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MODELLING INNOVATIVE LOGISTIC CLUSTERS FOR REINFORCING INTERNATIONAL ECONOMIC INTEGRATION USING AN EXAMPLE OF A METALLURGICAL COMPLEX

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Abstract: The aim of the article is to present the proposed model of an international innovative logistics cluster, which aims to stimulate the renewal of the economic potential of all interested partners with a focus on the metallurgy. Experts analyse ongoing changes and trends that have affected business and logistics processes and define certain trends that could lead to an improvement in the situation, such as the use of a "Cluster strategy". The subject of the research is the analysis of the cooperation between international scientific organizations, research centers and companies within the proposed cluster. A model of the structure of the cluster was created, which will make it possible to monitor global processes in the field of economics and logistics. A simulation of the production of a new product was performed to verify the proposed cluster's expected effects. Therefore, a model was used to determine the value of the company to capture complex links. This model is based on Method DCF using structural analysis principles to objectively evaluate the influence of factors affecting the change of cost potential in the immediate vicinity of the enterprise. During the verification of specific data, the considered project's value was quantified, and obtained results showed that synergy effects could be expected. The verification results show that the interaction and cooperation between universities, research centers, and industrial enterprises at the international level can be made more efficient with an emphasis on effective and lasting cooperation in the field of innovation and technology transfer.

1 Introduction

The characteristic feature of the development of a socioeconomic strategy is using a "Cluster strategy." Prof. M. Porter introduced the cluster definition. The clusters were initially based on a given area's competitive advantage, and the corresponding cluster participants were concentrated exclusively on a geographical basis. In his research, Porter emphasized that it is necessary to combine market efforts and concentration, allowing the given companies to achieve great results [1].

Using a sample of 310 cluster companies in Zhejiang, we find that a cluster company will increase its propensity for more geographic cross-border searches than local searches under competitive pressure [1].

Geographic clusters have been recently displaced by a promising new type of clusters - innovative clusters.

Innovative clusters are particularly typical for industrially developed countries, such as the USA, Canada, Italy, Germany, Czech Republic, and others. However, they are also starting to appear in developing countries, such as India, Brazil, or Russia. This type of the cluster differs because the companies that form a part of the given association do not necessarily have to be located in the adjoining areas. The objectives of such associations are mainly directed towards improving economic competitiveness, developing the given field and technologies, increasing economic activities in the given area, preserving export of products and services, reducing operating expenses and product cost, or securing and preparing highly qualified specialists [3],4].

An analysis of the available works related to the research of "Cluster models" shows that large, medium, and small companies utilize the stated models based on the following basic principles [5]:

- improving technologies and production processes when introducing innovations,
- interaction with educational and scientific and research institutions,
- professional growth of company employees,
- establishment of a unified legal, information, technological, innovative, and financial environment,
- creation of specific general (unified) company business policies and strategies in international economic activities.

The cluster demonstrates that which for some people, at first, may seem paradoxical: that these companies that compete can cooperate if it is a favourable cooperation based on the win-win principle [6].

Cluster policies provide system integration, based on innovations of large, medium, and small companies and other organizations, such as universities and science-research centers. The synergy effect of all partners' activities in the cluster determines the stable, competitive socioeconomic development of the selected industrial fields and territories at the regional and national level and the international level.

The empirical results show that industrial clusters' development attracts and promotes a large number of intermediary service-oriented organizations and institutions providing research and development and technical support, providing an innovative incubation platform. The government's policy should be biased towards establishing an effective mechanism for the interaction between scientific and technological innovation and industrial clusters to achieve a good situation of the interaction between the economy and science and technology [7].

When creating industrial clusters, special attention should be paid to implementing the cluster strategy, interaction among partners, implementing the innovation and investment policies, and optimizing the management of business processes and logistics. This task can be achieved by the modelling of the proposed cluster [8].

The COVID-19 pandemic has led to a worldwide economic crisis. According to the prognosis of the World Bank, it is expected that the gross domestic product (GDP) will significantly drop in 2020 due to the COVID-19 pandemic (Figure 1). Apart from that, it is expected that growth rate will be reduced by more than 13% in 2020 (Figure 2). Due to the blockades related to COVID-19, introduced in many countries, the largest production countries' production sector completely stopped. The industrial production in these countries is linked to the global trading network, and the COVID-19 pandemic led to outages in the supplier-customer chains. The container transport volume significantly dropped due to the reduction of world trade (Figure 3) [9,10].

Figure 1 Dynamics of global growth

Figure 2 Dynamics of trade growth

Figure 3 Trends in Container Shipping and Export Orders

Experts analysed changes and trends from the past that have affected trade and logistic processes and define specific trends that could improve the situation. They include dumping, developing partnerships, cooperation, combining services, implementing the latest I.T. technologies, developing services and partnership contracts, preparing strategies, and post-crisis plans inside the companies [11]. In this work, the attention is focused on specific trends that include the development of cooperation and partnerships in industrial companies, universities, and R&D centers and the introduction of I.T. technologies. Companies are starting to cooperate, develop unique complex offers for customers, and, as a result of that, enforce their joint positions by combining their services. Optimization and digitalization in the area of I.T. technologies have been a discussed topic for a long time. During the crisis related to the COVID-19 pandemic, this trend has become especially important [11].

As the novel COVID-19 pandemic unfolds, it has become necessary to reduce face-to-face contacts, leading to lesser network synergy being produced in an Innovation Cluster. The transformation into a Digital Innovation Cluster, which is less affected by physical distance, but can still maintain the networks' effectiveness, can be the key strategy for the future Innovation Cluster [12].

2 Methodology

The cluster theory and innovation logistic cluster's reference model consists of four main blocks, specifically a cluster core, service facilities, and additional and auxiliary objects. These blocks must ensure an innovative character of all cluster members [13]. That is why it is necessary during the first stage of the cluster establishment to determine all blocks' main potential participants.

2.1 Cluster core

The proposal envisions that the cluster core will be the Mining University - Technical University of Ostrava. The university is a concentrated source of many skills, bonds, relations, and partnerships. The university cooperates with the public as well as private companies. It actively conducts international education and project engineering activities, and it is a source of highly qualified workers. It also has its center of commercial technologies and sufficient resources. That is why it seems to be a natural choice to select it as the proposal's central core and leader.

2.2 Service facilities

Service facilities include communication networks, warehouses, manufacturers of machines and devices, small and medium companies in metallurgy, and energy suppliers. Participants of this block can also be international companies and entities.

2.3 Additional objects

Additional objects are companies and organizations of an educational and innovative orientation and other business partners who secure investments and introduce new technologies. This block providing a synergy effect, and the integration of the entire cluster is fundamental. The industrial metallurgy field is strongly developed in the Czech Republic as well as in Russia. That is why Russian universities were also included in the cluster, mainly to conduct employee educational exchanges to generate and spread knowledge. The main participants thus will be companies and research organizations from the metallurgic complex.

2.4 Auxiliary objects

Auxiliary objects are optional outsourcing objects. Although this block is optional, the cluster theory allows for significant reductions of the cost of outsourcing of selected processes since incorporation in a cluster creates long-term partnerships, which operate under better financial conditions than individual orders.

Some of the auxiliary objects include customs proceedings and inspections, wholesale companies, insurance companies, security agencies, audit companies, environmental centers, and others.

Apart from that, it is recommended to establish an advisory body for securing interaction between the involved participants and the state and district authorities in the form of a coordination council for strategic planning and for attracting investments for the cluster development. Figure 4 shows the graphic model of the organizational and functional structure of the proposed cluster.

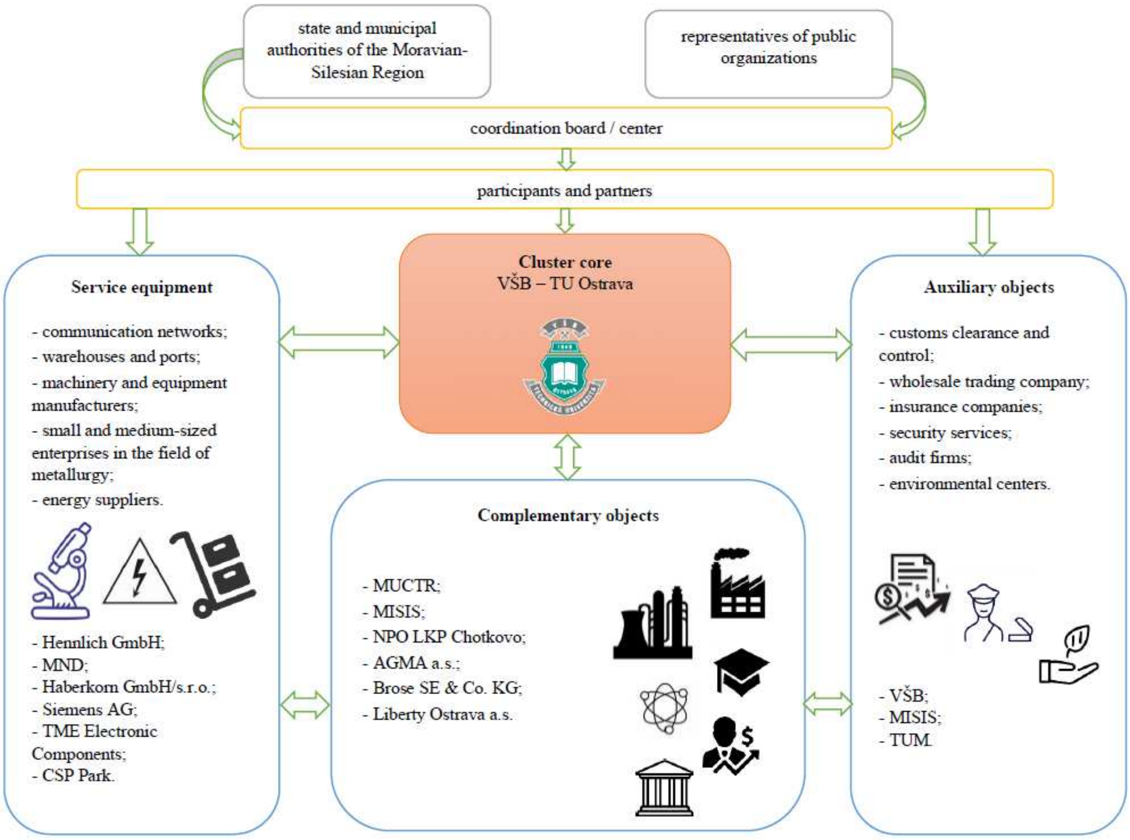

Figure 4 Graphic model of the organizational and functional structure of the proposed cluster

A model of the business processes and management needs to be prepared for the cluster's successful operation and development. The proposed information model of the fundamental business processes of the cluster is shown in Figure 5.

The preparation of the model of the proposed cluster's primary business processes revealed a complicated managerial structure. It is necessary to use an instrument to administer information and I.T. technologies to ensure the efficient operation of such complex systems. This model requires computer modelling with the objective of creating a unified information space. The expected consequences of using the proposed model of the integrated logistic cluster stated in Table 1 were analysed to define and assess the economic effects/impacts of the proposed cluster.

It generally applies that the most crucial effect during the early stages of the cluster development is represented by cost reduction and social effect.

An example of an industrial production-research cluster in the metallurgical area was used to verify the proposed cluster's expected effects. The experimental task was to prepare a new, antifriction enamel coating of the defined specifications for use in the aviation field - helicopters. During the production of the stated final product, the key role, i.e. antifriction enamel coating, is played by the chemistry, technology, and metallurgy fields [14].

The analysis was focused on the development of innovative technology at work in the association - enterprise for the production of innovative paints and varnishes Chotkovo (NPO LKP Chotkovo), MUCTR and "Institute for High Purity Substances and Reagents" (part of the Kurchatova Nuclear Research Center) and an extensive economic analysis, which also confirmed the effectiveness of the cooperation of selected entities - the company, MUCTR and the scientific research center "Kurchatova Nuclear Research Center".

A complex and structured production distinguishes the clusters in the industrial sector. That is why it is necessary to have a tool that will make it possible to capture and monitor these complex relations. A tool is needed for calculating production, prices, wages, expenses, etc. in individual parts of the Cluster. Semi-finished products are exchanged among these Cluster parts (internal and external) due to the created relations. Structural models appear to represent a suitable tool that has all attributes for capturing these required relations.

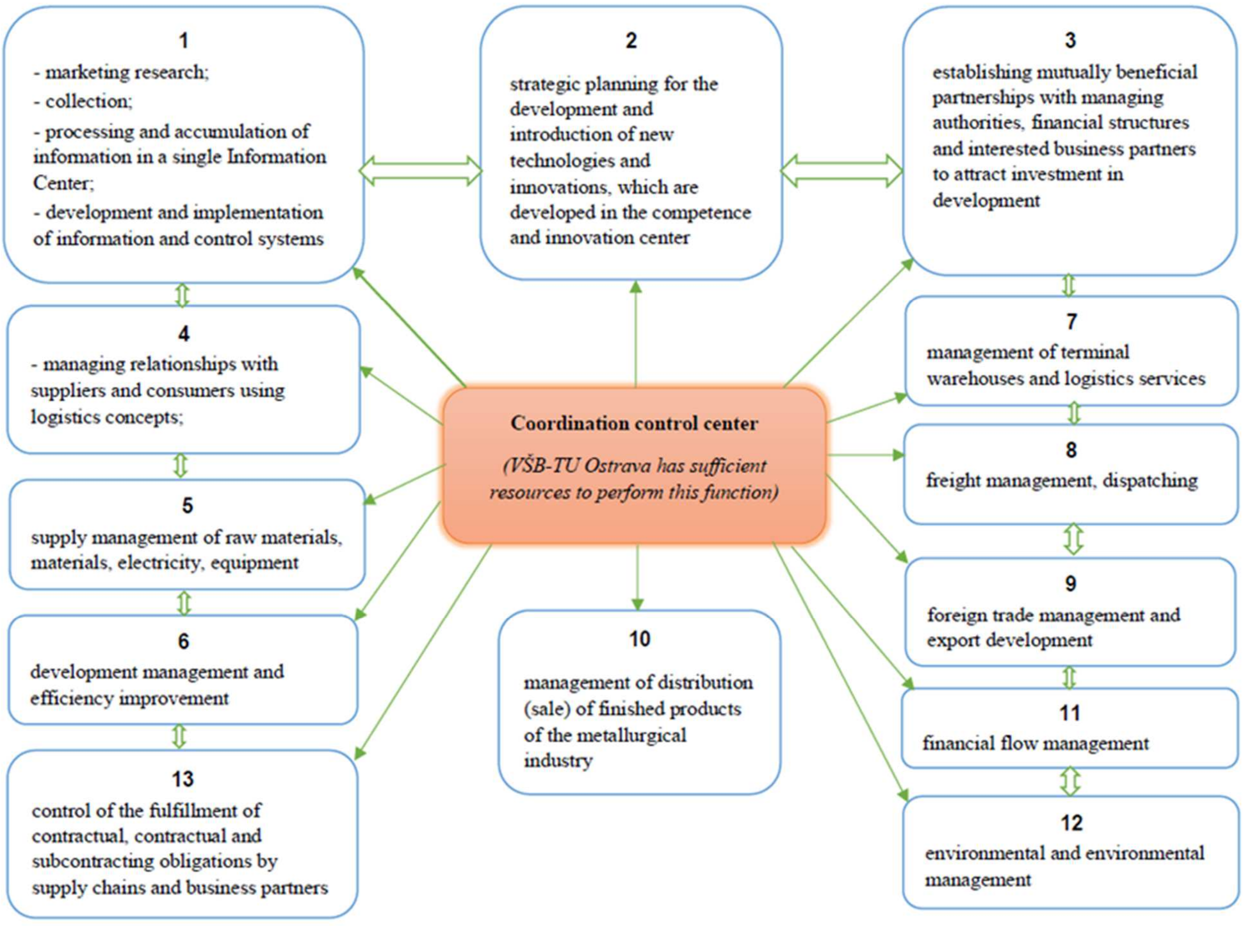

Figure 5 Proposed information model of the fundamental business processes of the cluster

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Table 1 Economic effects/impacts of the proposed cluster

Model consequence	**Effect**
Improving the quality of the logistic integration of the participants of the supplier chains based on a harmonization of economic relations and the establishment of partnership, mutually beneficial relations.	Increasing the income and profits of the participating companies through the synergy effect, increasing employee qualification.
Reduction of the overall and operation logistic expenses, including cost reduction related to transport and processing time.	
Increasing production of the given products.	
Improving the quality of the logistic services, increasing the number of services.	Improving the quality of the logistic services.
Information and communication reliability, accuracy, and timeliness.	
Securing coordination and interaction of individual transport types and other participants based on the creation of a unified space (4PL provider) and the implementation of the information and control systems.	Increasing profit and GDP growth based on the logistic integration and introduction of innovations.
Increasing profit and GDP growth based on the growing volumes of the given company productions.	
Increasing export of given products.	
Securing advanced reproduction and balanced development of the metallurgical industry.	Social effect.
Creation of new jobs.	

Structural models capture the field-to-field balance inside of the proposed system. Wassily Leontief named these models as an "input – output analysis" [15]. It is a descriptive model, the original objective of which was to display reproduction process relations at the national economic level [16]. Nevertheless, the model has gradually expanded to the company level. A structural model of the Leontief type describes the conditions of an equilibrium between the sources and the needs within the modelled system. A structural model of the Leontief type represents a static linear model of an economic system that quantifies the flow of products, raw materials, energy and other production factors inside of any production-consumption system as well as between such a system and its surroundings during the considered time period.

To simulate the synergy effects of the proposed cluster, part of the structural model for determining the value of a given company was used. The model was created based on the DCF method, using the structural analysis principles for an objective assessment of the impact of the factors that affect the potential cost changes in the immediate proximity of the given company [17]. We use Method DCF (discounted cash flow) for valuation of businesses. This method is considered to be the most accurate model for valuing this type of asset, compared to the other available valuation methods (e. g. capital asset pricing model and economic value added).

The following balance (distribution) equations were used for the calculations [18]:

$$X_i = \sum_{j=1}^{n} x_{ij} + Y_i \qquad i,j = 1,2\ldots,n \tag{1}$$

$$X_i = \sum_{j=1}^{n} x_{ij} + Z_i \qquad i,j = 1,2\ldots,n \tag{2}$$

where:
X_i - total value production of the i^{th} field ($i = 1,2,\ldots,n$),
x_{ij} - total value consumption of the production of the i^{th} field in the j^{th} -field of the given production-consumption system ($i, j=1,2, \ldots, n$),
Y_i - total value of the sales of the i^{th} field ($i = 1,2, \ldots, n$),
n - number of fields of the given (production-consumption) economic system,
Z_i - value of primary operating costs of the i^{th} branch (materials, energy, services, wages).

Based on the marketing, production and financial plans and documents from the operative database, a calculation of the revenues and expenses, income statement and Cash Flow for the planned final products - enamelled coating pursuant to various specification - were simulated for the proposed cluster: Enamel 1, Enamel 2, Enamel 3, Enamel 4 for a period of 10 years. Table 2 – 7 shows examples of the executed simulated calculations.

Table 2 Total value consumption of the production (I. quadrat) and total Y value of the sales (II. quadrat) for time period n

I. quadrant						II. quadrant	
Product	**Enamel 1**	**Enamel 2**	**Enamel 3**	**Enamel 4**	**Other**	**Y**	**Y**
						t	Price [EUR/t]
Enamel 1		0.645	1.121			50,000	516
Enamel 2				1.494		551,000	562
Enamel 3						110,000	694
Enamel 4						32,000	938
Other						31,000	1 000

In the case of Enamel 1, the coefficients of consumption (specific consumption) of Enamel 1 products are defined in Quadrant I, of which 0.645 tons are consumed to produce one ton of Enamel 2 and 1.121 tons to produce one ton of Enamel 3. In Quadrant II, the slingshot is defined as the sales volume of Enamel 1. The same is true for Enamel 2.

On the basis of these data, the total tonnage of production of the individual products listed in Table 3 is then calculated, which ensures both the mutual consumption of these products resulting from the consumption coefficients listed in Table 2 Quadrant I and the volume of sales of these products to external customers listed in Table 2 Quadrant II.

Table 3 Total X value of production for time period n

Product	**Units of measure**	**X**
Enamel 1	t	560,000
Enamel 2	t	599,000
Enamel 3	t	110,000
Enamel 4	t	32,000
Other	t	31,000

Primary operating costs are consumed to produce the products listed in Table 3. Table 4 shows the total *Z* value of primary operating costs, which is based on the sum of material, energy and service costs consumed for the production of individual types of products.

Table 4 Z value of primary operating costs for time period n (Quadrant III)

Operating cost						
Products	**Units of measure**	**Enamel 1**	**Enamel 2**	**Enamel 3**	**Enamel 4**	**Total costs**
Material 1	EUR	0	139,841,122	0	0	139,841,122
Material 2	EUR	122,407,426	0	0	0	122,407,426
Material 3	EUR	61,962,493	0	0	0	61,962,493
Material 4	EUR	- 1,478,484	24,355,123	-2,749,759	-3,444,643	-32,028,068
Material 5	EUR	14,605,328	0	0	0	14,605,328
Material 6	EUR	6,006,962	0	0	0	6,006,962
Material 7	EUR	9,176,473	5,491,777	782,550	204,699	15,655,499
Energy	EUR	19,406,904	17,507,259	3,604,443	196,196	40,714,802
Services	EUR	7,263,520	5,859,950	1,341,450	560,631	15,025,551
Total costs	EUR	239,350,563	144,344,985	2,978,684	-2,483,017	384,191,115

The revenues of the individual products in Table 5 below are based on the values of Table 2 Quadrant II. The operating costs in Table 5 are based on the total costs listed in Table 4. The profit of individual products and the total profit are calculated from the difference between revenues and operating costs.

Table 5 Income statement calculation for time period n

Income statement			
Product	**Revenues**	**Operating Costs**	**Profit**
	EUR	EUR	EUR
Enamel 1	25,800,000	239,350,563	-213,550,563
Enamel 2	309,662,000	144,344,985	165,317,015
Enamel 3	76,340,000	2,978,684	73,361,316
Enamel 4	30,016,000	-2,483,117	32,499,117
Other	31,000,000	0	31,000,000
Total	472,818,000	384,191,115	88,626,885

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At the end of the baseline period's structural model, the profit of the products (Enamel 1 - Enamel 4) and the whole cluster is known. The total profit of individual years then enters as a fundamental parameter for later determination of cash flow.

Table 6 Simulated income statement calculation for time period n + 10 year

Income statement			
Product	**Revenues**	**Operating Costs**	**Profit**
	thous. EUR	thous. EUR	thous. EUR
Enamel 1	0	79,831	-79,831
Enamel 2	13,708	17,032	-3,324
Enamel 3	84,614	212	84,402
Enamel 4	57,152	149	57,003
Total	155,474	97,224	58,250

At the end of the structural model in the period n + 10 years, the result of management of individual products (Enamel 1 - Enamel 4) and the whole cluster is known.

The structural model's dynamization was conducted for the subsequent ten time periods. The dynamization is necessary for determining the income statement of the partial periods. The structure of these structural models of individual time periods is identical to the initial structural model structure for the given time period (n). Modelled inputs for the given time period were applied to these structural models. Their definition is not easy and requires significant knowledge and experience when, for example, determining a realistic development prognosis of the planned inputs. As part of the conducted simulation, the expected price increase at the output amounting to 2.0% and the price increase at the input amounting to 1.0% were used.

Simulated income statement and Cash Flow calculations for time period n to n + 10 years is showed in Table 6. During time period n+1, the revenues dropped as a result of the cooperation within the frame of the Cluster due to internal handovers. The expenses decreased due to the cooperation, sharing knowledge, and using individual partners' technologies within the frame of the cluster.

The resulting cash flow used for valuation is then given by the difference between revenues and costs arising from structural models (profit of partial structural models) and by deducting the change in working capital. The calculations show that there is an increase in Cas Flow in the monitored period of 10 years (n + 1 to n + 10) due to the individual partners' cooperation, knowledge sharing, and use of technologies within the cluster (Table 7).

Table 7 Simulated income statement and Cash Flow calculation for time period n to n+10 years

Period	**n**	**n +1**	**n +2**	**n +3**	**n +4**	**n +5**	**n +6**	**n +7**	**n +8**	**n +9**	**n +10**
Revenues thous. EUR	472,818	130,093	132,695	135,348	138,055	140,816	143,634	146,506	149,436	152,425	155,473
Enamel 1	25,800	0	0	0	0	0	0	0	0	0	0
Enamel 2	309,662	11,470	11,699	11,933	12,172	12,415	12,664	12,917	13,175	13,439	13,707
Enamel 3	76,340	70,801	72,217	73,661	75,134	76,637	78,170	79,733	81,328	82,954	84,613
Enamel 4	30,016	47,822	48,779	49,754	50,749	51,764	52,800	53,856	54,933	56,032	57,152
Other	31,000	0	0	0	0	0	0	0	0	0	0
Operating costs thous. EUR	**384,192**	**88,896**	**89,785**	**90,683**	**91,590**	**92,505**	**93,430**	**94,364**	**95,308**	**96,261**	**97,224**
Enamel 1	239,351	72,993	73,723	74,460	75,205	75,956	76,716	77,483	78,258	79,041	79,831
Enamel 2	144,345	15,573	15,729	15,886	16,045	16,205	16,367	16,531	16,696	16,863	17,032
Enamel 3	2,979	194	196	198	200	202	204	206	208	210	212
Enamel 4	-2,483	136	137	139	140	141	143	144	146	147	149
Enamel 5	0	0	0	0	0	0	0	0	0	0	0
Profit thous. EUR	**88,626**	**41,197**	**42,910**	**44,665**	**46,465**	**48,311**	**50,204**	**52,142**	**54,128**	**56,164**	**58,250**
Working capital changes thous. EUR	0	-14,653	88	90	92	93	95	97	99	101	103
Cash flow changes caused by working capital changes thous. EUR	**88,626**	**55,850**	**42,822**	**44,575**	**46,373**	**48,218**	**50,109**	**52,045**	**54,029**	**56,063**	**58,147**

3 Result and discussion

The COVID-19 pandemic caused extensive financial difficulties in the area of worldwide trade and logistics. The global financial crisis has forced many companies to address the efficiency of all business processes [19]. Each production and non-production company must continuously look for possible sources of competitive advantages in its processes [20]. One of the possibilities of how to face these negative consequences related to the COVID-19 pandemic is the establishment of specific innovative field clusters (contrary to the classic, geographically-oriented clusters) since the objectives of such field-oriented clusters mostly focus on increasing the economic competitiveness level and on securing the development of the selected field.

A model of an international innovative logistic cluster was proposed as part of the project. Its objective will be to stimulate restoration of all partners' economic potential in the metallurgy area. In order to define and assess the economic effects of the proposed cluster, the expected consequences arising from the proposed model of the integrated logistic cluster were analysed.

Due to the expected flows of information and data, it is recommended to create a unified (shared) information space, which can be implemented, for example, in SAP, enabling effective implementation of research and development activities focused on ongoing cooperation in innovation and technology transfer.

The example of an industrial scientific-production cluster in the field of chemistry and metallurgy was used to verify the expected effects. the innovation process's specific subject was the development of a new anti-frit enamel coating with defined specifications for use in aviation - helicopters. The possibility of making the innovation process more efficient was analysed in order to reduce the costs of product innovation and production processes through the use of synergies from the cooperation between selected research centres and educational institutions and manufacturing companies.

Based on the marketing, production and financial plans and documents from the operational records of stakeholders, the calculation of the plan of revenues and costs, profit and cash flow for the planned final products - enamel coating according to various specifications: Enamel 1 - Enamel 4 was simulated for a period of 10 years.

As part of the analysis, it was found that with the effective cooperation of selected entities, costs can be significantly reduced, for example, for material equipment, tests and human resources, etc., by using the synergistic effect of the cooperation. The calculations show that there was a reduction in costs in the monitored period of 10 years due to individual partners' cooperation, knowledge sharing, and the use of technologies within the cluster. The total profit and cash flow increase within the created cluster during the monitored period (n +1 to n + 10).

The verification results demonstrate the functionality of the proposed model and its suitability for application in economic practice. However, it is necessary to be aware that the expected effects depend on the quality of the entered inputs for a given time period. As we have already stated, input definitions require significant knowledge and skills during the stage when a realistic development prognosis of the planned inputs is being prepared. That is why a precise quantification of the achieved synergy effects depends so much on the quality of the input parameters.

4 Conclusions

A typical feature of modern economic development is the transformation of developed countries into a new stage in the formation of innovative companies - building an economy particularly based on the creation, spread and utilization of the given knowledge, i.e. innovative development. The innovation activation process requires fundamental changes in the structure of social production and education and in the management and organization system, as well as action coordination, information exchange, mutual influencing among individual companies and transfer of technologies. From this perspective, it is recommended to use a “strategy cluster”, by means of which you can create and use a unified computer information system model for structuring and distributing the tasks of the participants of innovation projects and processes in the production area, which would allow for monitoring the global processes in the areas of the economy, logistics and management of important international centers.

The subject of further research will be an analysis of the cooperation among selected international research organizations, science and research centers and companies, the objective of which will be a simulation of the restoration of the economic potential of all the partners in the area of metallurgy, and the provision of a maximal synergy effect based on innovations and sharing of the economic interests of all participating partners within the framework of the supplier chain.

The following effects are expected within the framework of the proposed international innovative logistic cluster in the area of metallurgy:

- increasing the income and profits of the participating companies by means of a synergy effect, the introduction of innovations and increasing employee qualifications,
- improving the quality of the logistic services of the given participants,
- increasing profit and growing GDP based on the logistic integration and the introduction of innovations.

The most important step during the project commencement stage (cluster establishment) is defining the four main parts of the cluster, and the preparation of a graphic model since such a model allows the potential participants to unambiguously define the roles of all partners included in the cluster. if we consider the expected information and data flow, it is recommended to create a unified information space, which can be implemented in, for example, SAP.

In order to verify the expected effects of the proposed cluster, a production simulation was executed for the new product - antifriction enameled coating pursuant to various specifications for use in the aviation field - helicopters. the conducted calculations and obtained results have demonstrated that it can be expected that the given synergy effects will be fulfilled.

The already implemented project showed that the cooperation of selected scientific organizations, scientific research centers and companies in the field of chemistry and metallurgy brings economic effects. But due to legislative, legal and international restrictions and sanctions, complicated public procurement procedures and the inactive participation of many organizations, it is very difficult for Russian companies and research organizations to establish effective cooperation with foreign partners. We assume that the proposed model will be able to respond to the different legal and legislative conditions of potential collaborating partners - both from the corporate field and research centers and universities.

We believe that the proposed innovative logistics cluster can facilitate the interaction and cooperation of universities, research centers and industrial companies at the international level with an emphasis on effective and continuous cooperation in the field of innovation and technology transfer. the proposed model should be able to define the possibilities and limitations of the cooperation of individual stakeholders relatively precisely to maximize the synergy effect of innovation cooperation while respecting all specific conditions of each country, such as legislative, regulatory and economic.

From a practical point of view, the output of the work will be beneficial, especially for industrial companies. They will be able to use the model to quantify potential economic resources to develop the subject of the innovation process before starting the innovation process in the company, and then start effective cooperation with selected international research centers and educational institutions, realizing research and development activities focused on continuous cooperation in innovation and technology transfer.

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