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# Economic Clusters Efficiency Mathematical Evaluation

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**Abstract**

In this study we investigate the properties the concept of innovative clusters. We discuss the problems of cluster efficiency evaluation. The work ends with a methodological proposal of formal mathematical model for cluster evaluation, based on probability hypothesis verification.

Our result confirms the previously used propositions.

**Keywords:** Cluster Evaluation, Formal Mathematical Models, Hypothesis Verification.

## 1. Introduction

Bergman E. M. in [1] has surveyed the contemporary approaches to the cluster life-cycle. It is worth noticing that in straight majority of approaches for cluster stages are very rare and in addition the final stage is the stage referring to the stagnation (petrifaction, stagnating, exhaustion etc.). Meanwhile the observations of the mature clusters in the USA and Europe show that the maturity stage may lead for developmental transformation on condition of overcoming the crisis of identity. Therefore the analysis of the cluster life-cycle that takes into consideration crises occurring in particular phases of development is a useful tool for the rationalization of clustering process.

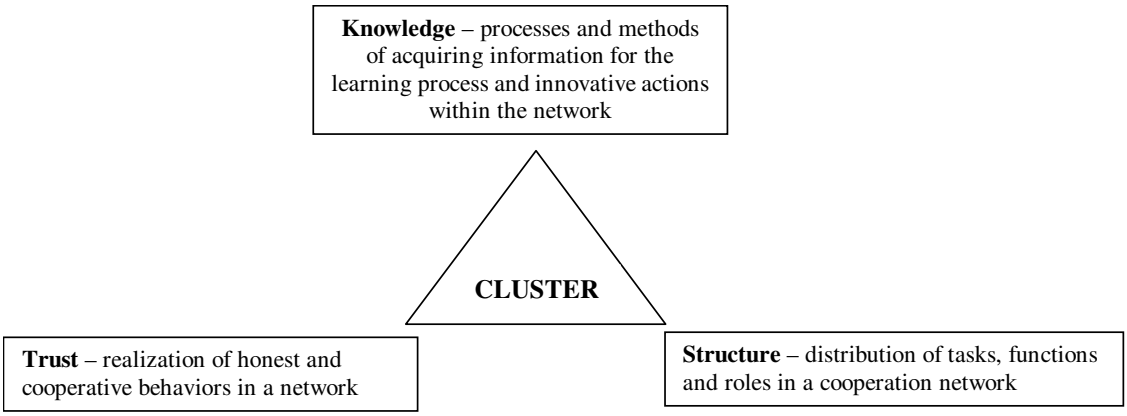
## 2. Main Approaches

The proposals of clusters creation stages were put forward by many researchers. Taking into consideration the basic stages of the process of cluster development and the results of study and empirical research (conducted in Poland) the model of the cluster lifecycle has been proposed, described by the authors of the paper in [2]. The model has the following stages:

I. *Identification* – a group of regional entitles (enterprises, scientific and administration units) identify a possibility of cooperation;
II. *Initiative* – within the group initiative persons identify specialization and knowledge to obtain/create;
III. *Innovative development* – development of cluster based on carried project by cluster member or by cooperation and existing business networks within the cluster;
IV. *Maturity* – during the stage of maturity cluster develops its structures and social responsibility, however, with decreasing its primary dynamics;
V. *Transformation* – new ideas are the beginning of new networks and structures which results new cluster.

The I-st identification stage – identification of business organizations, support units, research and development centers, required in order to verify cooperation possibilities. This is the time for meetings with initiators and experts, presentation of benefits from cooperation, encouraging the assessment of own competences versus the competition and potential cooperation partners. This is the planning stage of a potential cluster. The main objective of this stage is to define the type of partners for potential cooperation in a cluster, identifying the domains activities, network of connections, internal functions and operational systems as well as initial planning of the possible conditions for mutual cooperation. The choice of the form of cooperation (including cluster) generates a range of questions and problems presented by employed subjects, which triggers the *crisis of initiative*.

**Figure 1:** Principal mechanisms of cluster development




Regardless of it is the top-down or the bottom-up initiative, the divergence of expectations and emerging of new organizations requires specification of an idea for cooperation. The lack of common goals, links (vertical and horizontal) and experiences of cooperation, the smaller possibilities of success of cooperation we have in cluster. Some participants adopt skeptical attitude towards cooperation, the opportunistic approaches are dominant.

In the II-nd stage occurs the crisis of initiative, the solution of the *crisis of initiative* is based on the development by specialization – it is the first period of development that may last for several weeks or months. The first problems, topics and specializations appear, around which cooperation may be focused. The potential of the group is still dispersed but also encouraged to further actions aiming at creating partnership relations. This is a cluster organization stage, which is the most important because it shapes and conditions the form of the initiative. The following activities are of key importance:

- Mobilizing potential partners to share information and realize the necessity to recognize and define the potential, common business objective,
- Defining the common vision of development, mission and a strategic goal,
- Making the cluster partners undertake formal obligations including: mobilizing the realization of formal obligations at the institutional level, shaping the potential of social capital and increasing such potential).

Generation of common ideas breeds many doubts connected with mutual trust regarding the reliability and anticipation of partners' actions – the crisis of trust emerges. The employed subjects express their fears regarding the scope of engagement and the benefits resulting from it. The intellectual property protection is placed under a question mark.

The social relation during the III stage *of innovative development* leads to problems with trust among the cluster members. The solution of the crisis of trust is based on the *development by social capital*. The basic activity is to support a communication in a network based on responsibility and honesty of cluster's members. A result of that process is working out the commonly shared values of special significance that is attributed to them by cluster's participants[3]. Thanks to it the emotional engagement of cluster's participants in the processes of cooperation is obtained.

On this stage the potential and needs of the involved organizations have been initially recognized and realization of the first joint projects commenced. The level of trust between organizations increases, which results in the realization of joint projects related to the basic, most frequently shown areas of cooperation: e.g. joint advertising, common product package development strategy, establishing a network coordinating organization. It should be assumed, that the established cluster would develop through both an increase in market activity and individual, innovative development of each of the cluster participants as well as through adding new entities, which bring new competences required in the development process. This process also requires supervision and monitoring on the part of the cluster initiators until the stage of the cluster's independence, i.e. the maturity stage.

The growth of trust generates the needs of bigger or smaller formalization of cluster's activities and the development of new competences that cause very often the *crisis of structure.* This crisis concerns not only the determination of organization form but first of all the problems connected with development of new competences that are indispensable for continuous initiating, animating, coordinating and controlling the network's activity (network competences). The development of knowledge and trust generates the need of development of new competences and links between the cluster's members.

In the model in IV stage *(maturity)* occurs crisis of structure. The solution of the crisis of structure is based on the *development by cluster governance* – finding out the path of development is based on working out of new ways of keeping the strategic advantage of a cluster. Cluster governance is about the intended, collective actions of cluster actors to upgrade a cluster in order to build and maintain a sustainable competitive advantage as a cluster. In our view, cluster governance is specifically aimed at facilitating and improving processes of innovation. In other words, it is aimed at the main strategic issue facing the actors involved in processes of innovation in a cluster. It is concerned with the question 'how the value chain itself is moving'; how it can be reconfigured and where possible new synergies can be found [3].

On this stage positive external effects increase and relations between the cluster participants are not only connected with realization of the planned joint projects but also with current operations. The increasing trust level enables the creation of new products, which unite the cluster participants' potentials, building a common image, introducing standards and internal certification systems, etc., as well as initiatives, for which the competences of individual organizations are not sufficient. This stage requires achieving operational excellence, independent diagnosis of market trends, preparing strategies and increasing competences in strategic management. The length of the stage depends on the above mentioned factors as well as changes in the markets. Frequently, the cluster maturity stage requires improvement of technology and rationalization of the existing structures, processes and procedures as well as reformulation or reorientation of the strategy (it may be necessary to use professional consultants services).

The process of maturing of cluster is connected with exhaustion of development possibilities in given shape of cluster. The participants express their dissatisfaction resulting from the lack of new ideas, partners, new concepts. The *crisis of identity* emerges – the fall of activity and discouragement for further cooperation occurs.

The last stage of our model – V-th *Transformation stage* is connected with the crisis of identity. This crisis could be resolved by *open innovation* [4]. Innovative cluster as an innovative system is based mainly on knowledge transfer and is initiated through direct contacts between people. A high level of knowledge equals a high level of trust. Thanks to the rationalization of these mechanisms, supported by efficient coordination, we develop social capital, which is a driving wheel of the shaped cluster. Establishing relationships of non-market character favors exchange of information and knowledge by, for example, informal cooperation and assistance in managing business activities. However, there is a risk that the lack of transformation activities may cause the gradual decline of a cluster. The research of [5] results is that it often becomes necessary in the maturity stage to separate individual companies from an overgrown cluster, which could create their own clusters. Such separated

and independent clusters often function in a continuous process of cooperation and competition with the main units of the "origin cluster".

In the work by [5] after in [6-9] the formal model for evaluating the efficiency of a cluster was proposed. It was determined that there is the number of independent and dependent variables for such type of analysis. It was assumed that the main independent variables are to be:

- University knowledge – R&D expenditures in science and technology;
- University faculty capital – Number of faculty members in science and technology fields;
- University human capital – Number of degrees awarded in science and technology fields (bachelors, masters, doctors' degrees).

It was also assumed that the main dependent variable was:

- Number of technology-based firms in a cluster in each of principal technology fields for the park.

So, three main research hypotheses were included in our investigation:

- **H1:** There is a correlation between the strength of the university's research capacity in specific technology fields to the technical needs of firms located in the associated university research park. The variable research capacity referred to university's R&D [5].
- **H2:** There is a correlation between the number of faculty in specific technology fields at the university and the technical needs of firms located in the associated university research park. The variable human capacity refers to the total number of scientists in research and technology fields. Companies obtain knowledge by establishing relations with university scientists.
- **H3:** There is a correlation between the number of graduating students at the university and the technical needs of firms located in the associated university research park.

The variable of labor pool refers total number of degrees granted at university in science and technology fields.

Statistical analysis is the principal instrument for further research. The statistical procedures ought to be done into two steps. In the **first** one the null hypotheses must be formulated for each of the research hypotheses. The following null hypotheses can be formulated:

- **NH1**. There is no correlation between the strength of the university's research capacity in specific technology fields to the technical needs of firms located in the associated university research park.
- **NH2.** There is no correlation between the number of faculty in specific technology fields at the university and the technical needs of firms located in the associated university research park.
- **NH3.** There is no correlation between the number of graduating students at the university and the technical needs of firms located in the associated university research park.

We ought to choose the alpha level for statistical tests. It seems reasonable to choose 0.05; - it indicates that null hypotheses are rejected if the sample outcome was among the results that occurred no more than 5 percent. The statistical test is assumed to be the two-tailed test; the region of rejection is located at both left and right tails. The decision to locate the region of rejection in two tails must be based on the hypotheses and the size of the sample. Two tails test are usually more stringent than one tailed test. It indicates that a result which is significant in two tailed test is also significant in a one tailed test (but not vice versa).

At the **second** step descriptive analysis ought to be conducted. The descriptive analysis for variables will include percentages. It is assumed that correlation analysis will be performed using parametric test and Pearson product-moment correlation coefficient. Data ought to be normalized to determine the strength of each university using three variables of research capacity, human capital and specialized labor pool across major technological fields.

Still, all factors considered in the model are factors of internal to the enterprise nature. Our proposal consists in extending its frames by including different external parameters. In particular, we propose to consider the state-of-the-art of the legislative base in this matter and the grade of mutual trust between the economic agents.

The innovation risk is the reason by which many large companies don't realize broad-scale investments: they need at least some guarantee of success. So, from the practical point of view the application of research to the industrial process became the niche of small innovative firms.

So, the model described can be extended as follows taking into consideration the trust factor analyzed before:

- **H4:** There is a correlation between the grade of mutual trust between the economic agents and the technical needs of firms located in the associated university research park.
- **H5:** There is a correlation between the grade of legislative base development and the technical needs of firms located in the associated university research park.

The following null hypotheses can be formulated:

- **NH4.** There is no correlation between the grade of mutual trust between the economic agents and the technical needs of firms located in the associated university research park.
- **NH5.** There is no correlation between the grade of legislative base development and the technical needs of firms located in the associated university research park.

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