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On a group multicriteria method for project evaluation

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ON A GROUP MULTICRITERIA METHOD FOR PROJECT EVALUATION

Abstract

Experiences with a real case study are presented. The case study deals with allocation of EU structural funds in the capital region of Mazovia in Poland. A new in the practice of the funds allocation method supporting multicriteria analysis and selection of projects applying for the funds has been proposed and used in the study. According to the method, an interactive procedure has been implemented in which a group of experts formulates the multicriteria decision making problem, carries out the multicriteria analysis of the projects, and finally creates a ranking of the projects.

Keywords

multicriteria analysis, group methods, computer-based support, EU structural funds

Introduction

The structural funds of the European Union are the financial instruments by means of which the policy for support of multi-dimensional development, enhancement of economic and social cohesion, reducing differences of regional development standards and restructuring and modernizing the economies of those member states whose development level is below the average development level in the European Union is implemented.

In the 2007–2013 programming perspective, Poland may take advantage of the support within the framework of the following structural funds: the European Regional Development Fund (ERDF), the European Social Fund (ESF), the Cohesion Fund, the European Agricultural Fund for Rural Development (EAFRD), and the European Fisheries Fund (EFF).

The European Regional Development Fund (ERDF) is meant for financing undertakings in the regions with the development level substantially lagging behind the average for the EU, as well as in the regions with major restructuring activities in industry and employment. The funds are addressed particularly to financing investment in infrastructure and environmental protection, development of small and medium enterprises, creation of new jobs through investment in manufacturing, research and development activities. Potential beneficiaries are territorial self-government units, their unions and associations, entrepreneurs (small and medium), government administration bodies, national and landscape parks, National Forestry and its organizational units, R&D units, (other) units of the public finance sector with legal entity, non-governmental organizations, business support institutions, housing associations and housing cooperatives, as well as water law companies.

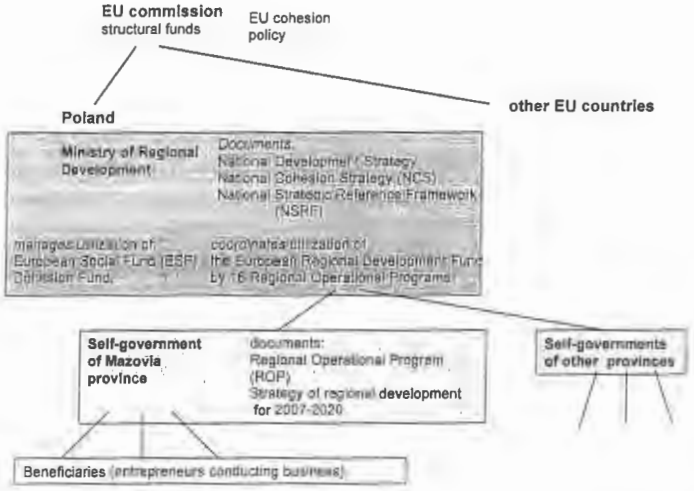

Fig. 1. Decision making units allocating and supervising utilization of the EU structural funds

Utilization of the ERDF is coordinated in Poland by the Ministry of Regional Development (see Fig. 1.). It is done according to the documents like the National Development Strategy (NDS) for Poland, the National Strategic Reference Framework, and the National Cohesion Strategy adopted by the EU Commission. The Ministry allocates the funds among regions – provinces being administrative units, called voivodships in Poland. The funds are allocated among beneficiaries on the regional level by the self-governments of voivodships within the Regional Operational Programs (ROP), negotiated and approved by the EU Commission. The Ministry, having the consent of the EU Commission, decided that the most important projects for regional development (called key projects) can be submitted and co-financed within the ROP before standard competitions for other projects will start.

The paper deals with the Regional Operational Program (ROP) of the capital Mazovian Voivodship for the years 2007-2013. A case study has been organized to support selection of the key projects from a list of projects submitted. The paper describes experiences with the case study.

There exists a rich bibliography on multicriteria analysis, ranking and group methods. Advance ordinal and cardinal approaches are developed. Respective reviews can be found in [5, 25, 26, 29]. A proposal including application of the outranking method to ordering projects is given by Górecka [4]. On the other hand, in the practice of the UE funds allocation, we deal with hundreds of projects applying, limited number of experts assessing the projects and very limited time for the assessment and selection process. The experts – assessors obtain evaluation sheets with predefined criteria and propose values for the criteria within given ranges of points. It is typical that different experts can understand the criteria in different ways. Finally, the classical weight method is still used to value the projects. This case study was organized with the idea that the experts should be involved in the whole MCDM process starting from its formulation. A relatively simple evaluation method, acceptable by the experts was looked for, which could improve the typical defects of the weight method.

A new in the practice of EU funds, multicriteria, group method supporting analysis, assessment and selection of the key projects has been proposed and implemented within the study. The method enables evaluation and ranking of projects on the basis of assessments made by a group of independent experts. The method includes full procedure of activities of the experts, starting from a formal definition of the multicriteria decision making problem, and leading to the final selection of the key projects. Implementation of the procedure is presented in the paper.

1. Procedure

The Self-Government of the Mazovian Voivodship announced in 2006 the competition for the key projects co-financed from the EU structural funds within the Regional Operational Program of the voivodship for 2007-2013. More than 150 projects applied for the competition. The list of the key projects had to be prepared together with the respective justification. The projects not qualified as the key projects could apply again in the standard competitions organized later.

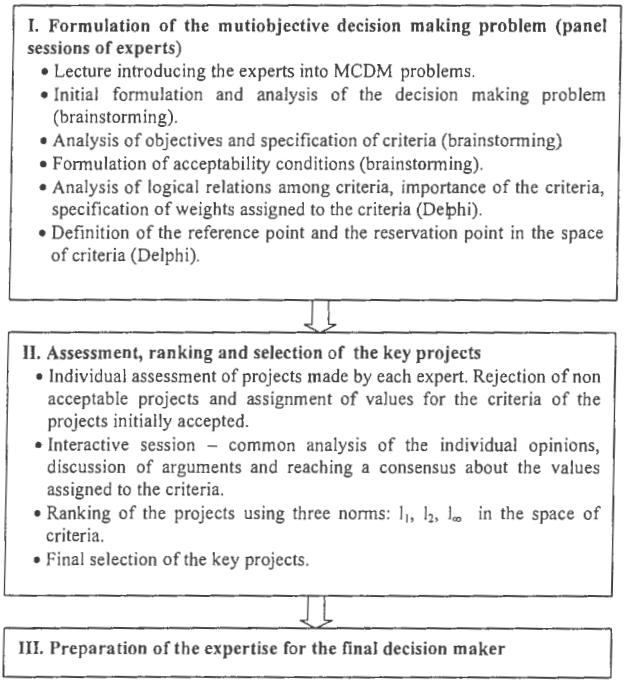

Fig. 2. Scheme of the procedure

A procedure, schematically shown in Fig. 2, has been proposed and approved. The figure presents activities made by a group of experts, leading to

preparation of the list of the selected key projects. It consists of three main stages.

The first stage deals with formulation of the multicriteria decision making problem (MCDM). It was started from a lecture introducing the experts into MCDM problems. The proper formulation of the problem requires specification of the following key components (see Chankong, Haims, [2]):

• Decision making unit. It is the decision maker and possibly a collection of men and machines acting as an information processor and generating the decision. In general case it can be the single or the group decision maker, system analysts, computing and graphical instruments.

• Set of objectives and their hierarchy. The objective defines the state of the system required by the decision maker.

• Set of criteria (attributes), relations objectives – criteria, the scales in which the criteria are measured. Values of the criteria measure the degrees of attainment of the objectives.

• Decision situation that defines the problem structure and the decision environment of the decision problem. Description of a decision situation should include the specification of input information required and accessible, set of alternatives, constraints, decision variables, relations: decision variables – criteria, and finally the states of the decision environment.

• Decision rule. The rule includes processing of the input information, analysis, value judgment, decision generation and implementation.

These elements were considered and specified during the case study.

The following work of experts was organized in the form of panel session with application of the brainstorming technique or the Delphi method, referred in brackets. At the end of the first phase the experts were asked to define, what should be the best in their opinion key project and next, what should be the worst one. These projects considered as points in the space of criteria refer respectively to the reference and the reservation point concepts in multicriteria analysis.

The second phase deals with the assessment method based on the cardinal approach to multicriteria, group decision making. It includes individual assessment of projects made by experts, common analysis of the individual opinions to reach a consensus, ranking and final selection of projects. The ranking is based on the distance of a given project measured to the reference point in the multicriteria space. Different norms are used to measure the distance. A special session was organized to make final selection of the key projects.

The third phase refers to formal preparation of the expertise including the indicated list of the recommended key projects, description of the implemented method and argumentation.

2. Multiobjective decision problem

2.1. Decision making unit and specification of objectives

The decision unit was the Board of the Self-Government of the Mazovian Voivodship, responsible for the final decision. The decision was prepared by the Department of Strategy and Regional Development of Board and by the Mazovian Bureau for Regional Development.

The meaning of the "key projects" had to be specified first as the basis for the formulation of objectives. The working team has been organized consisting of experts from the Department of the Strategy and Regional Development of the Government, experts from the Mazovian Bureau for Regional Planning in Warsaw and an adviser responsible for group multicriteria decision support. Working sessions were organized in which the "brainstorming" technique was used (Hwang, Lin [6]; Osborn [22]). The technique enables free and unlimited presentation of proposals but with strictly defined rules of analysis end evaluation of the proposals.

The team of experts decided that as the key projects - such projects should be selected, which substantially realize the directions of the activities specified in the development strategy of the province, taking into account: the directions of the spatial management defined in the spatial plan of the province, the competitiveness of the province in the international and the national context, the effects of synergy with other socio-economic spheres, and the innovativeness. The acceptability conditions were specified. The projects that do not produce the effects of the structural, socio economic and the spatial change in the region, or belong to other operational programs or have local character or do not fulfill the objectives of the Regional Operational Program for 2007-2013, should be rejected.

2.2. Input information, documents

The main objectives of the cohesion policy, taking into account the socio-economic conditions in Poland, are included in the document entitled "National Strategic Reference Framework for 2007-2013". The document elaborated according to the EU directives defines support directions from funding available from the EU budget in the forthcoming seven years within the European Regional Development Fund and the Cohesion Fund. It is a reference instrument for development of operational programs. According to the document the regional development programs were elaborated, negotiated and adopted by the

EU Commission. In the voivodships there are also other documents prepared, like development strategies, spatial management plans and others.

The team analyzed respective documents and decided that the assessment of projects should be made according to the objectives and the directions of activities given in the Development Strategy of the Mazovia Province till 2020, according to the objectives and priorities of the Regional Operational Program of the voivodship for 2007-2013, and to the specifications given in the Plan of Spatial Management of the Mazovia Province. The documents as well as the application questionnaires created the information base for the project assessment.

2.3. Features of the decision problem

It was found that the set of the objectives, which should be taken into account, is really complex. The Development Strategy of the Province till 2020 presents a hierarchical system including an overall objective, strategic and indirect objectives, directions of activities. The Regional Operational Program (ROP) for 2007-2013 includes also a hierarchical set of objectives, priorities and directions of activities. The criteria respective to the objectives have qualitative character. The projects submitted within the different priorities are hardly comparable.

It was found that the information included in the existing questionnaires is very limited. These questionnaires were elaborated earlier.

The decision had to be prepared in a very short time. The entire process, including preparation of the method, organization of the interactive sessions, assessment of all the projects, derivation of the ranking and the final list of the key projects had to be conducted in 10 days. The team had no earlier experience in such a work.

3. Specification of criteria, reference and reservation projects

The experts have been informed how they should understand the meaning of objectives and criteria. The objective defines the required state of the system that the DM would like to achieve. The criteria specified for an objective measure on a numerical scale the degree, to which the objective is achieved. Criteria should fulfill the following requirements (see Keeney, Raiffa, [8]). The values of the criteria should define in a unique and sufficient way the

achievement level of the respective objective. Each criterion should be comprehensive and measurable. A set of criteria should be:

- complete, i.e. all pertinent aspects of the decision problem are represented by criteria,
- operational, i.e. it can be utilized in some meaningful manner in the ensuing analysis,
- decomposable, i.e. simplification of the evaluation process is possible by disaggregating the decision process into parts,
- not redundant, i.e. no aspect of the decision problem is accounted for (by criteria) more than once,
- minimal – there is no other complete set of criteria representing the same problem with a smaller number of elements.

An interactive multi-round session has been organized in which experts worked according to the "brainstorming" technique. Proposals of criteria were generated to cover all the objectives specified in the Development Strategy of the Province and in the Regional Operational Program. The requirements presented above have been checked as well as accessibility of information from the application questionnaires. Finally, after analysis and discussion of all the objectives and their hierarchy, the following set of criteria has been specified, unanimously accepted by all the experts:

K1. The degree of realization of the activity directions specified in the development strategy and in the spatial plan of the voivodship.

K2. The influence of the project on the competitiveness of the voivodship in the national and international context.

K3. Effects of synergy with other socio-economic spheres.

K4. Innovativeness of the project.

In the case of large number of objectives specified in the above documents, the criteria have to be defined in an aggregated way. The experts have found a common view, how they should check the application sheets to evaluate the criteria of the assessed projects in the similar way.

Next, the experts were asked to define, according to their preferences, the best possible "key project", treated later as the reference one and the worst project, treated as the reservation one. They had also to analyze the logical relations of the criteria, to set the weights assigned to the criteria and to set the interval scales. The modified version of the Delphi method was applied. The original Delphi method has been elaborated in the Rand Corporation, see Linston, Turoof [16]. In the implemented version, the work of the group of experts was organized in the form of multi-round interactive sessions. In the consecutive rounds experts' proposals were presented together with respective argumentation. The proposals were jointly analyzed and discussed, especially in the case of divergent evaluations. On this basis, each expert could correct his opinion in the next round taking into account the arguments of other experts.

The weights assigned to the criteria have been fixed as follows: K1: 50%, K2: 20%, K3: 20%, K4: 10%.

The experts have defined the properties characterizing the best possible in their opinion key project. They specified when each criterion could be reached on the maximal level. The hypothetical project having all criteria on the maximum possible level was assumed as the reference one. The experts specified also the case when the particular criteria could be on the possible minimum level. This case refers to the hypothetical reservation project.

4. Project evaluation and ranking

An original method, which extends the cardinal approach described by Hwang, Yoon, [6] has been proposed to the experts. In comparison to the classical approach, a concept of the reference point was used in the place of the ideal point, several ways of measuring the distance to the reference point were applied and the Delphi method was used to find a consensus in the case of divergent opinions of experts. The reference point approach has been proposed and developed in the case of multicriteria analysis (Wierzbicki, [27], Wierzbicki et all, [28], Ogryczak, [20, 21]). The reference point and the reference set concepts are developed by Konarzewska-Gubała [9, 10]) in the case of multicriteria group decision support. It is utilized also in the methods supporting multicriteria cooperative decisions (Kruś, [11, 12, 13]).

The method proposed enables the group, multicriteria judgment of projects in the case of qualitative criteria. The interval scales are used. Experts evaluate projects assigning values for criteria using the scales. The expert's evaluations are discussed, corrected and set with use of the Delphi method. Each project is represented by a point in the space of criteria K1–K4. The ranking of projects is based on the distance to the reference point. Different ways of measuring the distance, compared also to the classical weight method have been proposed to the experts.

4.1. Idea of the evaluation method

We assume that experts have equal power and their evaluations have equal importance. Each expert evaluates each criterion for a given project by proposing a value from a given scale interval. Values given by experts are normalized. Let n be the number of experts, m – the number of evaluated projects, p – the number of criteria. The following steps are performed.

Step 1

Each expert k assigns a value a^k_{ij} to the project i for the criterion j. The normalized individual values are calculated:

$$d^k_{ij} = a^k_{ij} / \sqrt{\sum_{i=1}^{m} (a^k_{ij})^2}\ , \text{ where } k=1..n,\ i=1,..,m,\ j=1,..,p.$$

The vales are aggregated in the matrix

$$C = [c_{ij}] = \sum_{k=1}^{n} d^k_{ij} / n\ .$$

A vector of weights is given: $W=\{w_1,..,w_p\}$, such that $\sum_{j=1,...,p} w_j = 1$.

The collective values are derived in the matrix

$$F=[f_{ij}]=[c_{ij}w_j],\ i=1,..,m,\ j=1,..,p.$$

Step 2

The reference project defined by the experts in Section 3 is considered in the space of criteria as the reference point:

$$A^* = \{f^*_1,..f^*_p\},$$

and the reservation project - as the point:

$$A^- = \{f^-_1,..f^-_p\}.$$

Step 3

The importance ("value") of each project is derived on the basis of the distance between this project and the reference one. The distance can be measured in different ways. Three measures have been proposed to the experts and then considered by them.

The distance measured according to the norm l_1:

$$s_{i1} = \sum_{j=1}^{p} |\, f^*_j - f_{ij}\,|, \text{ where } i= 1,...m, \qquad (1)$$

- according to the Euclidean norm l_2:

$$s_{i2} = \sqrt{\sum_{j=1}^{n} (f_{ij} - f^*_j)^2}\ , \qquad (2)$$

- according to the Chebyshev norm l_∞:

$$s_{i\infty} = max\ (|f^*_1-f_{i1}|,...,|f^*_p-f_{ip}|). \qquad (3)$$

Step 4

The distance of a project i to the reference one is normalized to the 10-points scale.

decision making problem, makes the multicriteria analysis of the projects, evaluates the projects, and finally creates the list of the key projects recommended to the indicative investment plan approved by the Board of the Self-Government of Mazovia Province.

Keywords: multicriteria analysis, group methods, computer-based support, EU structural funds.

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Evolutionary algorithm with direct chromosome representation in multi-criteria project scheduling

In recent years project scheduling problems became popular because of their large real-life applications. In practical situations there is often necessity of using multi-criteria models for evaluation of feasible schedules.
Constraints and objectives in project scheduling are determined by three main issues: time, resource and capital. There are only few papers consider all of them. In researches on project scheduling the most popular is the problem with one objective. There are only few papers that consider multi-objectives project scheduling.
This paper considers multi-criteria project scheduling problem. There are three criteria used to optimize project schedule: resource allocation, time allocation and cost allocation.

Streszczenia referatów

3rd International Workshop on

MULTIPLE CRITERIA DECISION MAKING '09

Abstracts

Ustroń, 29 - 31 marca 2009

Akademia Ekonomiczna
im. Karola Adamieckiego
w Katowicach
Katedra Badań Operacyjnych

VII Ogólnopolska Konferencja
Naukowa

MODELOWANIE PREFERENCJI A RYZYKO '09

Agnieszka Kowalska-Styczeń
Politechnika Śląska

Wpływ rodzaju otoczenia na decyzje konsumentów

Artykuł porusza problem wpływu wielkości otoczenia na podejmowanie decyzji przez konsumentów. Najbliższe otoczenie rozumiane jest tutaj jako osoby, z którymi mamy styczność na co dzień czyli najbliższa rodzina, przyjaciele. W badaniach przeprowadzono symulacje wpływu otocznia na podejmowanie decyzji przez konsumentów za pomocą automatów komórkowych.

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On a group multicriteria method for project evaluation

Experiences with a real case study are presented. The case study deals with allocation of EU structural funds in the capital region of Mazovia in Poland. A new in the practice of the funds allocation method supporting multicriteria analysis and selection of projects applying for the funds has been proposed and used in the study. According to the method an interactive procedure has been implemented in which a group of experts formulates the multicriteria

$$G_i=10\times(1-s_i/s), \quad 0\le G_i \le 10,\ i = 1,..m, \tag{4}$$

where s is the distance of the point A^- (reservation) to the reference point A^*. The greater G_i means that the project i is better. The project equivalent to the reference one gets 10 points, while to the reservation one - 0 points. It can be shown, that in the considered case, the evaluation of projects with use of the the norm l_1 coincides with the evaluation obtained by the classical methods of weights.

4.2. Implementation

The above general idea of the method has been presented and discussed with experts. In the proposal, the values a_{ij}^k can be assigned by each expert in his own individual, arbitrarily assumed interval scale for each criterion. The values after normalization to the values d_{ij}^k are used in further steps of the procedure. The normalization can be made when all projects have been evaluated by a given expert. It means that evaluations of the same project given by different experts can not be compared before. The experts asked to have possibility to compare their evaluations on earlier stages of the procedure and agreed to have the same scale for all of them. They decided to have the scale of 10 points for each criterion, assuming 10 points to any criterion on the reference project level and 0 points to any criterion on the reservation level. The first criterion was divided into two subcriteria: K1a - degree of realization of the activity directions defined in the development strategy of the province (assessed on the scale of 0-7 points), and K1b - degree of realization of the directions of the spatial management defined in the spatial plan of the province (0-3 points). The experts decided that these sub-criteria are additive.

The experts initially evaluated several projects. The different rankings of the projects according to the norms (1), (2), (3) and according to the classical weights method were derived and presented to the experts. Figs 3, 4, 5 illustrate the ways of ranking. The set of projects is shown in each figure as a set of points in the space of two weighted criteria. The reference as well as the reservation point is shown. The continuous lines represent sets of projects being at the same distance to the reference point i.e. being in the same position in the ranking.

The classical method of weights is shown in Fig. 3. Selection of the key projects means that a border line of distance to the reference point has to be assumed. The projects below the line are rejected. Our real problem is considered in the four dimensional space. The border is defined in this case by a hyperplane. The weight method is very popular and traditionally applied in practice due to its simplicity and practicality. The question arises: Does it really reflect the preferences of experts? Let us see the project having a low value of

the criterion k_2 and a very high value of the other criterion (the project in question is indicated in Fig. 3). This project would be in the ranking higher than projects having balanced values of all criteria. Is it really correct according to the feeling of experts? The weight method is justified if the criteria are additive. In general, the description of experts' preferences may be nonlinear. The rankings derived with use of the norm l_2 and $l\infty$ serve as examples of such nonlinear descriptions of the preferences. Of course, use of other nonlinear descriptions is possible.

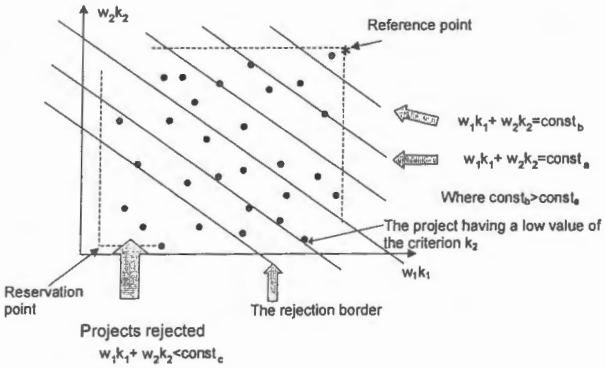

Fig. 3. The evaluation and ranking of projects according to the classical weight method

The experts decided that the key projects should be selected using the Euclidean norm. The rankings defined with use of the norm $l\infty$ and by the weight method were derived for the sake of comparison.

In practice, in typical implementations, each project is assessed by 5-7 or a bigger number of experts. Having the values given by experts, the extreme values are rejected and the mean value is derived as the collective one. In the considered case study, the time for the entire procedure was very limited. All the projects had to be analyzed and evaluated in a few days. The team of experts consisted of 7 specialists. In the applied solution, each project was analyzed and assessed independently by the experts from the Department for the Strategy and Regional Development of the Self-Government and from the Bureau for the Regional Planning of the Mazovian Voivodship. The experts checked whether a given project satisfied acceptability conditions mentioned in Section 2.1, and if so, made the assessment according to the assumed set of criteria. The assessments were treated as introductory. The special interactive session was

organized after the individual assessments had been made. In the session, the projects and the introductory opinions were analyzed again by all the experts,

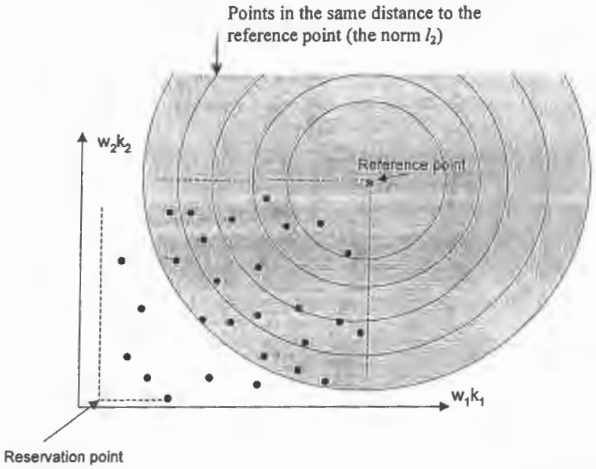

Fig. 4. The evaluation and ranking of projects according to the distance to the reference point (the distance measured by the Euclidean norm l_2)

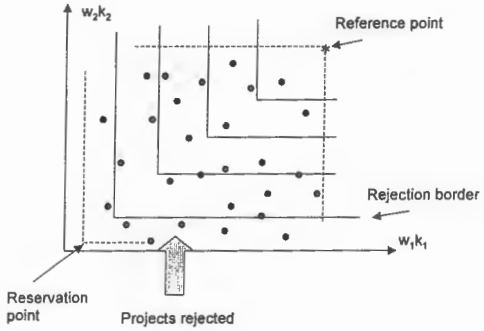

Fig. 5. The evaluation and ranking of projects according to the distance to the reference point (the distance measured by the norm $l\infty$)

especially in the case of divergent introductory opinions. The opinions could be corrected after the discussion and the negotiation of arguments according to the Delphi method. The experts were supported during the session by a computer-based system.

The system takes as inputs the experts' opinions. On this basis it produces evaluation of projects, derives the distance of each project to the reference point according to the assumed Euclidean norm, and also according to the l_1 and $l\infty$ norms. It generates the respective ranking lists. The system works in an interactive way. Experts can on line correct their opinions, obtain corrected results, analyze project evaluations and observe changes in the ranking lists.

The whole of the evaluation process was carried on under the confidentiality conditions ordered by the Ministry of Regional Development supervising the competition. The application sheets are confidential and could be analyzed by experts on the place only. Detail information about individual evaluations, discussions, preliminary scores is also confidential. The experts accepted the proposed procedure and made their work without difficulties. From operational point of view, individual assessments were made in the same way as in the traditional method. Only aggregated scores and analyzed variants of the ranking list were derived not by a hand, but by the computer-based system. Only in the case of 10% of projects, the individual opinions differed significantly. In this case, the experts had to present their argumentations during the final session and to discuss their opinions looking for consensus. In all the cases, they reached the consensus. A special discussion was needed to decide where to make the rejection border in the ranking list of all the projects. The projects having scores near the discussed border were additionally analyzed, so that the final decision was justified, and accepted unanimously.

The resulting list of the key projects established and approved by the team of experts, and the ranking list of all the projects have been presented and recommended to the Board of the Self-Government of the Mazovian Voivodship. On the basis of the list and the opinions of the experts, the indicative investment plan has been elaborated and accepted by the Board of the Self-Government of Mazovia. The list of the key project is presented on the website of the Self-Government.

5. Conclusions

An original in the practice of EU funds allocation, specially prepared group, multicriteria method has been applied to make the ranking and selection of the key projects. The ideas of different approaches have been used including the brainstorming techniques, the Delphi method and the extended cardinal approach to the group multicriteria decision making. To make the ranking, the

positions of the projects in the multidimensional space of criteria are analyzed. On the basis of the experts' opinions the distance of each project to the reference key project is derived. The projects closest to the reference one are selected as the key projects. It has been found that the experts comparing several different measures of distance have not selected the classical weight method but the nonlinear measure based on the Euclidean norm.

The weight method, frequently used, is justified under the assumption that all criteria are additive in the preference relation. In general, the assumption can be not fulfilled, but in practical implementations, it is frequently even not checked.

In this case study, the experts could make a choice. They did not approve the weight method, but selected and approved non-linear description of their preferences according to the Euclidean norm for measuring the distance of each project to the reference „key" project.

The method has been elaborated and implemented at the commission from the Mazovian Bureau for Regional Planning in Warsaw (Krus, [14]). The final list of the selected key project was the basis for the indicative investment plan elaborated and accepted by the Board of the Self-Government of the Mazovia Voivodship.

In the future works applications of the bipolar reference system ideas proposed by Konarzewska-Gubała [9] and developed by Trzaskalik [26] and of the interactive approach to ordinal regression, multiple criteria ranking using a set of additive value functions [5] are planned.

Bibliography

1. Bury H., Wagner D. (2007) Determining group judgment when ties can occur. In: Proc. of 13th IEEE IFAC International Conference on Methods and Models in Automation and Robotics MMAR 2007, Szczecin, Poland, 779-784.
2. Chankong, V., Haimes Y. (1983) Multiobjective Decision Making, Theory and Methodology. North Holland, New York.
3. Development Strategy of the Mazovian Province till 2020. Mazovian Bureau for Regional Planning in Warsaw, (2006), Warsaw, Poland. http://www.mazovia.pl/?a=news&id=2342
4. Górecka D. (2008) Multicriteria decision aiding in ordering projects co-financed by the EU structural funds. In: Multiple Criteria Decision Making '07, T. Trzaskalik (ed.), The Karol Adamiecki Univ. of Economics in Katowice.
5. Greco S., Mousseau V., Słowiński R. (2008) Ordinal regression revisited: Multiple criteria ranking using a set of additive value functions. EJOR, 191, 416-436.

6. Hwang C.L., Lin M.J. (1987) Group Decision Making under Multiple Criteria. Springer Verlag, Berlin/New York.
7. Hwang C.L. Yoon K. (1981) Multiple Attribute Decision Making Methods and Applications. A State of Art Survey. Springer Verlag, Berlin/Heidelberg/New York.
8. Keeney R. L., Raiffa H. (1976) Decisions with Multiple Objectives: Preferences and Value Tradeoffs. John Wiley & Sons Inc., New York.
9. Konarzewska-Gubała E. (1989), BIPOLAR: Multiple Criteria Decision Aid Using Bipolar Reference System, LAMSADE, "Cashier et Documents", 56, Paris.
10. Konarzewska-Gubała E. (1991): Multicriteria Decision Support (Wspomaganie decyzji wielokryterialnych). Prace AE we Wrocławiu Nr 551. Seria: Monografie i Opracowania nr 56 (in Polish).
11. Kruś L. (1996) Multicriteria Decision Support in Negotiations. Control and Cybernetics, 25, 6, 1245-1260.
12. Kruś L. (2002) Multicriteria Decision Support in Bargaining, a Problem of Players Manipulations. In: Multiple Objective and Goal Programming. Eds T. Trzaskalik, J. Michnik., Physica Verlag, Springer, Berlin.
13. Kruś L. (2008) Computer Based Support of Multicriteria Cooperative Decisions – Some Problems and Ideas. In: Multiple Criteria Decision Making 07'. Ed. T. Trzaskalik. The Karol Adamiecki University of Economics in Katowice.
14. Kruś L. (2006) A Method of Group, Multicriteria Evaluation of Regional Projects from the Point of View of their Importance for Development of the Mazovian Voivodship (Metoda grupowej, wielokryterialnej oceny projektów regionalnych z punktu widzenia ich istotności dla województwa mazowieckiego). Expert's Report commissioned by the Mazovian Bureau for Regional Planning in Warsaw, Warszawa. (in Polish).
15. Lewis A.C., Sadasky T.L., Connoly T. (1975) The Effectiveness of Group Brainstorming in Engineering Problem Solving. IEEE Trans. On Engineering Management, EM-22, 3, 119-124.
16. Linstone H.A., Turoof M. (1977) The Delphi Method, Techniques and Applications. Addison Wesley, Reading, Massachusetts.
17. National Development Strategy (NDS) 2007-2015 for Poland (2006) Ministry of Regional Development, Poland.
18. National Cohesion Strategy (NCS) 2007–2013 (2006) Ministry of Regional Development, Poland.
19. National Strategic Reference Framework for 2007-2013 (2007) Ministry of Regional Development, Poland, 2007, http://www.mrr.gov.pl/NR/rdonlyres/A1A61D68-4528-499F-9199-5FE0E0533F0D/31941/NSRO_maj2007.pdf, Warszawa.
20. Ogryczak W. (2001) On Goal Programming Formulations of the Reference Point Method. *Journal of the Operational Research Society.* 52, 691-698.

21. Ogryczak W. (2008) Reference Point Method with Lexicographic Min-ordering of Individual Achievements. In: Multiple Criteria Decision Making 07'. Ed. T. Trzaskalik. The Karol Adamiecki University of Economics in Katowice.
22. Osborn A.F. (1963) Applied Imagination. Charles Scribner Sons, New York, 3rd edition.
23. Plan of Spatial Management of the Mazovia Province. Mazovian Bureau for Regional Planning in Warsaw, http://www.mbpr.pl/, Warszawa, 2004.
24. Regional Operational Program for the Mazovia Province 2007 – 2013. Self-Government of the Mazovian Voivodship, Warszawa, 2008. http://www.mazovia.pl/?a=rpo_wm
25. Słowiński R., Greco S,., Matarazzo B. (2002) Axiomatization of utility, outranking and decision rule preference models for multi-criteria classification problems under partial inconsistency with the dominance principle. *Control and Cybernetics*, 31, pp. 1005-1035.
26. Trzaskalik T. (2006), Multicriteria methods on financial market in Poland. PWE, Warszawa (in Polish).
27. Wierzbicki A. P. (1982), A Mathematical Basis for Stisficing Decision Making. *Mathematical Modeling*, , 3, pp.391-405.
28. Wierzbicki A. P., Makowski M., Wessels J., (2000), Model Based Decision Support Methodology with Environmental Applications, Kluwer, Dordrecht.
29. Zopounidis C., Doumpos M. (2002), Multicriteria classification and sorting methods: A literature review. *EJOR*, 138, 2,pp. 229-246.