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THE DEVELOPMENT AND DESIGN OF ENGINEERING ECONOMIC INDICATOR SYSTEM FOR NANOTECHNOLOGY INDUSTRY PRODUCT MANUFACTURING: A CASE STUDY OF LATVIA

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The current scientific paper is developed to continue the research on further commercialisation of the nanotechnology products of manufacturing industries in Latvia. To create the system of engineering economic indicators for multifunctional nanocoating technologies, the scientific indicators and their theoretical justification have been used, the issues from the experts' analysis and survey of the Latvian companies operating in the nanotechnology industry have been summarised.

Keywords: *commercialisation, engineering economic indicator, innovation, innovative material manufacture, nanotechnology, research and development, system.*

1. INTRODUCTION

One of the functioning problems of a company as a socio-economic system is the system efficiency resulting from the ratio of invested resources and the results achieved. Therefore, in a segment of enterprises operating in a certain field, it is possible to increase resource utilisation returns through the establishment of an indicator model that would directly describe the activities of a specific field and development specifics while covering the interrelationships on the effect of macroeconomic and demand factors.

The goal of the research is to provide the fundamentals for the system of engineering economic indicators for multifunctional nanocoating technologies appropriate for Latvia. The **subject of the current research** is engineering economic indicators. The **research object** is defined using the Eurostat indicators' classification of the high-tech aggregates or intensity of the industry: the authors have worked with high-technology (HT), medium-high-technology (MHT), and medium-low technology (MLT) to keep with the set goal. The research has the following **limitations:** 1) to identify the manufacturing companies producing innovative multifunctional materials and/or working with such type of technology; 2) the research is carried out focusing on Latvia. Within the research, the following methods have been used: quantitative data analysis, relative value calculation and comparison, analysis, synthesis and grouping. Differences of the analysed systems for multifunctional nanocoating technologies are discussed in the theoretical substantiation section of the publication. Within the current scientific paper, the scientists provide part of the results from the practical survey "Innovative Material Manufacture in Latvia" carried out by the Institute of Civil Engineering and Real Estate Economics of Riga Technical University from mid-December 2014 to mid-February 2015. The paper is delivered to continue the research on further commercialisation of the nanotechnology products of manufacturing industries in Latvia [1]. The current paper is structured into six parts, including Introduction and Conclusion. The main sections of the scientific research provide theoretical and practical issues for the development and design of the engineering economic indicator system, SWOT analysis, factor analysis and life cycle assessment from the results of the practical survey performed.

2. COMPETITIVENESS ASSESSMENT FOR THE SELECTION OF ENGINEERING ECONOMIC INDICATORS

Based on the results of the project "BIRTI. Science, Technology and Innovation Strategy for Smart Specialisation 2014–2020", additionally using the expert method and the information obtained from in-depth interviews of nanofield/ industry representatives, the authors have performed a SWOT analysis. The object of SWOT analysis is nanotechnology/nanomaterial research and manufacturing process/field in Latvia.

Table 1

SWOT Analysis of Nanotechnology/Nanomaterial Research and Manufacturing Field

Strengths	*Field*	*Weaknesses*	*Field*
1. Fundamental research in the nanofield in the academic environment	R	1. Small number of people involved in scientific research	R, M
2. Enterprise experience in the area of knowledge commercialisation	M	2. The lack of young specialists with specific knowledge in the nanofield	R, M
3. The ability of enterprises to offer niche products	M	3.Uncompetitive level of remuneration	R, M
		4. Poor quality of scientific publications/citation rating	R
		5. Poorly developed nanotechnology transfer infrastructure	M
		6. Underdeveloped clusters	R, M
		7. Disproportionate funding sources	R, M
Opportunities	*Field*	*Threats*	*Field*
1. The efficient attraction and use of external financing	R, M	1. Unfavourable innovation climate for development in the field	R, M
2. Arranged legislation	R, M	2. The change in the national financing strategy	R
3. Effective public political support	R, M	3. The global financial market stagnation and investor indifference	R, M
4. Arrangement of conceptual strategic issues	R, M	4. Outflow of qualified human resources from Latvia	R, M
5. Public interest in this area	R, M	5. Unconscious risks affecting development in the field	R, M
6. Increase in knowledge capacity (study programme specialisation)	R, M		

R – a research field; M – a manufacturing field

In the metalworking industry, benefits are received by enterprises implementing an aggressive development policy, entering new and promising markets, flexibly responding to market demands and changes in the working environment [2], while the strengths of enterprises dealing with nanomaterials are related to the ability to commercialise the fundamental research results that are predominantly achieved in the academic environment. From 2008 to 2012, RTU scientists applied for 11 patents related to the acquisition of nanoparticles, nanocomposites, nanoscale coatings, body nanoacceleration determination, nanostructured materials, whose physical dimensions are in the range of microns and/or nanometres. In the manufacturing sector, research activities are very weak, or in some segments of nanofield they are not observed because of the total number of scientists and other professionals who conduct research by normal working day equivalent, exactly in the business sector: in 2010 22.6 % were employed, in 2011 16 %, in 2012 15.8 % and in 2013 18.2 % [3]. The small number of R&D employees in the private sector demonstrates that the industry lacks knowledge absorption capacity, which in turn does not promote scientific and industrial cooperation. Insufficient number of employees in science, research, technology development and innovation, and insufficient renewal of personnel involved in these areas lead to Latvian innovation system failures; as a result, from all the EU member states in the field of innovation, Latvia takes the next-to-last place, leaving behind only Bulgaria [4].

According to the 2014 Annual Report of the Latvian Council of Science, in physics and astronomy publications and conference materials are of the global fundamental importance; however, according to the OECD assessment publications directly in the nanofield have a low citation rating. In the academic environment, 5.6% of the total number of scientists and researchers work in materials sciences in Latvia. According to the authors' scientific and practical research results, a limited number of researchers working in the field is a topical issue, and entrepreneurs themselves are also trying to address it since a significant investment in human resources is made directly in high-tech (HT) – intensity field. Entrepreneurs also recognise the fact that they are not able to ensure staff qualification improvement [1]. In 2010, RTU established the study programme "Material Nanotechnologies and Nanoengineering", whose contribution to the development in the field could be seen over the next few years.

Research centre of national significance for nanostructured and multifunctional materials, constructions and technologies "LATNANO-C" is still undergoing the development stage. Analysing publicly available information on clusters, it can be concluded that there are activities taking place in cluster development (NanoTech-Energy, Space Technology Cluster, Metal Processing Cluster, "Latvian Clean Technology Cluster"). By contrast, specific equipment at enterprises is only appropriate for a certain enterprise niche. Scientists investigate fundamental scientific problems in which they are interested, while entrepreneurs are trying to produce and sell what the customer wants. Difference in strategic direction is a lack of cooperation between entrepreneurs and representatives of scientific research institutions.

Nanofield is developing in different manufacturing industries with different capital investment parameters and quality of workforce. It should be taken into account that nanotechnology is a narrow field of specialisation and the outflow of qualified human resources from Latvia may pose a threat to the further development of the field. According to the authors' scientific and practical research results, entrepreneurs are able to pay competitive salaries. However, in the set of innovation system problems Latvia is characterised by "Cheap labour and resource advantages", which means that at the European and world scale the level of remuneration is not sufficiently high [5].

Within the SWOT analysis, commercial activities of enterprises selected for the research have been evaluated – the existence of patents and the infrastructure necessary for the manufacture of innovative materials or the use of innovative technologies. Figure 1 demonstrates the average coefficients of each infrastructure element on the basis of assessment provided by nanoprofile companies. Responses by enterprises have been rated as follows: 1 – proprietary infrastructure elements are ensured, 2 – only outsourcing is used; 3 – both proprietary services and outsourcing are used, 0 – infrastructure element is not used by the enterprise at all.

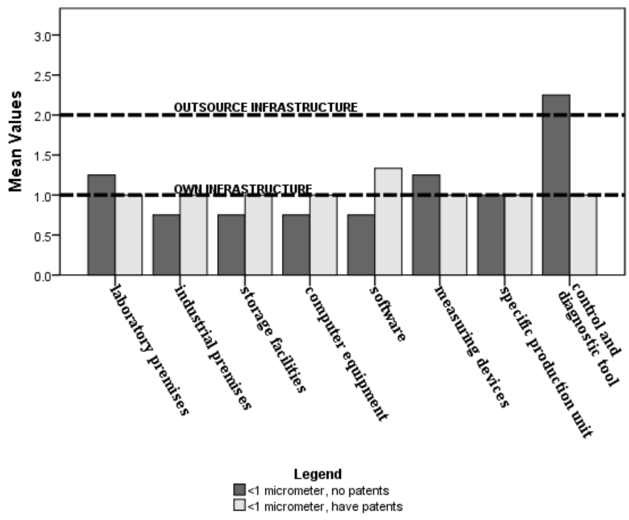

Fig.1. Correlation of the respondents' patenting activity to the creation of technological infrastructure. Structure of the identified nanocompanies' responses (developed by the authors based on the research findings).

Based on the evaluation results, as reflected in Fig.1, nanocompanies that are patent owners are characterised by the full provision of all infrastructure in their manufacturing activities. Providing computer software is the only element of the infrastructure, which tends to be used for outsourcing. By contrast, in the group of enterprises that do not have their own patents, the results are different. Among these respondents there are manufacturing companies that do not use special storage facilities or industrial premises, or do not require hardware or software. Performing the analysis of qualitative indicators, it is evident that there is mainly an exceptional case, which affects the overall result because it corresponds to the narrow specialisation of a manufacturing company in the production of medical supplies, but the average mathematical result in this question group tends to a boundary "provision of proprietary infrastructure elements". With regard to laboratory premises, measurement equipment, as well as testing and diagnostic equipment, some nanocompanies use outsourcing. Here, a number of cases should be mentioned indicating the clustering characteristics of the local market.

3. BCG MODEL TECHNOLOGY USE FOR CHARACTERISING ENGINEERING ECONOMIC INDICATORS

Within the scientific project "Development of Multifunctional Nano-coatings for Aviation and Space Techniques Constructive Parts Protection" No.2013/0013/1DP/1.1.1.2.0/13/APIA/VIAA/027, one of the research components in the development of engineering economic indicator system is partly BCG (Boston Consulting Group) model or Growth-Share Matrix use technology.

Substantiation for this model use with respect to the technology developed within the project is the model itself. The relative market share of business units against major competitors and industry development dynamics are assessed. It is known that the industry of innovative multifunctional material manufacturers in the world has very high growth rates, which is one of the main issues of the company's strategic development stimulation. By contrast, in the area of nanomaterials the necessity to attract capital investment and timeliness assessment exert considerable influence on the production commercialisation and development success. It can be determined assessing the development dynamics of a certain innovative material industry and the performance of existing or emerging market niche players.

According to the BCG model basic formulas [6], there is a topical issue related to market or industry scale and volume determination. As a result of evaluation, the authors have concluded that the data on industry volume determination are arguable as multifunctional nanocoating technologies have a quite extensive spectrum of application. In the previous studies, the authors have demonstrated that the use of innovative multifunctional materials is an interdisciplinary and not clearly identifiable area [1]. For example, a new technology [7] created within the project can be used widely in economic sectors such as aviation and aerospace, automotive, computing, manufacture of electronic and optical products, as well as in scientific research and development. Thus, it can be concluded that the global market scale is clearly applicable to such technology development. In the Latvian market, due to the production of small capacities and narrow specialisation the domestic competition could also not be as fierce as it is potentially in a broader – interregional and transnational market. According to the results of the BCG analysis of specialist evaluation with regard to the world-wide business mergers, for purchase and sale transactions worth more than 1.5 billion US dollars from 2001 to 2011, 42% of the cases accounted for the acquisition of technology licenses, which was the largest number of responses [8]. The second most popular activity is striving to achieve the leading position in a specific product market segment. In the current dynamic process of globalisation [9], in each of the above-mentioned types of use for business start-up or in case of business continuing there is the need for strategic planning and evaluation of product or technology development perspectives in a certain market. Returning to the BCG model formulas, as mentioned above, the volume of an innovative multifunctional materials industry is difficult to be identified, but also the market share of each individual market participant in the nanomaterial industry is arguable. Information about the production and sales share of nanoproducts of the total company turnover is still confidential in a number of cases.

Being aware of the BCG model weaknesses and limitations related to industry volumes of innovative multifunctional materials that are difficult to identify, as well as due to lack of economic data in certain companies, but also judging the BCG model as a whole, the evaluation is provided based solely on market growth dynamics as the only industry attractiveness factor and the relative market share as a competitive advantage, but also in a market niche of narrow specialisation the company's economic performance evaluation indicators may significantly differ from indicators within the industry [10], which is insufficient in case of dynamically developing nanomaterial manufacturing market. The authors of the present paper conclude that at the final stage of the research it is necessary to develop guidelines, which can be used to draw conclusions regarding development opportunities of nanomaterial manufacturing market as part of preparing competitiveness assessment.

First, the scientists consider that within the assessment of identifiable sector development the BCG (Boston Consulting Group) model or Growth-Share Matrix use technology may be partially attributed by the following mathematical expressions:

1) Within the framework of determining the relative market share, to evaluate the total value added of each sector the following formula modified from Liu and Sha, 2012 [6] can be used:

$$a_i = \frac{\sum_{t=m}^{z} y_t}{\sum_{t=m}^{z}\sum_{i=1}^{n} y_t} \times 100\% \tag{1}$$

where 'a_i' represents the ratio of the gross industrial output value of industry 'i' during the period from 'm' to 'z', 'y_{it}' represents the gross industrial output value of industry 'i' in year 't', 'n' represents the number of industries.

2) To calculate the market growth rate, the formula of average growth rate can be used.

$$\overline{T_b} = \sqrt[n-1]{\frac{Y_n}{Y_1}} \tag{2}$$

where $\overline{T_b}$ – the base average growth rate, Y_n – the value of the final period, Y_1– the value of the initial period, n – the number of years of the period under study.

Second, in each of the production development (life cycle) stages, from research and development to maturity and decline stages, multifunctional nanocoating material manufacturing company should identify internal and external factors affecting business performance, which could be different, or factors can be assessed by different priorities depending on the product development stages. In this context, the information from the market or entrepreneurs' scientific and practical survey results is of decisive importance.

4. THE FACTOR ANALYSIS OF BUSINESS LIFE CYCLE MODEL

In a range of studies on nanomaterials, researchers (Grieger et al. 2012; Hischier and Walser 2012, Som et al. 2010) use the product life cycle model to assess the environmental performance of nanoproducts, risks posed by nanoparticles to human health and the environment. In this way, relative environmental sustainability indicators are evaluated for nanoproducts compared to their conventional counterparts [11]–[13].

A certain similarity with the product life cycle theory is shared by the company's life cycle concept, which has been introduced within the framework of the company's management theory to explain changes in the company in the context of time. By a life cycle stage one understands a "unique combination of parameters relating to the organisation and its structure" (Hanks et al. 1993), since the life cycle as a whole is the progression through various dimensions of time periods and influencing factors [14].

According to the analysed results of the practical survey "Innovative Material Manufacture in Latvia", criteria from the formulated question groups have been selected. Below, the results of the factor analysis are given based on the responses of manufacturing companies of a nanoprofile.

The factor analysis results (Table 2) have been obtained using the SPSS software by the following methods: Extraction Method: Principal Component Analysis, Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 10 iterations. Only cases for which up to 1 micrometre = "yes" are used in the analysis phase.

Table 2

Rotated Component Matrix of the Factor Analysis for Manufacturing Companies of a Nanoprofile

Component 1		Component 2		Component 3	
Factor name	Coefficient scale	Factor name	Coefficient scale	Factor name	Coefficient scale
government support and international funding	0.93	expansion of production	0.89	short-term loans	0.95
solvency of customers	0.90	research and development	0.89	competition in Latvia	0.92
promotion campaign	0.88	expansion into new markets	0.89	for promotion	0.86
increase of production capacity	0.88	improvement of products, materials, technology	0.77	ensuring health and safety arrangements	0.84
modernisation of machine tool stations	0.88	increase in the average salary	0.76	environmental protection requirements	0.82
planned investments in the near future	0.88	attraction of investors	0.75	labour efficiency	0.80
for research and development	0.88			marketing campaigns and promotion	0.76
launch of new production	0.70			long-term loans	0.73
attraction of investors	0.61			sensitivity to market fluctuations	0.73

Calculations demonstrate that in the nanocompany responses correlation can be found and divided into three groups of factors.

The first group or "Component 1" comprises the following factors (in order of priority): government support and international funding; insignificant impact of solvency of customers; planned investments in marketing campaign organisation to promote product/service to the market in the near future; the company's internal potential to increase production capacity; short-term planned investments in the modernisation of production facilities as well as in research and development; readiness for launching new production, and attraction of investors.

This factor group has a quite firmly expressed goal to initiate the product commercialisation and even promote the company's openness and readiness to attract investors that might be characteristic of product development or implementation stages. In this context, it would not be typical to attribute one factor – insignificant impact of customer solvency – to the product implementation stage, because after product testing or speaking more broadly – the development stage – solvency of customers is becoming a major indicator to determine turnover in the further product development life cycle.

The second group of factors or "Component 2" includes the following factors (in order of priority): planned investments in production expansion, research and development, as well as entering/ expansion into new markets in the near future; the evaluation of company's abilities for improvement of products/ materials/ technologies, as well as an increase in the average salary and attraction of investors. As a result of providing positive responses, this group would describe enterprises undergoing the development stage of product life cycle. It can be concluded that compared with the first group of factors, which depend on external investment, the second group of factors "Component 2" comprises enterprises with a longer working experience that may provide competitive salaries to specialists as they consider themselves.

The third group of factors or "Component 3" consists of the following factors: short-term loans as the most appropriate funding for new innovative multifunctional material/ technology introduction or further development of the company; competition in Latvia; over the past 3 years the company has used outsourcing for product/ service promotion to the market; the evaluation of company's ability to ensure work safety and to follow environmental protection requirements and productivity control, as well as to implement marketing activities; long-term loans as the most appropriate funding for new innovative multifunctional material / technology introduction or further development of the company; sensitivity to market changes.

The factors of the third group point to the evaluation of the local market of companies for the benefit of wider target markets, the dominance of short-term loans to ensure the company's development, which may indicate that enterprises that fall under this group need funding for specific commercial purposes, perhaps even for the product/ service promotion to the market, as they are referred to as outsourcing, but also long-term loans are acceptable. It can be stated that such companies undergo the product development or maturity stage. This group of factors includes other essential company's abilities that have not been highly ranked in other groups, i.e., ecology, productivity control and ensuring employee-friendly work environment.

Most often the following quantitative characteristics are mentioned in relation to the company's life cycle stages: business turnover; dividends; volume of capital investments; the age of the company. It is possible to use only two numerical indicators: the age of the company and the turnover growth rate [15]. However, the age of the company is used as a criterion only at the growth stage (up to 10 years). In turn, the numerical expression of business turnover is above 15 % at the growth stage, while at the maturity stage it is below 15 %.

On average, young companies have higher sales growth, return on assets, and investment rates than mature companies. Young companies also obtain external financing at a higher frequency than mature ones. This difference is particularly notable for equity issues. The differences in the mean values across the young and mature company subsamples are statistically significant at the 5 percent level [16].

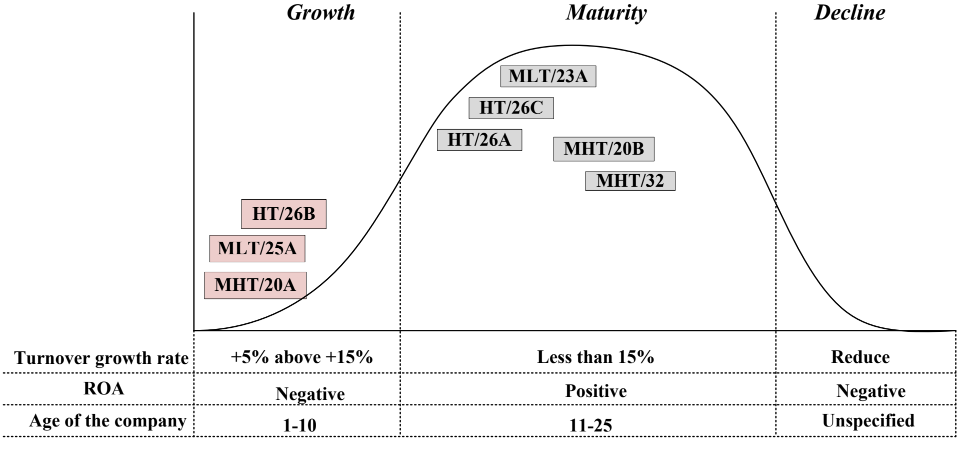

Fig. 2. Life cycle assessment of the development of nanotechnology industry of Latvia according to the performance indicators of the respondents and type of industry (developed by the authors based on the research findings).

Using the analysis results of external environmental factors and the demographic data, turnover growth rate, ROA indicator of the eight Latvian companies dealing with nanocoatings (Fig. 2), the authors have concluded that three of the companies undergo the growth stage, while five companies have reached the maturity stage.

At the growth stage, the turnover is not yet stable, because the customer base is under the formation stage, with a tendency to increase. The cash flow being affected by external financing, investment and development is particularly sensitive at this stage. Here, the important role is played by external environment favourable conditions and the company's ability to use them to generate the cash flow for further development. If at this stage the company can be considered young, then empirical studies [17] related to the development of start-ups prove that the company's achieved results are significantly affected by the industry structure and the company's chosen strategy. The authors conclude that to ensure the successful further development of companies, the important role is played by the information about this sector influencing factors and indicators that characterise these factors.

5. THE DESIGN OF ENGINEERING ECONOMIC INDICATOR SYSTEM

As a growing applied science, nanotechnology has a considerable global socio-economic value, and the benefits afforded by nanoscale materials and processes are expected to have significant impact on almost all industries and all areas of society [18].

It is known that the development of nanotechnology directly affects the following industries: aerospace, automotive, biotechnology, ceramics, chemicals, computing, defence, electronics, metals, materials, paper, plastics, renewable/sustainable energy, textiles and telecommunications [19]. Furthermore, nanotechnology continues to play an important role in the economies of most developing and developed countries [20], [21]. Undoubtedly, under the circumstances of today's global spread of knowledge and technologies the development of nanotechnologies is directly dependent on the country's socio-economic, political and legal as well as environmental situation.

In Latvia, the nanotechnology use area is developing in various industry sectors, so the use of innovative multifunctional materials is interdisciplinary and the industry volume of innovative multifunctional materials is difficult to be identified. Based on the theoretical substantiation and practical analytical assessment of multifunctional nanocoating technology that allow identifying the most significant scientific and technological, engineering and economic, ecological, legal, political and social aspects of new technology implementation and use, as well as using the SWOT analysis of nanotechnology/ nanomaterial research and manufacturing field, the authors have developed the system of engineering economic indicators for multifunctional nanocoating technologies (see Fig. 3).

Figure 3 demonstrates that the use of multifunctional nanocoating technologies and the manufacturing of products take place in the multi-dimensional environment and can be differentiated according to the engineering economic indicator system that, based on the previous studies, is modelled taking into account the characteristics of different indicators, criteria and functions. The authors divide the system under consideration (Fig. 3) into 10 groups of indicators that include, respectively, subgroups with specific indicators:

Economic indicators characterise the economic development of a company, country or region and reflect the country's economic upturn or downturn, thus indirectly showing the connection with social factors. If the income level of population/ enterprises increases, there will be an increase in demand for innovative multifunctional materials and consequently in supply, but if the income level decreases, there will be a decrease in both demand and supply. The same happens to the availability of financial resources, including credits, employment in the country, the country's economic growth in the context of demand and supply.

The impact exerted by the group of **social indicators** can be explained by the fact that market demand is partially also due to the public interest in this area. In the age of rapid technological development, the level of public awareness of nanotechnologies and materials is increasing, as evidenced by the inclusion of nanothemes in science cafes, traveling exhibitions and Internet informative articles [22]. In the

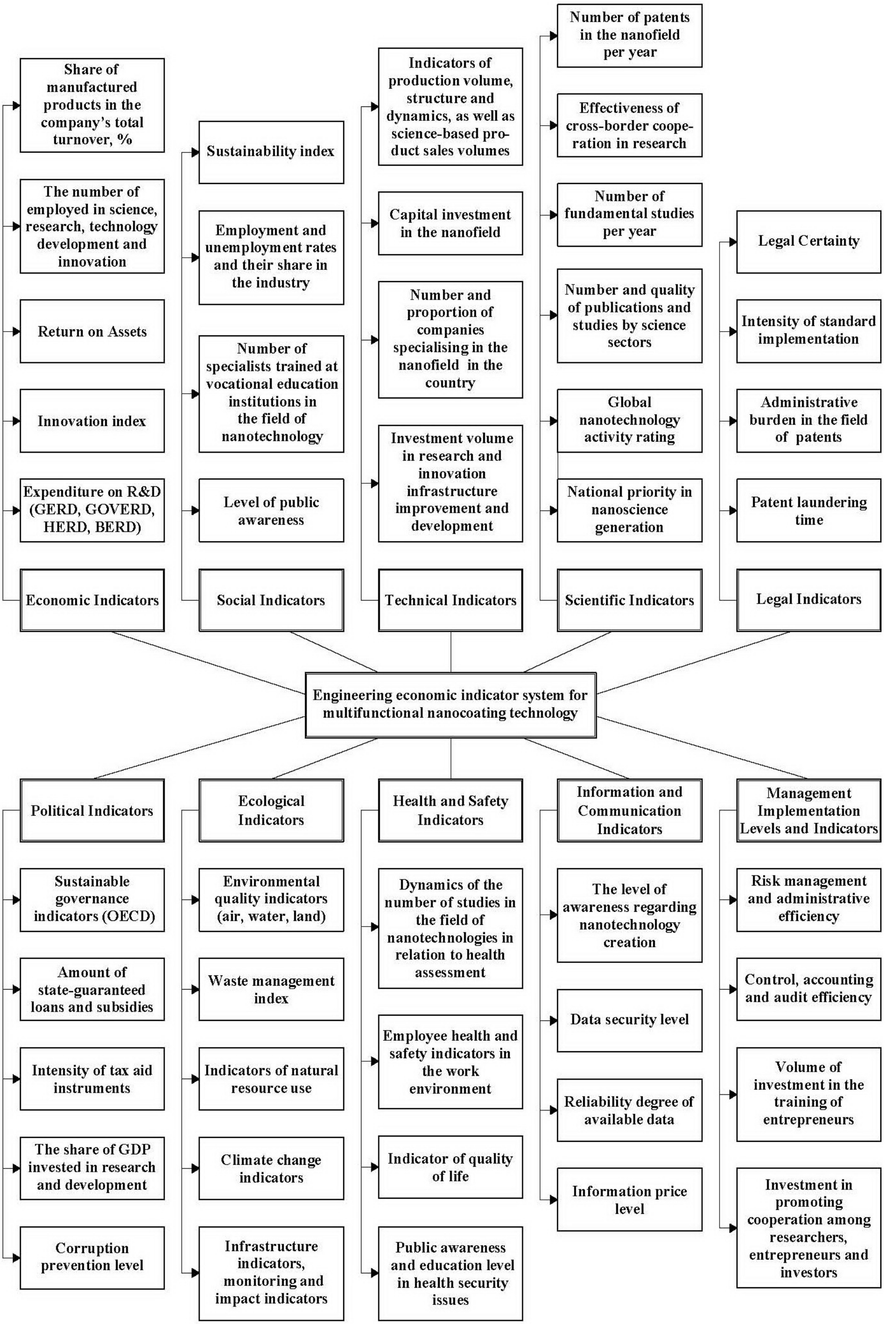

Fig.3. The design of engineering economic indicator system for multifunctional nanocoating technology (developed by the authors based on the research findings).

group of social indicators, it is worth mentioning the sustainability index, which is based on the internationally recognised methodology. It helps Latvian enterprises diagnose sustainability of their activities and corporate responsibility level [23]. The sustainability index was introduced in 2010 in Latvia and, since the receipt of the assessment is voluntary, it has been used by only 200 enterprises.

Technical Indicators. In the group of technical indicators, an important role is played by technology transfer and innovation infrastructure development indicators (investment volumes in technology development centres, incubators, prototyping laboratories, pilot plants), which demonstrates that it is necessary to create an appropriate environment in order to develop new technologies and commercialise research results. As the technology transfer infrastructure is not developed in Latvia, Latvian entrepreneurs, especially small and medium-sized enterprises, and scientists cannot implement a technology transfer stage relevant for an innovation process before the product is not prepared for entering the production stage. In the field of nanotechnology, the number and proportion of specialised enterprises in the country should be defined according to the following types of specialisation: multifunctional material obtaining process, resulting multifunctional materials, and the technology used.

Scientific Indicators. Unfortunately, at present in Latvia scientific and research capacity is weak compared to the EU average indicator, and in recent years Latvian performance in research and innovation has not significantly improved [24]. Therefore, using the indicators characterising the development of scientific environment, especially for assessing the development of a certain area, the entrepreneurs have the opportunity to forecast the directions of investment attraction.

Legal Indicators characterise the efficiency of regulatory laws and regulations on the use of nanotechnologies and the manufacturing of nanomaterials. Patent laundering time, the intensity of implementation of standards and the administrative burden in the field of patents are of importance for innovative multifunctional material enterprises. Taking into account that Latvia is characterised by volatility and changes in legislation, the quality of business environment in the field of nanotechnology may be limited. As it is known, the quality of the business environment is one of the most important elements for increasing the country's competitiveness – the more legally stable and secure environment is created for entrepreneurs by the country, the more investment can be expected in the national economy, which means job creation and welfare of the population. According to 2014 Rule of Law Report, Latvia's government and administration generally act in a predictable manner. Government decisions have in some cases been challenged in court on the basis of a breach of the principle of legal certainty. Problems may occur in small municipalities due to a lack of professionalism [25].

Political Indicators characterise the impact of political decisions on the development of innovative material area: sustainable governance indicators, volume of state-guaranteed loans and subsidies, tax aid instrument intensity, corruption index, the share of GDP invested in research and development, etc. Sustainable public administration provides the opportunity to manifest oneself in the following areas – tax and innovation policy, investment environment, lending policy.

Ecological Indicators. In Latvia, the research and manufacturing processes related to nanomaterials and technologies are a new and very topical direction, in which materials with specific properties are used. Therefore, the potential impact exerted by manufacturing and exploitation processes on the environment requires a responsible and reasonable management approach. Ecologically oriented management increases the responsibility of the company not only for a safe and friendly production of goods, but also for the wise use of natural resources and green technology choice [26].

Health and Safety Indicators. As stated on the Health-EU Portal, "today it is not known whether the tests used to identify and assess the related hazards and risks by 'classical' chemicals can also be applied to nanomaterials, and this causes some concern. The current risk assessment methods are sufficiently flexible so that they can be applied to nanomaterials. Moreover, most of the toxicological and ecotoxicological methods are likely to be used to identify the related hazards." [27]. As any industry enterprise also companies working in the nanotechnology industry have the opportunity to monitor that their employees follow health and safety requirements in the work environment using the following indicators: occupational injury and disease, disease and fatality [28]. Taking into account the above-mentioned considerations, the authors would recommend actualising studies in the field of nanotechnology related to health assessment also in Latvia.

Information and Communication Indicators. The extent of information provided on nanotechnology creation means the efficiency of a decision support system for entrepreneur communication with interested parties, product creation and sales processes as well as risk management. Companies typically use information systems to address their potential customers with targeted messages on the website, to handle the financial statements and to manage their human resources [29].

Management Implementation Indicators. The National Development Plan of Latvia for 2014 – 2020 states that the business structure of Latvia, as the country with small and open economy, consists mainly of micro, small and medium-sized enterprises that do not have sufficient capacity to invest in research and development, and therefore the high-tech sector is poorly developed. To enable employees in the private sector to use innovations generated by the researchers in the national economy, it is necessary to build a culture of innovation supported by a targeted and effective innovation system that covers and integrates legal, education, science, research and financial conditions for the successful commercialisation of research results, as well as for continued cooperation between science and industries, and provides an increase in private investment in science and research [30].

According to the identified problems, the state responsible institutions should envisage the volume of investment in promoting cooperation among researchers, entrepreneurs and investors in order to develop a new way of thinking and to create a new mentality dominated by the values and priorities in relation to engineering and economic solutions of innovative multifunctional materials, to promote the development of education towards professional competence in the field of material nanotechnology and nanoengineering, as well as information and scientific-methodical provision would be a positive precondition for the management of nanomaterial manufacturing market development.

6. CONCLUSION

1. The system of engineering economic indicators has been developed for multifunctional nanocoating technologies on the basis of analytical assessment of multifunctional nanocoating technology, which allows identifying the most significant scientific and technological, engineering economic, ecological, political, and social aspects of new technology implementation and use, reducing the vulnerability of new technologies under the conditions of global spread of knowledge and technologies.
2. The fundamentals for the system of engineering economic indicators for multifunctional nanocoating technologies appropriate for Latvia are being developed. A possibility of their adaptation in other countries is acceptable, and requires further investigation due to market distinctions and information availability.
3. The various types of indicators of the engineering economic indicator system and combinations with them for multifunctional nanocoating technologies create large and diverse market segments, which should be skillfully separated and acquired separately by a professional market participant – an entrepreneur or an analyst.
4. The company's correct positioning in the viewpoint of market segmentation gives it a competitive advantage in the market and increases business efficiency. Proper market structuring, segmentation, through its analysis, create the preconditions for accounting of segment specific features and improving the quality of analysis.
5. The results of SWOT analysis demonstrate that in the field of nanomaterials there are risks in both research and manufacturing that are seen as weaknesses, but strengths of the field are mainly based on manufacturing companies.
6. Companies that have been operating for less than 10 years in the field of multifunctional nanomaterial manufacturing in Latvia face the problems – high financial risk and inefficient return of capital – indicated in the company's life cycle concept.
7. The estimate of development of nanotechnology industry manufacturing market using SPSS software, SWOT analysis, BCG technology and life cycle assessment of the development of nanotechnology industry of Latvia according to the performance indicators of the respondents and type of industry indicates cluster formation characteristics of the market. The opportunities for cluster development in the Latvian nanotechnology industry manufacturing market are visibly correlating and respectively interfering only in the context of global market.
8. The analysis of the present research, its most significant results and conclusions demonstrate the need to continue the research on the development of nanotechnologies in several directions, including new, viable and competitive business creation and development in Latvian regions by providing the necessary business environment and advisory services, improving technology transfer infrastructure and creating the appropriate solvent demand, as well as attracting foreign capital and foreign investment in the development of smart specialisation area to assess challenges, effects and risks.

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INŽENIEREKONOMISKO RĀDĪTĀJU SISTĒMAS ATTĪSTĪBA UN IZVEIDE NANOTEHNOLOĢIJU INDUSTRIJAS PRODUKTU RAŽOŠANAI: LATVIJAS PIEREDZE

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K o p s a v i l k u m s

Zinātniskā publikācija ir sagatavota kā turpinājums nanotehnoloģiju industrijas produktu komercializācijas pētījumam Latvijā. Lai izveidotu inženierekonomisko rādītāju sistēmu daudzfunkcionālajām nano-pārklājumu tehnoloģijām tiek izmantoti zinātniskie indikatori, to teorētiskais pamatojums, kā arī Latvijas inovatīvo daudzfunkcionālo materiālu ražotāju aptaujas un ekspertinterviju rezultāti.

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