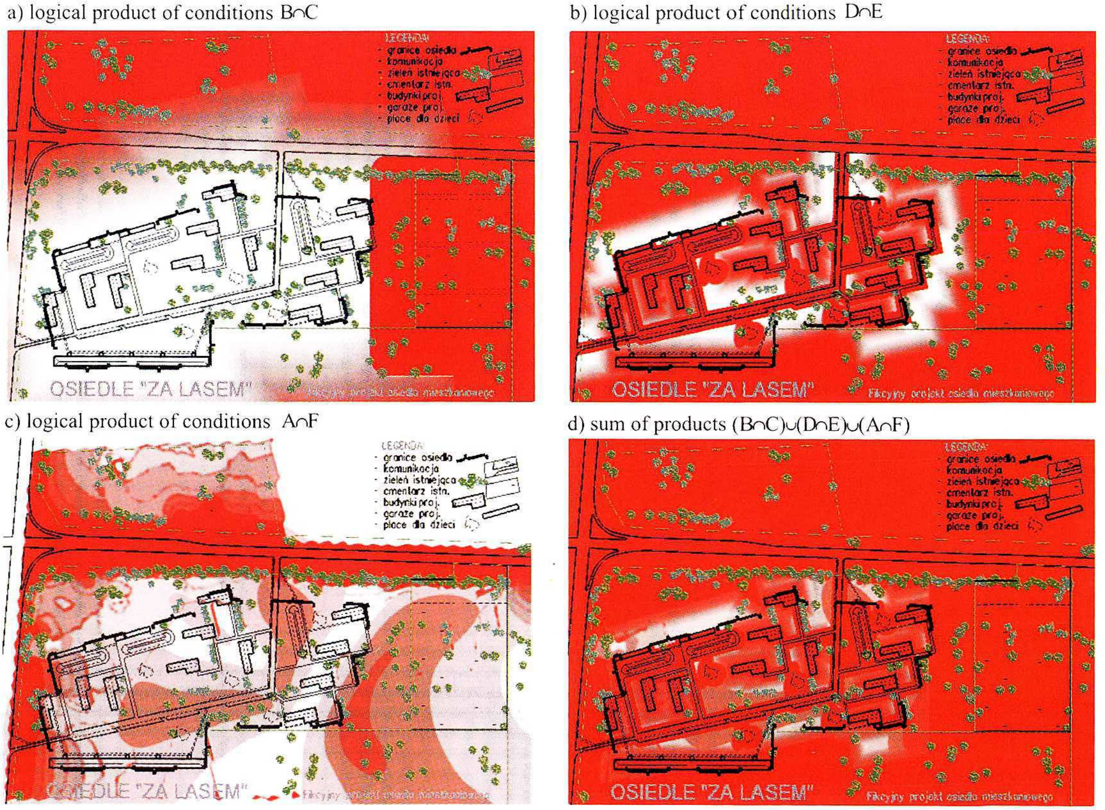

Fig. 6. The modified maps of conditions of water intake localization

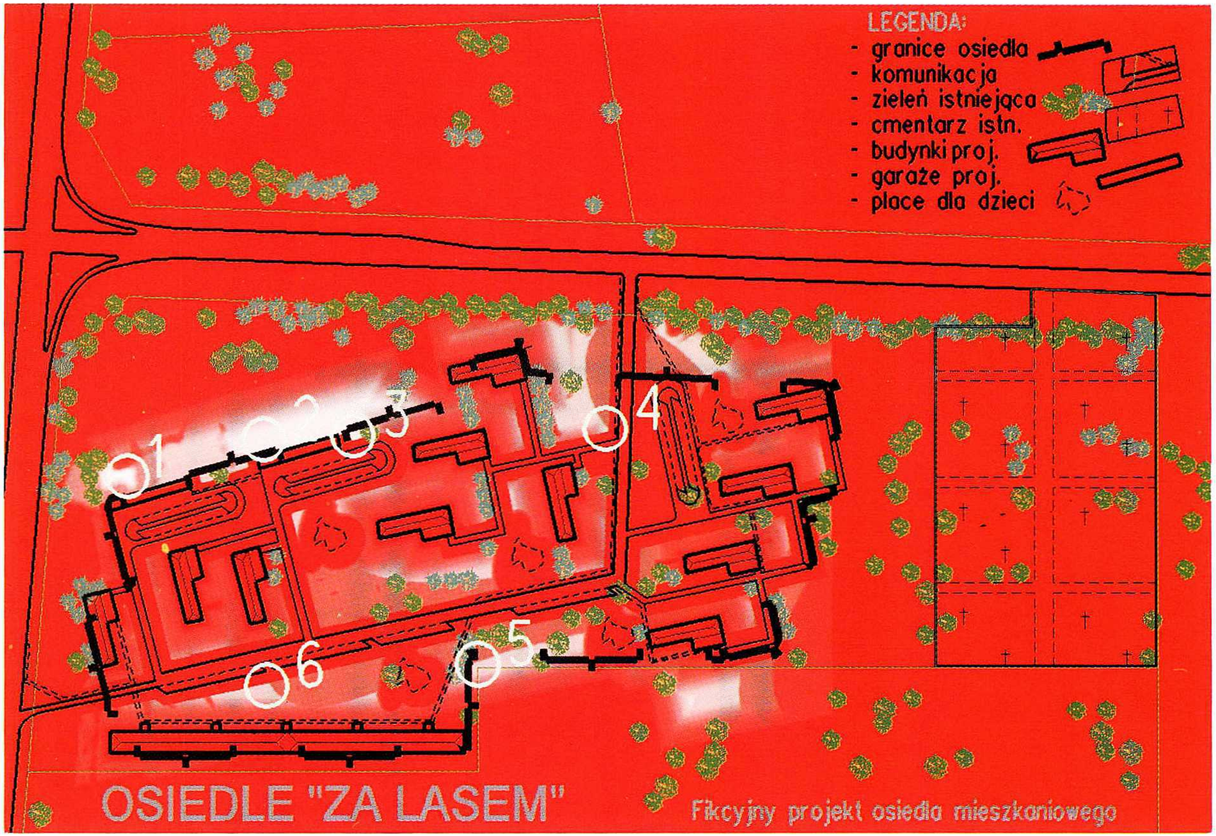

Fig. 7. The places of testing of values of positive features on the final decision map

Lets construct for these places a chart making possible the comparison and attribution and adequate solutions (actions). Because we consider only one set of conditions, this in which all of them are in certain percent fulfilled, we have to change the form of the chart.

Table 4

	localization indications	(1)	(2)	(3)	(4)	(5)	(6)
	percentage values of fulfilment of all conditions	81%	71%	71%	56%	56%	52%
1	good localization (over 90%)	–	–	–	–	–	–
2	localization that needs additional road investment (range 70%–90%)	+	+	+	–	–	–
3	there are no good conditions for water intake (less then 70%)	–	–	–	+	+	+

The normalized value of localization estimation for the most suitable place (1) we can read as 81% fulfilment of expectation for water intake localization in this place. This solution might satisfy an investor as well as future inhabitants of a housing estate who should be conscious that the value of any additional investment invention would rise the price of flats in the housing estate.

Chart 4 is different from the standard ones but it still has basic assumption of decision analyses. The estimation presented in it has obviously features of subjectivity resulting from the choice of percentage levels of fulfilment of expectations. Such a choice should be always a reflection of knowledge and experience of persons taking up such important decision.

CONCLUSIONS

The case illustrated in the example of the choice of place for water intake allowed to learn the positive sides of a suggested solution, that according to the author's intention should have a universal character. It illustrates an idea of using cartographic techniques in the decision analyses. The applications of such decision charts similarly as other tools supporting decision has always an economical aspect which has important influence on the obtained effects. There was suggested the substitution of simple *Yes/No* choice factors by value factors and connect it with a map if the decision has a spatially oriented character. It was suggested that the colouring of a map would help to find an answer, attributing output values of the colour from the standard scale. In this work the scale corresponds to saturation of red colour but we can imagine the application of double colour in which white would be replaced by more readable green colour (assumptive sign of assent) getting in this way the broadened colour scale – an equivalent of a part of spectrum limited by red and green. This conception was suggested in other articles [6, 7]. The intention of the author is to develop the idea and introduce it to practice.

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Ireneusz Wyczałek

Kartograficzne rozwinięcie techniki tabel decyzyjnych

Streszczenie

Spośród metod rozwiązywania zagadnień decyzyjnych w pracy przedstawiono technikę tabel decyzyjnych oraz zaproponowano ideę jej rozwinięcia kartograficznego. Problem omówiono bazując na przykładzie praktycznym dotyczącym wyboru miejsca ujęcia wody dla nowo powstającego osiedla mieszkaniowego. Zaproponowano technikę skali barwnej do wizualizacji kryteriów wyboru oraz operacje logiczne na obrazach barwnych w celu automatycznego znalezienia miejsca najbardziej spełniającego zadane warunki. Wyniki zestawiono w zmodyfikowanej tabeli decyzyjnej. Wskazano dalsze możliwości rozwoju metody.

Иренеуш Вычалек

Картографические развитие техники решающих таблиц

Резюме

Среди метод предназначенных для решения решающих вопросов в работе представлена техника решающих таблиц, а также предложено её картографические развитие. Проблема обсуждается на практическом примере, касающимся выбора места водозабора для недавно построенного жилищного посёлка. Предложен метод цветной шкалы для визуализации критерий выбора, а также логические операции на цветных изображениях, чтобы автоматизированным способом найти места, которые больше всего удовлетворяют заданные условия. Результаты составлены в модифицированной таблицы решений. Указаны дальнейшие возможности развития метода.