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Multi-Criteria Scheme for MAP-Cluster Identification[1]

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1. Introduction

The economic clustering is recognized as one of the most innovative economic policies in enterprises' competitiveness and operational development and reached a new understanding over the last decade. The reasons for cluster formation and consequent benefits for productivity and acceleration of innovation activities were presented in (P o r t e r, 1998). A number of case studies have documented clusters, their characteristics and evolution over time[2].

This paper describes multi-criteria scheme of MAP-Cluster approach presented in (P o p c h e v and R a d e v a, 2007) and is an extension of previously developed decision support method for investment preference evaluation of Bulgarian public companies described in (P o p c h e v and R a d e v a, 2004; P o p c h e v and R a d e v a, 2006). The scheme of MAP-Cluster was performed by general purpose decision support software system MKA-2 for application of multi-criterion analysis and XLMiner®[3] for application of cluster analysis. DSS MKA-2 supports four different methods application – the weighting method AHP (the analytical hierarchy process), see (S a a t y, 1994), the outranking method ELECTRE III, see (R o y, 1996), PROMETHEE II (B r a n c e and M a r a s c h a l, 1994), and the interactive method CBIM (N a r u l a et al., 2003). This system was developed at the Institute of Information Technologies – Bulgarian Academy of Sciences. The "build in" interface modules enable successful realization of different types of procedures such as information extraction by the decision maker (DM) as well as four types criteria entry – quantitative, qualitative, ranking and weighting, see (V a s s i l e v et al., 2005).

[1] This work is supported by the Institute of Information Technologies – BAS under grand No 010077/2007.

[2] http://data.isc.hbs.edu/cp/index.jsp

[3] XLMiner® is a data mining add-is for Excel by Resampling Stats, Inc., © 2003.

The rest of the paper is organized as follows. Section 2 gives a general organization and idea of multi-criteria MAP-Cluster scheme. Section 3 presents an short illustrative example. Conclusions are given in the last section.

2. Multi-criteria MAP-Cluster scheme

The latent economic cluster identification here is set as multi-criteria analysis problem in conjunction with *k*-means cluster analysis. MAP-Cluster is four staged scheme allowing: “cluster mapping”, “aiming and criteria definition”, “strategic positioning” and “strategic clustering”.

The entire process is assumed to be closely related to the Cluster Initiative Committee (CIC), consisting of an entity – initiator and a consultant group. Here, cluster initiative committee is acting as a DM who defines the economic, technological, production and trading aims, scope, activities as well as the assessment criteria of the cluster.

The stage “cluster mapping” includes design of organizational and technological structure of the economic cluster by setting of necessary business groups and representative enterprises. These entities are subject to particular assessment in order to be included as basic potential elements of the economic cluster.

The second stage “Aiming” includes formulation of main goals (aims) of cluster project. The information here is mostly expert, nevertheless it is stated in quantitative or qualitative parameters. To each aim a set of criteria is formulated. The expert qualitative or quantitative assessments of those criteria are used as an input data in the next stage. Each aim from the “Aiming” stage here in formulated as a discrete multi-criteria analysis problem.

The stage “Strategic positioning” includes multi-criteria analysis application. It is preformed by general purpose decision support software system MKA-2. As many aim the DM sets in the previous stage as many problems should be defined and accomplished. All cluster elements (alternatives) obtain here an assessment parameter (number), which we assume and interpret as elements’ strategic position according to the respective aim. In the result a matrix is set out. The rows represent the elements of the cluster map and the columns represent the strategic positions by each aim.

The last stage “Clustering” actually clusters enterprises by several strategic positions according to the aims set in the second stage. The main purpose here is obtaining a cluster which is able to complete the technological and organizational map as it is set in the first stage. It is preformed by data mining add-is for Excel XLMiner for *k*-means cluster analysis. It allows extension of those two dimensional problems determined by the number of aims and by the set of enterprises to a clustering problem in a multidimensional space.

The “Mapping” and “Aiming” stages should be considered as parallel and interconnected but not as strictly sequential stages. The idea is that the entity – initiator sets the aims and assessment criteria as well as the cluster map almost simultaneously. It is in “strategic Positing” where the conformity between the entities, the aim and criteria is performed.

The simplified illustration of MAP-Cluster identification scheme is shown in Fig. 1.

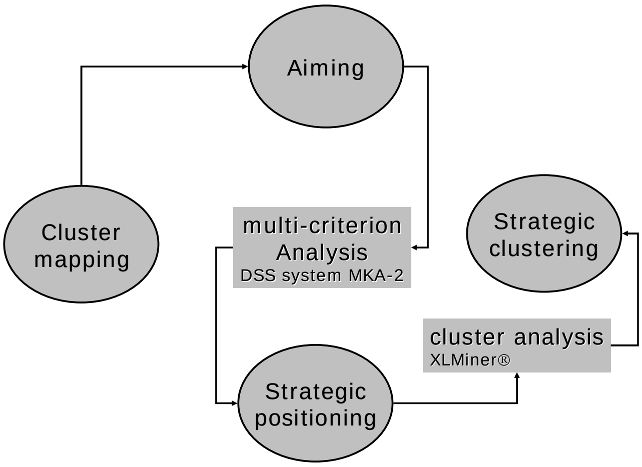

Fig. 1. Illustrative scheme for MAP-Cluster identification

2.1. Stage 1. Cluster mapping

In this initial stage the process of identification is closely related to the DM who defines the economic, technological, production and trading aims, scope, activities as well as the assessment criteria of the cluster project. It is recommended for the DM (entity – initiator in the cluster initiative committee) to be in a strong market position in order to assure the leading role and sound cluster policy. It is also essential for it to represent at least one of the businesses covered by the map.

As it is shown in Fig. 2 the cluster map represents the entire technological and organizational structure of the economic cluster the only goal of which is production of certain product or service.

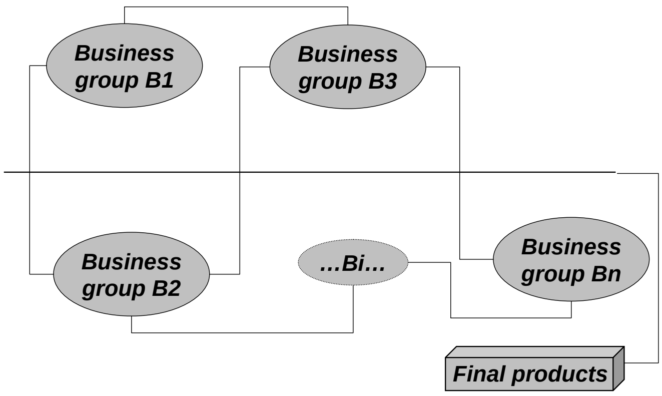

Fig. 2. Cluster map scheme

The design depends on the DM and is not hieratic by nature, because all enterprises do not lose it's independence by anticipation in the cluster project. Depending on the desired target products or/and services of the cluster DM is free to define as many business groups B_i as it is needed i = 1, …, n.

Each business group includes enterprises a_{ij}, which exact number j, j=1, ..., m, in the current B_i depends on the currently available active business entities in a given geographical region and on the technological compatibility with the rest representatives of groups in the cluster. Those enterprises form the initial set of alternatives subjected to multi-criteria analysis in later stages.

2.2. Stage 2. Aiming and criteria definition

The purpose of this stage is definition of the cluster's aims S_i, i=1, …, l, regarded as qualitative concepts. Depending on the context a set of criteria $\{s_{i1}, s_{i2}, \ldots, s_{in}\}$ is assigned to each respective aim S_i. Criteria could be qualitative, quantitative, ranking as well as weighting, depending on available data. The number of aims (qualitative concepts) and defined corresponding set of criteria are specified by DM. The aims of the cluster are interpreted and defined as individual multi-criteria analysis problems (Fig. 3).

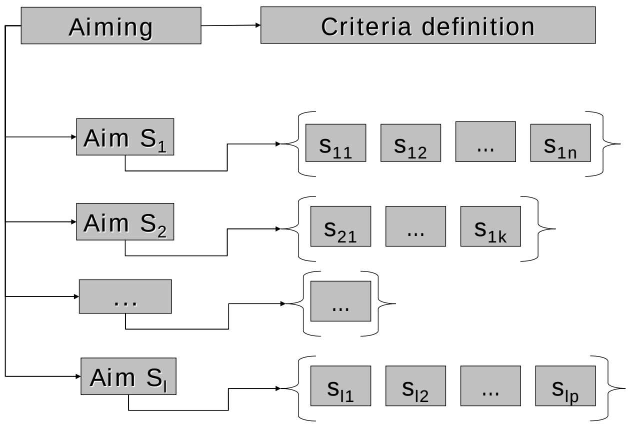

Fig. 3. Aiming and criteria definition scheme

2.3. Stage 3. Strategic positioning

In this paper we assume that each enterprise a_{ij} could be represented by its individual initial strategic position sp_i in respect to aim S_i and corresponding criteria set $\{s_{ij}\}$. These are integral estimates representing current performance and potential ability of entities to innovative development. The purpose of this stage is obtaining of these integral estimates for all entities through all qualitative concepts under consideration. The integral estimates are multi-criterion problem's results for elements included in the cluster's map.

$$\mathrm{sp}_i = \sum_{i=1}^{k} w_j s_{ij}.$$

At this stage the multi-criteria analysis is applied. The elements included in the cluster's map (stage 1) form the input alternatives under consideration. Thus, the number of aims corresponds to the number of discrete multi-criteria analysis problem as well as the number of objects in the cluster map corresponds to the input alternatives.

The AHP weighting method in MKA-2 was used. The entities' strategic positions are assumed to be defined by the resulting ranked scores acquired by AHP weighting method. All scores were used in the next stage.

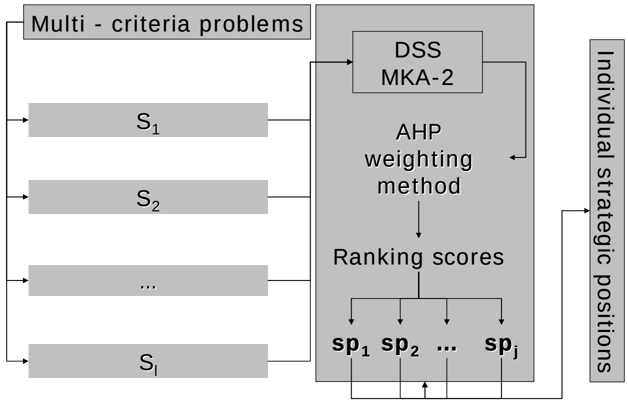

Fig. 4. Strategic positioning scheme

2.4. Stage 4. Strategic clustering

The purpose here is the identification of the most closely strategically positioned entities with a potential for latent economic cluster. The idea which is seen behind seeking close strategic positions is that it is easer to develop collaboration between relatively equal by performance enterprises than to spend resource for compensation of identified inequalities in the initial stage of cluster initiative. In order to complete the cluster mapping it is also rational to look for at least one representative enterprise from each business group.

Strategic clustering (Fig. 5) was performed by *k*-means clustering algorithm used in XLMiner (S h m u e l i at al., 2007).

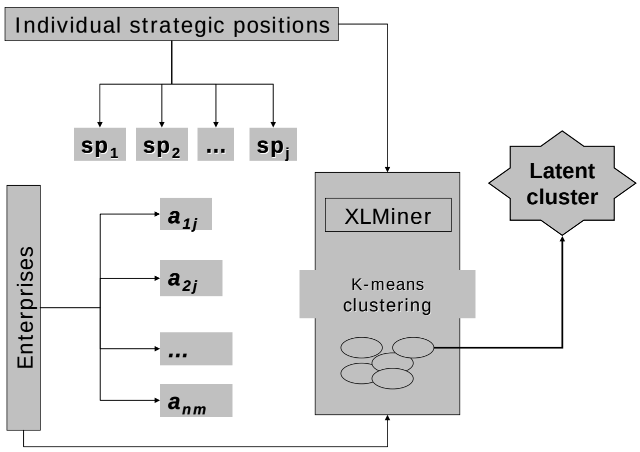

Fig. 5. Strategic clustering scheme

3. Short example

Stage 1. For the purposes of the present paper, the cluster map was constituted by four business groups: B_1 – Primary producers (PP); B_2 – Products producers (P); B_3 – Material Procurement (MP); B_4 – Marketing (M). Data about 12 enterprises was used as representatives of different business groups and are qualitatively specified and assessed by DM.

Stage 2. The aims of enterprise clustering were defined as follows:

S_1: "competitiveness improvement";

S_2: "management improvement";

S_3: "innovation activity improvement";

S_4: "readiness for clustering".

According to the aims four different multi-criterion problems were defined and subjected to multi-criterion analysis.

Competitiveness $\{CC_n\}, n = 1, \dots, 4,$ with suggested criteria:

CC_1: Products' price – minimization qualitative criterion;

CC_2: Products' quality – maximization qualitative criterion;

CC_3: Products' protection – maximization qualitative criterion;

CC_4: Market share – maximization qualitative criterion.

Management $\{MC_k\}, k = 1, \dots, 5,$ with suggested criteria:

MC_1: Existence of company strategies – maximization qualitative criterion;

MC_2: Personal qualification – maximization qualitative criterion;

MC_3: Effective management – maximization qualitative criterion;

MC_4: Other cluster belonging – maximization qualitative criterion;

MC_5: Certificates and applied standards availability – maximization qualitative criterion.

Innovation activity $\{IA_l\}, l = 1, \dots, 3,$ with suggested criteria:

IA_1: Innovation activity – maximization qualitative criterion;

IA_2: Products improvements – maximization qualitative criterion;

IA_3: Management improvements – maximization qualitative criterion.

Clustering potential $\{CP_m\}, m = 1, \dots, 4,$ with suggested criteria:

CP_1: Social and political position – maximization qualitative criterion;

CP_2: Technological compatibility – maximization qualitative criterion;

CP_3: Financial performance – maximization qualitative criterion;

CP_4: Ecological safety – maximization qualitative criterion.

Stage 3. The AHP weighting method in MKA-1 was used to solve multi-criterion problems from Stage 2.

The input criteria had nine available levels: exceptionally low, essentially low, very low, low, satisfactory, good, very good, essentially good, and exceptionally good. DM assesses all entities.

The application AHP algorithm in MKA-2 requires DM to compare pair-wise the input criteria. The DM preferences are set out in Table 1 for the CC problem, Table 2 for MC the problem, Table 3 for the IA problem and Table 4 for the CP problem.

Table 1. Criteria pair-wise comparison for problem CC

Competitiveness	CC_1	CC_2	CC_3	CC_4
CC_1	1	1	7	0.125
CC_2	1	1	4	0.2
CC_3	0.1429	0.25	1	0.125
CC_4	8	5	8	1

The resulting criteria weights are: CC_1 = 0.1531; CC_2 = 0.1358; CC_3 = 0.0417 and CC_4 = 0.6694.

Table 2. Criteria pair-wise comparison for problem MC

Manadgement	MC_1	MC_2	MC_3	MC_4	MC_5
MC_1	1	5	0.143	5	8
MC_2	0.2	1	6	9	9
MC_3	6.993	0.1667	1	9	9
MC_4	0.2	0.1111	0.1111	1	0.167
MC_5	0.125	0.1111	0.1111	5.988	1

The resulting criteria weights are: MC_1 = 0.2807; MC_2 = 0.3379; MC_3 = 0.3331; MC_4 = 0.0184 and MC_5 = 0.0299.

Table 3. Criteria pair-wise comparison for problem IA

Innovation	IA_1	IA_2	IA_3
IA_1	1	0.25	6
IA_2	4	1	1
IA_3	0.1667	1	1

The resulting criteria weights are: IA_1 = 0.3487; IA_2 = 0.4836; IA_3 = 0.1677.

Table 4. Criteria pair-wise comparison for problem CP

Criteria weight	CP_1	CP_2	CP_3	CP_4
CP_1	1	0.167	0.125	0.2
CP_2	5.988	1	2	8
CP_3	8	0.5	1	8
CP_4	5	0.125	0.125	1

The resulting criteria weights are: CP_1 = 0.042; CP_2 = 0,493; CP_3 = 0.374; CP_4 = 0.0909.

Finally, four strategic position values were assigned to each of the 12 entities under consideration. The summarized results are shown in Table 5. The entities in this table are consequently sorted by business groups.

Table 5. Strategic position values of entities

Entities	**CC**	**MC**	**IA**	**CP**
a_{11}	0.8457	0.6738	0.6294	0.4997
a_{12}	0.9020	0.7331	0.5332	0.8594
a_{13}	0.8243	0.7191	0.6294	0.7252
a_{21}	0.9797	0.6442	0.8062	0.7476
a_{22}	0.4076	0.6750	0.7086	0.8364
a_{23}	0.7629	0.7560	0.4869	0.6202
a_{31}	0.8927	0.8110	0.6063	0.7567
a_{32}	0.7496	0.7659	0.8450	0.8820
a_{33}	0.8138	0.8150	0.7705	0.6053
a_{41}	0.8886	0.7562	0.6232	0.5061
a_{42}	0.7284	0.6843	0.7102	0.6529
a_{43}	0.8545	0.6285	0.5891	0.4087

The strategic position values were used as an input for *k*-means clustering performed in the next stage.

Stage 4. The choice of the number of clusters *k* is imposed by the consideration that DM whishes to identify a cluster within which there is at least a single entity from each business group according to the criteria CC, MC, IA and CP. The algorithm was run with different values for *k*. In this example DM requirements were satisfied for $k = 5$. The results from the cluster analysis over the set of all entities and four the criteria used are set out in Table 6.

Table 6. *k*-Means clustering – predicted clusters

Entity	C-id	C-1	C-2	C-3	C-4	C-5
a_{11}	3	0.56	0.18	0.04	0.46	0.31
a_{12}	5	0.53	0.27	0.41	0.35	0.14
a_{13}	**2**	**0.44**	**0.09**	**0.26**	**0.28**	**0.12**
a_{21}	5	0.59	0.29	0.36	0.30	0.19
a_{22}	1	0.00	0.43	0.60	0.38	0.53
a_{23}	**2**	**0.48**	**0.17**	**0.23**	**0.44**	**0.29**
a_{31}	5	0.52	0.17	0.31	0.31	0.10
a_{32}	4	0.38	0.31	0.50	0.00	0.28
a_{33}	**2**	**0.49**	**0.15**	**0.25**	**0.30**	**0.26**
a_{41}	3	0.60	0.18	0.08	0.46	0.29
a_{42}	**2**	**0.37**	**0.10**	**0.25**	**0.28**	**0.25**
a_{43}	3	0.63	0.28	0.09	0.57	0.40

The nearest strategic positions were found for enterprises a_{13}, a_{23}, a_{33} and a_{42} clustered in C-id2. It could be assumed, that these enterprises have shown a potential to form and develop a latent regional economic cluster.

4. Conclusion

The present paper describes multi-criteria scheme for MAP-Cluster application based on discrete multi-criteria analysis problems combined with k-means clustering. The approach allows:

– Initial cluster mapping constituted in order to cover and complete the production business cycle subjected to economic clustering;

– Definition of multi-criterion problems according to predetermined aims of initiated clustering;

– Entities' strategic position estimation;

– The economic cluster identification by nearest strategic positions detection.

Assuming that the integral estimates of entities' strategic positions were correctly obtained and properly interpreted it is possible to use them for overall cluster strategic positioning, setting and managing of its new desirable position in order to achieve better economic performance. The cluster's strategic position could be also used for positioning of already formed economic cluster on the life cycle curve.

Further improvements of the MAP-Cluster would require quantitative data applications, increase of the number and accuracy of aims and accompany criteria definition. It is also of practical use to separate the overall cluster's aims from enterprise entities assessment, to apply and analyze the results obtained by the outranking method ELECTRE III, PROMETHEE II and interactive method CBIM. The *k*-means clustering algorithm could be replaced by Grid-based method which seems to be more appropriate in economics application and overcomes the shortcomings of the first.

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Многокритериальная схема MAP-Cluster идентификации

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(Р е з ю м е)

В работе представлена многокритериальная схема идентификации латентных экономических кластеров – "MAP-Cluster". Схема состоит из четырех этапов. На первом этапе – "Mapping" – осуществляется проектирование организационной и технологической сети экономического кластера и задаются необходимые технологические группы и формирующие их элементы. На втором этапе – "Aiming" – формулируются основные цели и критерии кластеризации. На третьем этапе – "Positioning" – при помощи методов многокритериального анализа осуществляется стратегическое позиционирование элементов кластера на технологической сети. На завершающем четвертом этапе – "Clustering" – использование кластерного анализа позволяет определить те элементы технологичной сети, которые формируют проектируемую организационную структуру.