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Multi-Criteria Models for Clusters Design[1]

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Abstract: *The paper describes economic agents' integration in clusters on a predefined technological network. The process is divided and directed by three multi-criteria models. The first one allows selection of economic agents. The second one aims at definition of alternative cluster designs. The third model evaluates the risk of the clusters. The process and models are tested on nineteen economic agents.*

Keywords*: Multi-criteria decision, economic clustering, small and medium enterprises, risk evaluation.*

1. Brief introduction and problem formulation

Economic cluster is a union of enterprises (suppliers, manufacturers, elements of infrastructure and research organizations) associated with the creating of a value added that ensures growth of competitiveness along with sustainable increase of productivity of each element. The key advantage of the clusters is the direct stimulation of competitiveness of national and regional economy development. The disadvantage is clusters' efficiency dependence on national policies on public-private partnership and the regulation of governmental institutions relations.

Small and Medium Enterprises (SMEs) as Economic Agents (EA) are carriers of a certain potential in the clustering process. According to [12, 2] the association on different technological networks for products/services production and marketing is one of the efficient management tools for synergy effects utilization on performance. The regional economic researches on clustering and product integration [1, 17] are related mostly to the identification and performance

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assessment of naturally occurring clusters through "top-down" management activities. The analysis of the prevailing concepts also reveals their main orientation towards existing clusters and are less applicable to the establishment of new ones [10, 15, 14].

The literature analysis shows that some frequently used methods in solving economic problems are traditional multi-criteria analysis and optimization, and models based on fuzzy sets theory [4-8]. The solutions obtained by traditional methods are sufficiently accurate and require less time, intellectual and information resources in comparison to the solutions obtained by the methods of fuzzy logic. This defines the wider application of traditional methods for solving practical problems [13].

The development of a cluster as a "down-top" initiative is a challenging problem associated with a complex decision making process where the main goal is voluntary consolidation of different participants, interests, resources and technologies in a mutually productive structure. One side of the problem is the selection of appropriate participants. The other side is the cluster itself, how it would perform and assure sustainable competitiveness of its elements. The third is the overall approach to management and direction of this process to a feasible and economically reasonable decision.

This paper presents multi-criteria models for clusters design under conditions of sustainable competitiveness enhancement and considering the effects of business environment. It is organized in four sections. The next section describes an overall approach to cluster design. The third section presents a detailed description of the three above mentioned models. A numerical example on cluster design is given in the fourth section. The summary of results is presented in the last section.

2. An approach to clusters design

Establishing a cluster means a voluntary association of enterprises. The initiative is usually taken by a group of managers who have to recruit the appropriate candidates. This is a multi-criteria decision process. The proposed approach to cluster design involves several interconnected problems of selection, evaluation and verification, and it is interactive by nature.

The first step is the decision itself to unite the efforts, ideas and recourses of some group of enterprises in order to improve their sustainable competitiveness in manufacturing products/services. This decision evolves into a cluster structure aiming, where broad intentions are defined as a plan and strategy. The next step is the description of the technological network. In this particular approach, the network is predefined, i.e., the consistency of the production process is known in advance. The separated processes are presented by nodes of Technological Network (TN), such as primary production of raw materials, processing, packaging, trading, etc. A list of the enterprises is assigned to each one of the network nodes. This list is subject to selection and determination of the different alternatives of cluster design.

The enterprises selection is decided by given criteria, constraints and evaluations incorporated in three models. The first model evaluates the performance level and sustainable development of the enterprises by a set of criteria. It aims at the first and the second level of selection, where the initial list is restricted according to a given cut-off value or conditions of estimations' proximity. The output of the model is a group of enterprises used for determination of the cluster alternatives.

The second model evaluates the investment preference of the alternative cluster designs. *Investment preference is an integral evaluation, characterizing the perspectives of growth, investment returns, efficiency of asset utilization and environmental interaction* (*markets, suppliers, customers*) *of the cluster*. This is a measure of the material, financial and non-financial resources. The model aims at the third level of selection, where the Decision Maker (DM) deals with cluster alternatives and selects from an ordering rank, where the top ranked alternative is the most preferable.

The third model evaluates the risk associated with a selected cluster alternative in the second model. Risk is a combination of the probability of an event and its consequence [18]. The risk evaluation aims at quantitative assessment of uncertainty factors. Herein it is assumed to represent the risk by the synthetic characteristics Net Present Value (NPV), the Internal Rate of Return (IRR) and the cash flows standard deviation (σ). This is the fourth level of selection.

The final decision is made after performance verification of the economic agents, included in the selected cluster alternative associated with the minimum risk. The verification concerns the predicted criteria values for a post-integration period. Its objective is a confirmation that all agents maintain or improve their performance.

An overall approach is an interactive, multi-criteria decision process for evaluation, ranking and selection of groups of economic agents and alternatives at their allocation on a predefined technological network. It is schematically depicted on Fig. 1.

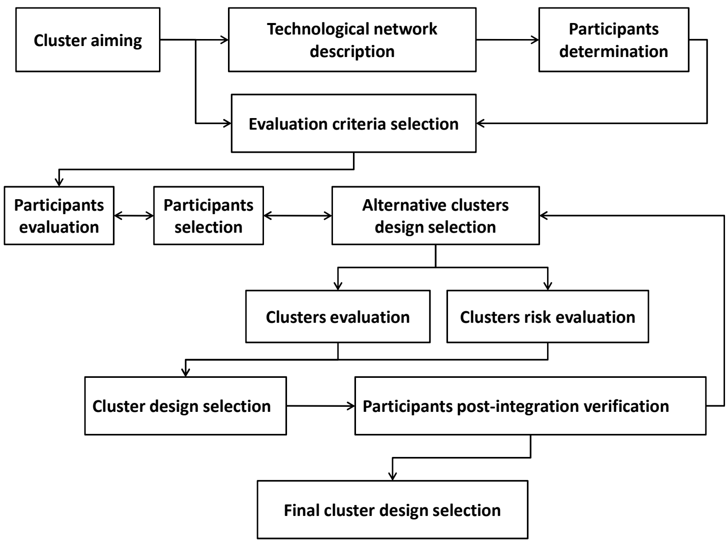

Fig. 1. Cluster structures design

3. Multi-criteria models

3.1. PLE-SDP Model

The objective of the Performance Level Evaluation and Sustainable Development Positioning Model (PLE-SDP Model) is the selection of a subset from a given set of agents. The agents are preliminary allocated among the nodes of a TN. The selection is based on ranking by an integral criterion named Performance Level Evaluation (PLE) and on the proximity of another integral criterion named Sustainable Development Position (SDP).

The following multi-criteria problem can be defined: *To rank the agents allocated to a particular node of TN. To rank all agents allocated on the TN. To select groups of agents for determination of the alternative cluster designs*.

The PLE-SDP Model produces three resulting outputs:

A descending ranking of the agents by nodes of the TN in respect to PLE;

A descending ranking of the agents for the entire TN in respect to adjusted PLE;

Groups of agents for cluster alternative designs in respect to SDP.

The solution of the problem involves five steps.

Step 1. Input data recruitment and processing

1. Description of the TN (number of nodes m, industry, relations and connections in the products/services production and marketing process);
2. Compilation of the lists of agents for each node of TN;
3. Compilation of the lists of evaluation criteria, here called a “passport”. This is a database or a simple table, where all required data are collected and organized for further processing.

Step 2. Ranking of the agents by TN’s node

For ranking Promethee II method from DSS MKA-2 [16] could be applied. This method provides a full ranking of the decision options.

The decision options (alternatives) for selection are initially recruited agents. Each agent is evaluated by a number of criteria. The pattern of PLE structuring depends on specific DM’s requirements, aims of clustering or particular industry.

Let us denote by $f(.)$ each one of the assumed criteria in PLE in the maximization problem $f: A \rightarrow R$.

For any two alternatives $a, b \in A$ a comparison is made with respect to the criterion $f(.)$. Two cases are possible:

$f(a) > f(b) \Rightarrow aPb$, when a is preferred over b;

$f(a) = f(b) \Rightarrow aIb$, when the althernatives are indistinguishable.

In this preference structures, the amplitude $d = f(a) - f(b)$ is not included. To do this, a preference function $P(a, b)$ is used, which describes the preference intensity of the alternative a over b as a function of deviation d; $P(a, b)$ assumes the following properties:

$$0 \leq P(a, b) \leq 1 \text{ and}$$
$$P(a, b) = 0, \text{ if } d \leq 0, \ f(a) \leq f(b);$$
$$P(a, b) = 1, \quad \text{if } d \gg 0, \ f(a) \gg f(b).$$

In Promethee each criterion is compared to a generalized criterion represented by d or it can be set as a pair $((f(.),\ P(a,b))$.

In the multi-criteria analysis problems, for each criterion a generalized criterion is defined. For each pair of alternatives $a, b \in A$ and for each criterion j, there is a set:

$$\{f_j(a), f_j(b), d_j = f_j(a) - f_j(b), P_j(a,b)\}.$$

For each pair of alternatives, a preference index $\pi(a,b)$ for all criteria is defined as follows:

$$\pi(a,b) = \sum_{j=1}^{k} \omega_j P_j(a,b),$$

where:

$\sum_{j=1}^{k} \omega_j = 1$ and ω_j , $j = \overline{1,k}$ are the criteria weights.

In case of equal weights

$$\pi(a,b) = \frac{1}{k}\sum_{j=1}^{k} P_j(a,b).$$

The index $\pi(a,b)$assumes the following properties:

1) $\pi(a,a) = 0;$

2) $0 \le \pi(a,b) \le 1,$ for $\forall\ a,b \in A.$

Let us consider the following evaluations for each alternative $a \in A$:

$$\Phi^+(a) = \sum_{x \in A} \pi(a,x),$$

$$\Phi^-(a) = \sum_{x \in A} \pi(x,a).$$

These evaluations are called positive and negative outranking flows.

The evaluation $\Phi^+(a)$ shows how the alternative a stands before all other alternatives. The greater value means better alternative.

The evaluation $\Phi^-(a)$ shows how the alternative a is preferred over all other alternatives. The smaller value shows the out performance of the alternative a.

With these outranking flows three preference relations *P*, *I*, *R* can be defined:

aPb, if

$$\Phi^+(a) > \Phi^+(b) \wedge \Phi^-(a) \le \Phi^-(b),$$
$$\Phi^+(a) \ge \Phi^+(b) \wedge \Phi^-(a) < \Phi^-(b);$$

aIb, if

$$\Phi^+(a) = \Phi^+(b) \wedge \Phi^-(a) = \Phi^-(b);$$

aRb, in other cases.

When performing a full ranking, the net outranking flow $\Phi(a)$ is used:

$$\Phi(a) = \Phi^+(a) - \Phi^-(a).$$

$\Phi(a)$ is a balance of flows. The bigger value of Φ(a) means better alternative. This value olso represents the performance level evaluation PLE of ranked agents.

Step 3. Ranking of agents for the entire TN

The ranking could also be obtained by Promethee II. The adjusted PLE is estimated according to the deviations Δf of the individual current criteria values from its basic values:

$$\Delta f_{ij} = 1 - \frac{\left(f_{i_{\text{base}}} - f_{ij}\right)}{f_{i_{\text{base}}}},$$

where:

i is an index of the technological node;

j is an index of the agent;

f_{ij} is a current value of criteria of j-th agent in i-th node;

$f_{i_{\text{base}}}$ is a criteria base value of i-th node;

Δf_{ij} is the deviation of the current value of the indicator of j-th agent from the basic value of the i-th node.

Step 4. Selection of agents

The selection involves comparison of two ranks and determination of the cut-off value for PLE and adjusted PLE estimates. This is an expert procedure entirely depending on the DM.

Step 5. Grouping of agents

Grouping involves positioning of agents on a two-dimensional grid called "*Polygon of sustainable development*". On axis x the estimation values of the integral criteria Economic Creativity (EC) are plotted. On axis y, the estimations of the integral criteria Growth Through Competitiveness (GTC) are plotted. The patterns of EC and GTC structuring also depend on specific DM's requirements, on the aims of clustering or particular industry.

The grouping allows selection of agents for completion of the TN of the cluster. It may show the following options:

- No grouping. This means that SDPs are dispersed and the formation of a cluster may result in negative synergy due to different level of agents' development.
- Occurrence of a large number of small groups, which hampers the design of a cluster.
- Presence of a small number of large groups, which may functionally complete the TN.
- Presence of a small number of large groups, which may not functionally complete the TN. This is a prerequisite for clustering, but it requires further analysis and decisions concerning compensation or not of the functionality of the empty nodes.

According to the results of agents' grouping, PLE-SDP model considers three options:

1) a cluster could be designed with a compete technological network;

2) a cluster could be designed with an incomplete technological network;

3) a cluster could not be designed from the given set of economic agents.

In options 1 or 2, the process of the cluster design continues with applying the IP model to the designed cluster alternatives. In option 3, the solution cannot be reached and the process should be returned back to some of the initial steps of the model.

3.2. IP Model

The purpose of the Investment Preference assessment Model (IP Model) is to rank the cluster alternatives. The ranking is based on an integral criterion, defined as an Investment Preference (IP). It is assumed as an indicator of sustainable competitiveness of the cluster, estimated by a multi-criteria problem [10, 11].

The subject of the IP Model is assessment of a calculated consolidated budget of a cluster alternative by a system of criteria known as criteria Balanced SCorecard (BSC). It involves the following steps:

Step 1. Construction of the BSC

The construction of the BSC is based on an approach, described in [3]. BSC is recommended as an accurate and efficient approach to evaluation of the effectiveness of financial and non-financial resources utilization in the organization.

The indicators included in BSC are divided into four main strategic directions: financial performance, market performance, internal business processes optimization, and human resources development. The construction of BSC is a multi-criteria expert procedure.

Step 2. Calculation of a consolidated budget of cluster alternatives

The consolidated budget is calculated based on forecast data. Any technique could be used. Herein it integrates individual budgets developed by different strategic directions. In the budget, all planed activities in the cluster development, strategic goals achievement, costs of the required financial and non-financial resources are assessed. The estimations are based on the forecast values of revenues and expenditures aggregated for all planed activities. A functional diagram is shown on Fig. 2.

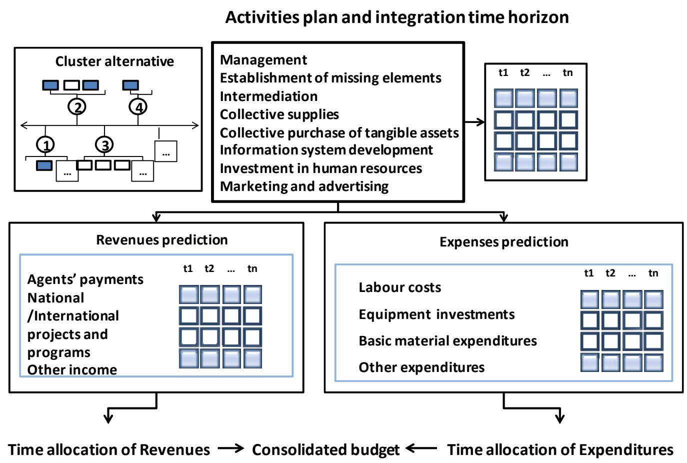

Fig. 2. Consolidated budget estimation

Budget verification requires the resulting Net Cash Flows (NCFs) at the end of the forecast period to be positive. If NCFs meet this condition, the budget is considered eligible. A corresponding cluster alternative is acceptable. The evaluation of the corresponding cluster alternative proceeds with an IP Risk

Evaluation Model. If NCFs are negative at the end of the forecast period, the planning and calculating procedure should be reconsidered by returning to some previous stages or to the beginning. If NCFs do not satisfy the verification condition within 3-4 iterations, it is recommended to have the cluster alternative excluded from the selection procedure.

3.3. IP Risk Model

The aim of Investment Preference Risk Evaluation Model (IP Risk Model) is to assess the uncertainty factors associated with the post-integration period of clusters' work. In the application problems for risk analysis, the most commonly used methods are dynamic. The usually recommended methods are the NPV, IRR and σ. Based on the priorities of integration, it is possible to assess the risk in terms of the performance of NPV, IRR and σ.

For calculation of NPV, IRR, σ, and the final $\mathrm{IP_{RISK}}$ assessment, five steps are recommended.

Step 1. Elaboration of k scenarios ($k \geq 3$) of the currently consolidated budget A_i, where i, $i = 1, \dots, n$, is an index of the i-th cluster alternative under consideration.

The k scenarios represent different economic situations. In the common cases, the scenarios are optimistic, realistic and pessimistic. For NPV, IRR and σ calculations, the net cash flow is required. The realistic scenario is represented by a discounted net cash flow calculated in an original consolidated budget. The elaboration of the optimistic and pessimistic scenario estimations is an expert's procedure. For each scenario, the probabilities of occurrence are also required.

Step 2. Calculation the NPV of cluster alternatives

The NPV value for k-th scenario is calculated by the formula:

$$\mathrm{NPV}_{i,k} = \left(\mathrm{NCF}_{i,k} - K_{i,k}^{0}\right)p_{i,k},$$

where:

k is the index of scenario;

$\mathrm{NCF}_{i,k}$ is the net cash flow of i-th cluster alternative for k-th scenario;

$K_{i,k}^{0}$ is the amount of initial investments (if available)of i-th cluster alternative for k-th scenario;

$p_{i,k}$ is the probability of i-th cluster alternative for realization of scenario k.

Step 3. Calculation the IRR of the cluster alternatives

In IRR calculation, the integrated average NPV is used:

$$\mathrm{NPV}_i^{\mathrm{Integrated}} = \sum_{k=1}^{q} \mathrm{NPV}_{i,k} \Big/ k.$$

IRR of i-th cluster alternative is calculated by the formula:

$$\mathrm{IRR}_i = r_1 + (r_2 - r_1)\frac{\mathrm{NPV}_{i_{r1}}^{\mathrm{Integrated}}}{\mathrm{NPV}_{i_{r1}}^{\mathrm{Integrated}} - \mathrm{NPV}_{i_{r2}}^{\mathrm{Integrated}}}$$

where:

r_1 is a rate of return where $\text{NPV}_{i_{r1}}^{\text{Integrated}}$ is a positive value;
r_2 is a rate of return where $\text{NPV}_{i_{r2}}^{\text{Integrated}}$ is a negative value.

Step 4. Calculation of standard deviation σ of cluster alternatives
For calculation of $\sigma$of the i-th cluster alternative, the next formulas are used:

$$\sigma_i = \sqrt{\sum_{k=1}^{q} \left(\text{NCF}_{i,k} - \overline{\text{NCF}_k}\right)^2 . p_k};$$

$$\overline{\text{NCF}_k} = \sum_{k=1}^{q} \text{NCF}_k . p_k;$$

$$\sum_{k=1}^{n} p_k = 1.$$

The following formula is used when equal weights are assigned to estimated scenarios (the Laplace principle):

$$\sigma^{\text{L}}{}_i = \sqrt{\sum_{k=1}^{q} \left(\text{NCF}_{i,k} - \overline{\text{NCF}_k}\right)^2 . q^{-1}};$$

$$p^{\text{L}} = \frac{1}{q}.$$

Step 5. Cluster alternative selection
The selection procedure is based on LINCOM and MAXIMIN algorithms [9].

The consolidated budgets of the clusters represent alternatives evaluated by BSC criteria. The set of alternatives is denoted by $A\ \forall i(A_i \in A)$. A_i are evaluated by numerical functions. The output data are written as a matrix $\|x_{ij}\|$, where i is the number of alternatives (row number), j is the number of criteria (column number). The number x_{ij} is the evaluation of i-th alternative by j-th criterion. It is assumed that the number j of private criteria is finite and the last criterion is denoted by K_j. The algorithms require that the numbers x_{ij} and weighting coefficients $\lambda_j\ \forall j(\lambda_j > 0)$ and $\sum_{j=1}^{n} \lambda_j = 1$ to be known.

MAXIMIN method requires normalization of x_{ij}. For each particular criterion, the only acceptable assessment is the minimum score. The algorithm ranks as a top alternative the one, which worst score, is the maximal one. The evaluation of alternative A_i is $t_i = \max_j(\lambda_j, x_{ij})$, or $t_i^{\text{L}} = \max_j(\lambda^{\text{L}}, x_{ij})$, where $\lambda^{\text{L}} = 1/n$, meaning that the principle of indifference (Laplace) (also called principle of insufficient reason) is applied. The method is based on the guaranteed result, but uses a small part of information contained in the matrix $\|x_{ij}\|$. This is considered as a limitation of the model application.

LINCOM method is used when the set of numeric functions (private criteria) are normalized and aligned to the maximizing criteria. The evaluation of the alternative A_i is $s_i = \sum_j \lambda_j x_{ij}$ or $s_i^{\text{L}} = \sum_j \lambda^{\text{L}} x_{ij}$. The algorithm ranks the alternatives in a decreasing order of s_i.

The analysis of ranks of cluster alternatives, as obtained from IP Model and IP Risk Model, may show two possible situations:

Ranks of both models show the same cluster alterative on a top position. The procedure continues with cluster verification;

Ranks show different cluster alternatives on a top position. The procedure again continues with verification, but is applied to agents, included in all cluster alternatives, top ranked by both models.

3.4. The cluster design verification

The final selection of the cluster design is decided after verification of the performance of the included agents for some post-integration period. The aim is to confirm that all agents have maintained or improved their performance. Then it is assumed that the integration would achieve the main goal – improving the sustainable competitiveness of the agents in the cluster. In this case the alternative is considered as final. If the verification shows no improvement in agents' performance, the cluster design process should be repeated fully or partly (depending on the DM).

In order to verify agents' performance, the DM determines a list of economic indicators. It is advisable the use of indicators, able to adequately assess sustainable competitiveness and general status of the agents. Performance verification is based on forecast data for some future period, specified by the DM. The information sources are: consolidated budget of current cluster structure, individual estimated budgets, agents' balances and expert forecast evaluation.

In case that the values of an analyzed indicator show improvement or at least retention during the post-integration period for all agents, the cluster alternative is assumed to be finally selected. In case the analysis shows a decrease in the indicator values for at least one agent of the cluster, the selection procedure returns to some of its initial stages. In case of positive verification for two or more clusters, it is advisable to select the one with a better risk performance.

4. Numerical example

Cluster selection and design are experimented over the following input data:

Cluster economic sector – canning industry.

Technological network type – mixed type.

Number of technological network nodes – five.

Number of agents under consideration:

Agents allocations and identifiers:

- Node 1 "Primary Producer" {PP1, PP2, PP3, PP, PP5};
- Node2 "PRocessors" {PR1, PR2, PR3, PR4, PR5, PR6};
- Node3 "PackaGing" {PG1, PG2};
- Node4 "SCientific units" {SC1, SC2};
- Node5 "Trading and marketing" {T1, T2, T3, T4}.

List of criteria for Level of Performance Evaluation (PLE):

- {Profitability =Revenue/ Realization costs};
- {Liquidity=Current assets/Current liabilities};
- {Turnover=Revenue/Current assets};
- {Indebtedness=Long term debt/Equity};
- {Efficiency=Net profit/Personnel};
- {Investment activity=Investment costs/ Realization expenses};
- {Human resources investments=Training costs/Realization expenditures};
- {Market share (percentage)};
- {Share of regular clients(percentage)};
- {Interest in Integration(yes/no)};
- {Performance=Average wage/ Sales revenues};
- {Efficiency of fixed assets=Net profit/Fixed assets}.

The presented list is optional and open to any suggestions, additions and elaboration depending on specific DM's requirements, aims of clustering or particular industry.

List of criteria for SDP:

- EC:{Investment activity=Investments / Total expenses}, {Interaction with research units (qualitative criterion)}, {Level of technological development (qualitative criterion)}, {Data ware (qualitative criterion)}, {Personal qualification (qualitative criterion)};
- GTC:{Quality of products (qualitative criterion)}, {Market share on basis value}, {Expertise managerial staff (qualitative criterion)}, {Business successfulness= (Net profit / Fixed assets) + (Net profit/ Number of employees)}, {Degree of development prospects clarity (qualitative criterion}.

Agents' "Passports":{fixed assets; capital; other receivables; current liabilities; long-term; costs for implementation; employees; average wage; investment expenditures; training costs; net profit; market share; share of permanent customers; structural integration attitudes}.

BSC criteria: {operations gross profit, fixed assets' profitability, productivity, investment, investments in knowledge, the final product market share, share of regular customers, scientific institutions relations intensity}.

Post-integration performance verification criteria: {efficiency, operations' efficiency, fixed assets efficiency}.

4.1. The rankings of PLE-SDP Model

a. Promethee II PLEranks by TN nodes:

Node 1: PP3 (0.6666); PP5 (0.25); PP1 (0.1667); PP6 (0.0833); PP2 (–0.1667); PP4 (–1.0833).

Node 2: PR6 (1.3333); PR5 (0.75); PR4 (0.1667); PR2 (–0.25); PR3 (–1); PR1 (–1.2499).

Node 3: PG2 (0.6666); PG1 (–0.6666)

Node 4: SC2 (0.3333); SC1 (–0.3333).

Node 5: T1 (0.5833); T2 (0.25); T3 (–0.25); T4 (–0.3333).

b. Promethee II PLEranking of agents for the entire TN:

SC2 (6.2309); PG2 (5.3067); PP1 (4.5594); PP6 (3.1371); PP3 (2.9566); T1 (1.6931); PR6 (1.675); PR5 (1.0902); PR4 (0.4332); PP5 (0.3032).
T3 (–0.148); PR2 (–1.3357); PP2 (–1.6425); T2 (–1.6426); PP4 (–1.953); PR1 (–3.2671); PG1 (–3.4078); PR3 (–3.7544); SC1 (–4.1695); T4 (–5.6063).

In this example, the assumed cut-off value is zero. The selected agents with positive PLE values are the following:

{SC2>PG2>PP1>PP6>PP3>T1>PR6>PR5>PR4>PP5}

This ranking is compared to rankings by TM nodes:

Node 1: {PP3 > PP5 > PP1 > PP6};
Node 2: {PR6 > PR5 > PR4};
Node 3: {PG2};
Node 4: {SC2};
Node 5: {T1 >T2}.

The list of economic agents selected for "polygon" analysis is:

{PP1, PP3, PP5, PP6, PR4, PR5, PR6, PG2, SC2 and T1}.

The agents positioning on the "polygon" is shown on Fig. 3.

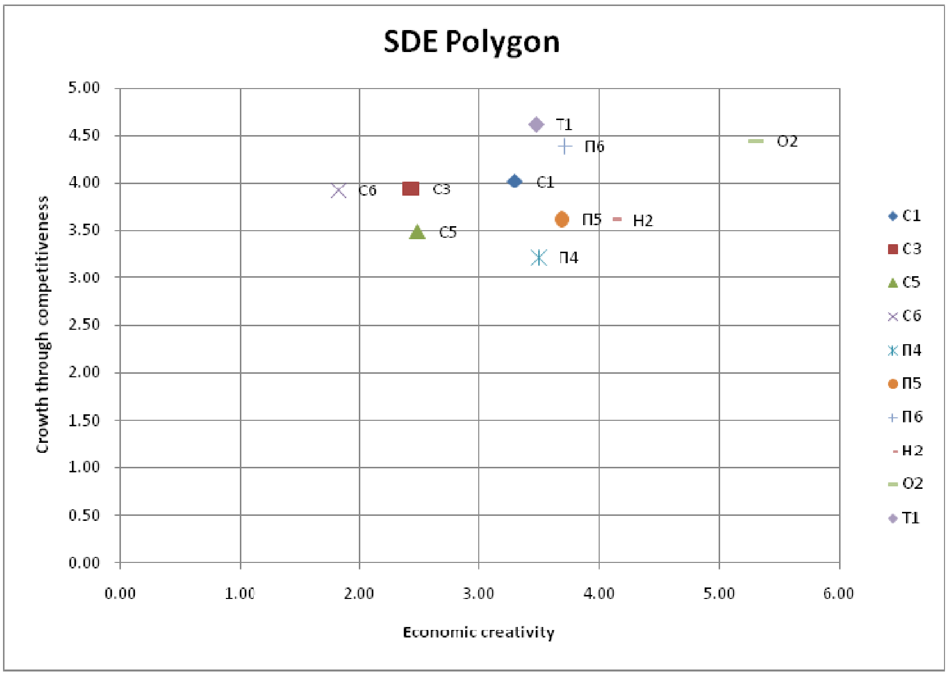

Fig. 3. Sustainable development polygon

With the exception of agent PG2, the analyzed agents could be considered as forming, a group allocated on TN as follows: "Primary producer" {PP1, PP3, PP5}, "Processors" {PR4, PR5, and PR6}, "Packaging" {empty}, "Scientific units" {SC2}, "Trading and marketing" {T1}.

The group is not sufficient for completing the TN. The “Packaging” node is needed to be compensated either by establishing of a new agent or by outsourcing. These two possibilities allow forming of two alternatives for cluster design:

Alternative 1. Cluster with four nodes: “Primary producer”, “Processors”, “Scientific units” and “Trading and marketing”. The node “Packaging” is compensated by outsourcing.

Alternative 2. Cluster with five nodes: “Primary producer”, “Processors”, “Scientific units”, “Trading and marketing” and “Packaging” filled by a newly established agent.

4.2. The estimations and rankings of IP Model

Activities planning for both alternatives are set in Table 1.

Table 1

Activities planning	Integration periods									
	Alternative 1					Alternative 2				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Management	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Establishment of missing elements								**X**	**X**	
Intermediation	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Collective supplies		**X**	**X**	**X**	**X**		**X**	**X**	**X**	**X**
Information system development			**X**	**X**	**X**			**X**	**X**	**X**
Investments in human recourses	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Advertising	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**

The aggregated esimations of net cash flows, discounted net cash flows and accumulated net cash flows are presented in Table 2.

Table 2

Alternative	Flows	Integration periods					
		1	2	3	4	5	Total
Alternative 1	Net cash flows	–91.24	89.43	119.02	181.88	270.11	569.20
	Discounted net cash flows	–86.07	79.59	99.94	144.06	201.84	439.36
	Accumulated net cash flows	–86.07	–6.48	93.45	237.52	439.36	
Alternative 2	Net cash flows	–85.24	95.43	27.03	38.88	319.13	395.24
	Discounted net cash flows	–80.41	84.94	22.70	30.80	238.47	296.49
	Accumulated net cash flows	–80.41	4.52	27.22	58.02	296.49	

The budgets of both cluster altertatives are considered to be acceptable.

BSC criteria assesment is presented in Table 3.

Table 3

BSC criteria	Alternative 1	Alternative 2
Operations gross profit	1.53	1.17
Fixed assets' profitability	4.52	0.64
Productivity	35.14	15.76
Investments	0.12	0.27
Investments in knowledge	0.19	0.21
Final product market share	0.30	0.30
Share of regular customers	0.35	0.35
Scientific institutions relations intensity	10.00	10.00

IP Model output: Promethee II ranking of cluster alternatives: {Alternative 1 > Alternative 2}. This ranking does not include risk assessment.

4.3. The estimations and rankings of IP Risk Model

Resulting outputs of IP Risk Model are presented in Table 4. NPV and IRR values are used as maximizing criteria. The σ value is a minimizing criterion.

Table 4

Normalized values	NPV	IRR	$1/\sigma$	$1/\sigma^L$	t_i	s_i	t_i^L	s_i^L
Alternative 1	1.00	1.00	0.64	0.60	0.81	0.12	0.81	0.15
Alternative 2	0.67	0.27	1.00	1.00	0.76	0.05	0.74	0.07
λ_j	0.3	0.2	0.3	0.2				
λ^L	0.25	0.25	0.25	0.25				

IP Risk – model ranking:

{Alternative 1 > Alternative 2}.

Top ranked is Alternative 1. The cluster is supposed to outsource the "Packaging" activity. Final selection is determined by post-integration economic agents' verification.

4.4. Post integration period verification of economic agents

The list of agents {PP1, PP3, PP5, PR4, PR5, PR6, SC2, T1} is verified by the following criteria: {efficiency, operations' efficiency, fixed assets efficiency}. The estimations are based on five-years post-integration period. The results are plotted on Figs 4, 5 and 6.

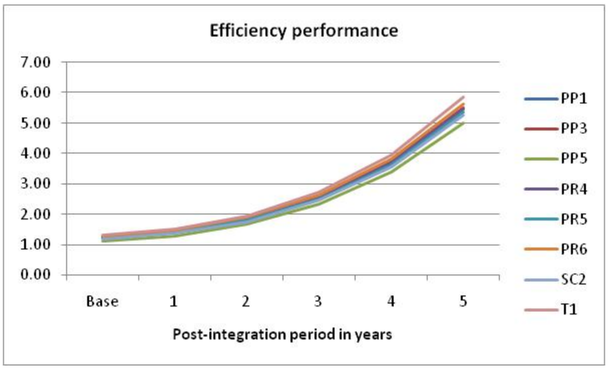

Fig. 4

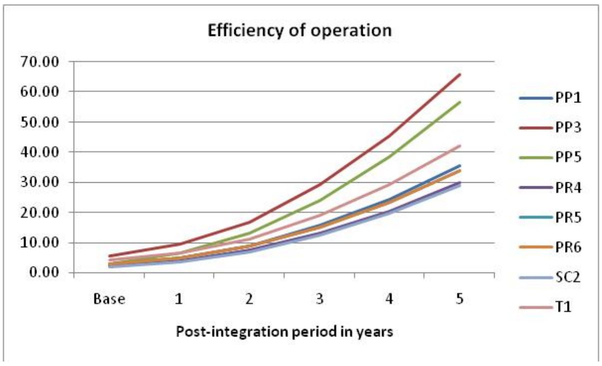

Fig. 5

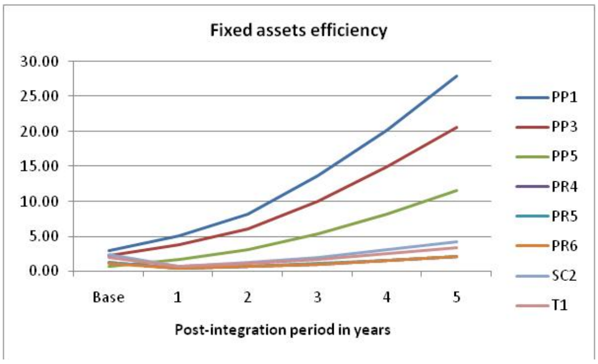

Fig. 6

During the post-integration period of five years, the economic agents in the selected cluster show gradual increase of the verified criteria.This allows assuming that Alternative 1 would be beneficial for included agents. In this case, an incomplete technological network is not an obstacle to develop a synergy effect by clustering.

5. Conclusion

The paper presents three multi-criteria models for economic cluster design. Each model uses the results of the previous one. They allow step-by-step evaluation, ranking and selection of groups of economic agents and alternatives of their allocation over a predefined technological network. The description shows the initial data preparation, problems formalization, constraints and criteria determination and the solutions associated with the cluster design. The selections are based on the resulting ranking of the agents and cluster alternatives. The evaluation of the performance level and sustainable development positioning of the agents give ranks for the initial list of candidates' selection. The investment preference and risk evaluations give the alternative cluster designs ranking. The example demonstrates the data definition, models output rankings, analysis and verification of the final decision.

The problem of cluster design may be formulated in different ways. The approach proposed shows just one of the possible scenarios. Most of the used evaluations are recommended frames rather than single-size standards. The specifications and adjustments to each particular clustering depend on the experience, capacity and economic realities in the area of implementation. The development of suitable software solutions based on scenario simulation would improve the accuracy of the predicted variables and solutions. The obtained results allow outlining of several directions for future research. One possible direction is the application of the fuzzy decision theory for investment preference evaluation with respect to the fuzzy characteristics of industrial environment and its impact on economic clusters. Another one is the investigation and evaluation of the synergistic effect developed by clustering in order to functionality and accuracy improvement of the models. The development of appropriate tools for active risk management will improve clusters' post-integration performance.

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