

## POSSIBILITIES OF QUANTITATIVE ASSESSMENT OF THE STATE OF ACTIVITIES OF SCIENCE AND TECHNOLOGY PARKS

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**Abstract.** Science and technology parks (STP) play a special role in the knowledge-based economy. An STP is a place where scientific ideas and thoughts are transformed into products and services. As socio-economic systems, they create a basis for the development of start-ups, knowledge transfer, cooperation between enterprises and scientific institutions and, thus, the commercialization of innovations and other research results. For this reason, the focus of STP functioning is the object of scientific research. On the other hand, there are enough unresolved issues. In most cases, individual aspects of STP activities are upset. There is a lack of research related to the assessment of park activities in a comprehensive, systemic manner. Without a general indicator, it is impossible to compare the activities of individual STPs, it is impossible to study their impact on the performance of enterprises, etc. The aim of the article is to develop a methodology for a comprehensive quantitative assessment of the activities of scientific and technological progress and to test it using the example of parks in Poland.

**Keywords:** science and technology parks, multi-criteria assessments of their activities.

**JEL Classification:** O33, O38, R11.

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## 1. Introduction

Science and technology parks are one of the key pillars of the modern knowledge-based economy, connecting the potential of science and industry to promote innovation. Their importance stems from their unique ability to create ecosystems that facilitate the emergence of new technologies, knowledge transfer and strengthening economic competitiveness at the regional and global levels.

The dynamic development of science and technology parks is a response to the growing need for synergy between the scientific and business sectors. They support the activities of small and medium-sized enterprises (SMEs), start-ups and corporations, creating an environment that promotes cooperation and knowledge exchange. As a

result, they play a key role in solving global technological and societal challenges, such as the transformation of the digital economy, sustainable development or combating climate change.

The special importance of science and technology parks is seen in their ability to shape local economies. They are hubs of innovation that not only create jobs and attract investors but also support the development of regional industrial clusters. These actions are especially important in regions facing economic problems, where parks act as a catalyst for growth and modernization.

The number of science and technology parks has been growing systematically for decades. Initially, they were concentrated in countries with a high level of technological development, such as the United States or Japan, but

over time, the idea began to gain popularity around the world. The dynamic development of science and technology parks was driven by the growing need to support innovation, entrepreneurship and effective technology transfer between the scientific and industrial sectors.

In Europe, the turning point in the development of these institutions was the 1990s and the beginning of the 21st century, when, thanks to the support of European Union funds, a real boom in their creation occurred (Staszaków, 2013). Financing from EU structural funds made it possible to create many infrastructure facilities designed to support innovation, especially in Central and Eastern European countries. This approach became an important element of cohesion policy aimed at reducing economic disparities between regions.

Today, science and technology parks operate on almost all continents, serving as key nodes in global innovation networks. Their development is no longer limited exclusively to highly developed countries – there is also growing interest in this model of supporting innovation in developing countries, which see the potential for accelerating economic transformation in parks. Along with this trend, the parks themselves are evolving, adapting their functions to changing market needs and challenges, such as digitalization, sustainable development or energy transformation.

Due to the special role that scientific and technological parks play in the knowledge-based economy, their activities are considered in scientific publications in a broad and multifaceted manner. On the other hand, there is a lack of research aimed at a comprehensive assessment, in studying specific individual aspects of their functioning. In this situation, it is impossible to compare the activities of individual parks, evaluate their impact on the performance of enterprises with which they cooperate, etc.

The aim of the article is to develop a methodology for a comprehensive quantitative assessment of the activities of scientific and technological parks and to test it using the example of parks in Poland.

The article consists of an introduction, literature review, research methodology, results, and discussion. The introduction discusses the importance of for a country's economic development and points out gaps in evaluating their performance. The Methodology section provides a complex evaluation methodology for STP performance, which is based on non-linear multi-criteria evaluation. In the results section of the article, the methodology is illustrated with the performance of Polish STPs. The discussion emphasizes that the research fills an important gap in STP performance evaluation by providing a complex evaluation methodology. The conclusions present the main research findings, limitations of further research, and outline directions for future studies.

## 2. Literature review

There are many different definitions of science and technology parks in the scientific literature. Concepts such as

science park, research park, science and technology park, business park are used interchangeably (Shearmur & Doloreux, 2000; Chan & Lau, 2005; Link & Scott, 2007; Sofouli & Vonortas, 2007). Comparing the definitions, it can be argued that science and technology parks are similar concepts. The main difference concerns, first, the results of their activities and the work performed. At the first stage, production is limited to the prototype level. A technology park is also a place where innovative solutions can be additionally produced on an industrial scale (Waligóra, 2015).

An important area considered in the literature on science and technology parks is their role in the knowledge-based economy. Science and technology parks are created in strictly defined geographical, economic, social and institutional conditions, while performing certain functions: incubation, innovation, integration and promotion (Table 1).

**Table 1.** The role of science and technology parks in the knowledge-based economy (source: own development based on Błaszczuk et al., 2017)

Function	The role of science and technology parks
Incubation	Parks facilitate start-up and help overcome market and administrative barriers for young firms;
Innovative	Parks stimulate innovation processes;
Integration	Parks create an optimal business environment in which new firms can emerge;
Promotional	Parks become a tool to attract potential investors.

A research problem that arises when analysing park activities and evaluating them is that science parks may have different goals and objectives. To evaluate the success of science parks, it is necessary to understand and agree on the goals that are most important for each science park and then evaluate their performance against the established goals using a set of performance indicators (Dąbrowska, 2011).

A number of articles provide information on the performance and development dynamics of individual science and technology parks (Barbera & Fassero, 2013; Howard & Link, 2019; Hu, 2011; Kulke, 2008; Marszałek, 2018; Miao & Hall, 2014; Pach, 2014; Palmowski & Tarkowski, 2016; Yan et al., 2020; Zou & Zhao, 2014) or on groups of parks in a given area (Sofouli & Vonortas, 2007; Suzuki, 2004; Yang et al., 2009; Motohashi et al., 2009).

The literature has also examined the impact of S&T parks on the performance of firms located in them (Albahari et al., 2018; Diez-Vial et al., 2017; Vásquez-Urriago et al., 2014; Barge-Gil & Modrego, 2011; Colombo & Delmastro, 2002). Firms operating in parks can improve their performance due to the benefits associated with knowledge transfer and shared resources, which is especially useful in the early stages of a firm's or industry's life cycle.

Young companies can benefit more from a park than established firms, both in terms of economic growth and innovation potential (Diez-Vial et al., 2017). Evidence shows that companies located close to existing parks exhibit

higher innovation activity, and the number of years of operation has a positive effect on the level of innovation. Important factors for park choice have also been found to include the degree of connection with universities, access to financing, economic situation, as well as access to the labor market, rent, and sales level (Löfsten & Lindelöf, 2001; Monck et al., 1998).

The impact of locating firms in a park or cluster has also been assessed (Huang et al., 2012). The authors examined how locating in different types of clusters and parks, depending on firm size or internal R&D capabilities, affects firms' innovativeness. Empirically testing hypotheses using data from 165 manufacturing firms in the information and communications technology sector and considering examples of parks and clusters, the authors found that in developing economies, firms experience greater innovation advantages from locating in science and technology parks than from clusters. They also hypothesize that firms located in science and technology parks experience greater advantages in terms of innovative performance than larger firms.

The activities of science and technology parks are carried out by international and national associations of these institutions, such as International Association of Science Parks and Areas of Innovation (IASP), Association of University Research Parks (AURP, USA), as well as the Association of Organizers of Innovation and Entrepreneurship Centers in Poland (Stowarzyszenie Organizatorów Ośrodków innowacji i przedsiębiorczości w Polsce [SOOIPP], 2022).

Most studies focus on individual parks or groups of parks (Barbera & Fassero, 2013; Howard & Link, 2019; Hu, 2011; Kulke, 2008; Marszałek, 2018; Miao & Hall, 2014; Pach, 2014; Palmowski & Tarkowski, 2016; Yan et al., 2020; Zou & Zhao, 2014; Sofouli & Vonortas, 2007; Suzuki, 2004; Yang et al., 2009; Motohashi et al., 2009; Vásquez-Urriago et al., 2016). Although these studies provide important information on the structure, activities, and quantitative indicators of parks, they have their limitations. First of all, such studies often use quantitative methods.

Descriptive studies do not allow for a precise analysis of the performance of science and technology parks in the context of their impact on local economic development and innovation. Many of these studies focus on indicators related to area, number of companies and employment, but lack a more in-depth analysis of the data that would allow understanding the real impact of parks on innovation, technology transfer or the effectiveness of cooperation with research institutions. The studies presented in the literature also rely on different sets of indicators, which makes it difficult and sometimes impossible to compare the performance of individual institutions.

The study aimed to assess the performance of science and technology parks through their impact on the performance of the companies located there. For this purpose, comparative questionnaire surveys of companies located in parks and those with offices outside the parks were used (Diez-Vial et al., 2017; Vásquez-Urriago et al., 2014; Barge-Gil & Modrego, 2011; Colombo & Delmastro, 2002;

Löfsten & Lindelöf, 2002). Among the most frequently compared indicators, the authors highlighted the level of employment, sales volume, profitability, market share, number of jobs, and R&D expenditure. Questionnaire surveys conducted among park managers were also used (Albahari et al., 2018).

Another research method used to assess park performance is benchmarking. The aim of such studies was to support the management and staff of science and technology parks in the process of strategic and operational management by demonstrating the best results achieved by parks in individual management areas and identifying the best practices applied by parks in Poland (Hołub-Iwan et al., 2012). Benchmarking analysis of parks in Poland has proven to be a valuable tool for assessing their current status. However, each method has its limitations – in this case, the problem was the overly broad questionnaire and the use of indicators adapted to specific stages of park development. Benchmarking studies were financed by EU funds but are currently not carried out due to lack of funding.

A performance indicator matrix was also used to evaluate the parks' performance. The main objective of the research was to identify the key characteristics of an effective technology park from the perspective of various stakeholders, such as universities, local governments, public institutions and private investors. The research also used data from 120 interviews with representatives of these various groups. The matrix was developed specifically for parks in the early stages of maturity, which is its main drawback (Dąbrowska, 2011).

Significant, comprehensive studies covering technology parks and other innovation centers in Poland were carried out in 2022. The report (SOOIPP, 2022) used a diverse research methodology, including secondary data analysis and a questionnaire survey. The secondary data analysis was based on the use of previous reports on the activities of Innovation and Entrepreneurship Centers for 1998–2020, standards for the functioning of innovation centers, as well as accreditation systems developed at the national and regional levels.

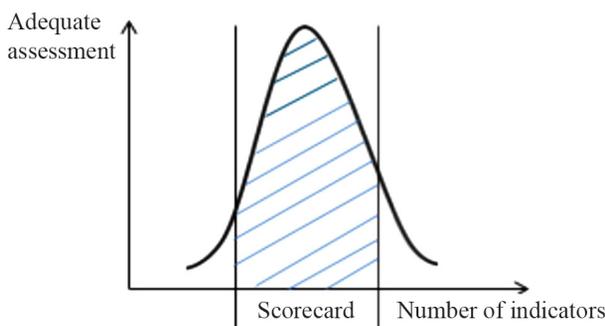
The use of existing reports and standards, although valuable, may result in the perpetuation of previous assumptions or limitations of research, especially if the data are partly outdated or based on different socioeconomic conditions. The questionnaire study relied partly on self-assessment by respondents, which is associated with the risk of subjectivity. Data may be distorted due to different interpretations of questions or a tendency to present the activity in the best possible light.

The report presents various indicators regarding the performance of science and technology parks, but the authors do not provide an assessment of the reliability of the indicators presented. The report also contains the values of the indicators achieved by individual parks, which differ in size, level of employment and nature of activities, which makes it difficult to unambiguously assess the performance of individual units.

The analysis of the literature sources shows that only individual aspects of STP performance are exclusively examined. There are practically no studies that evaluate it holistically (or in a complex manner). This situation makes it impossible to compare the activities of individual parks with each other, and the analysis of their impact on company performance results is not feasible. This necessitates the need to propose such a methodology.

### 3. Methodology for studying the quantitative assessment of the state functioning of scientific and technological parks NTP

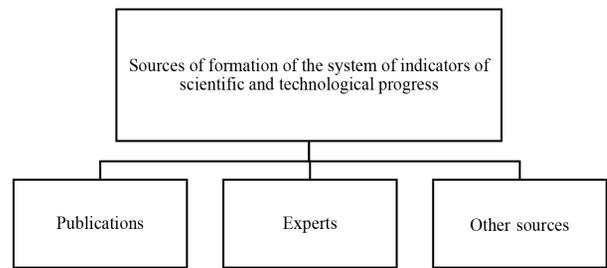
From the literature review it is clear that science and technology parks are complex socioeconomic systems. In reality, they are manifested by many different aspects. Their formalized expression is indicators. In order to adequately assess the state of scientific and technological parks, it is necessary to form a system of indicators. The main requirement in this system is the number of indicators. It is directly related to their importance. If the number of indicators is too small, this will affect the adequacy of the assessment, since important aspects of the STP activity may not be taken into account, and vice versa – if there are too many of them – then in addition to important ones, the system may include indicators of secondary importance. This complicates the calculations, increases their subjectivity, etc. Thus, the system of indicators of STP activity should consist only of indicators that are essential for assessing the STP activity (Figure 1).



**Figure 1.** Basic diagram of the formation of the system of indicators (source: compiled by the authors)

At the first stage, a list of possible indicators is compiled. The source is scientific articles, monographs, books on this topic. The list can be supplemented by a survey of experts. Such a need may arise if there is a need to take into account the specifics of the functioning of the scientific and technological progress. An additional source can be various directives, departmental documents, reports, etc. (Figure 2).

Based on the list of possible indicators, their system is formed, i.e., unimportant indicators are removed from it. This can be done using a table (Table 2).



**Figure 2.** Sources of formation of the system of indicators of scientific and technological progress (source: compiled by the authors)

**Table 2.** Table of formation of the system of indicators based on their list (source: compiled by the authors)

No.	Source	The source provides the following indicators			
		1st	2nd	...	.... n- th
1					
2					
...					
i-th					
n-th					
Total		$\Sigma_1$	$\Sigma_2$	...	$\Sigma_n$

The system of indicators, depending on their number, can be of one or several hierarchical levels. This circumstance arises if it is necessary to determine their weights by expert means. Experts can adequately assess only a limited number of indicators. In literary sources, without any evidence, it is indicated that it should not exceed 10–12. Therefore, single-level systems of indicators make sense in the case when it consists of a small number of them.

In a multi-level system, homogeneous indicators are combined into blocks. Calculations based on such a system are made as follows. First, the values of each block are determined by summing up the products of the values and weights of its indicators. After that, the weights of the blocks are determined and, accordingly, taking into account the already determined values, they are combined into an index that generally reflects the state of the scientific and technological progress (Ginevičius, 2009).

A quantitative approach and its methods are an appropriate tool for quantitative assessment of the state of functioning of scientific and technological progress.

Quality plays a key role in modern society, as it determines the degree of satisfaction of consumer needs, the efficiency of processes and the competitiveness of products or services. Given the diversity of objects of assessment, there is a need for a universal science that would allow a systematic approach to measuring quality. Qualimetry is just such a science – a discipline that develops principles, methods and means of quantitative assessment of quality regardless of the area of application. It allows standardizing approaches to assessment, ensuring the

objectivity of comparisons and making informed decisions in any area of activity where quality is important.

Assessing the quality of socio-economic systems is a complex and multi-faceted process that requires taking into account numerous factors that influence the efficiency of such systems. Socio-economic systems include, in particular, enterprises, economic sectors, territorial communities, regions and states as a whole. The quality of these systems is determined by the ability to consistently meet the needs of the population, adapt to changes in the external environment, ensure social justice, economic efficiency and sustainable development. Both quantitative and qualitative indicators are used for assessment - employment level, labor productivity, population income, poverty level, access to services, human development indices, etc. The system's ability to self-organize, develop innovatively and manage resources effectively is also important. The qualimetric approach in this context allows formalizing the assessment, constructing integral indicators and comparing different socio-economic systems with each other to identify best practices and areas for improvement.

The application of qualimetry to the multi-criteria assessment of science and technology parks (STP) is an appropriate tool for formalizing the analysis of their effectiveness, innovation potential and socio-economic impact. STPs are complex socio-economic entities that unite infrastructure, scientific institutions, business structures and investors to promote technological development.

It allows for a systematic consideration of many criteria for assessing scientific and technological progress. Such as the level of commercialization of scientific developments, the number of startups created, investment volumes, the productivity of scientific personnel, indices of cooperation with business, the efficiency of resource management and the impact on regional development. Thanks to the development of a single assessment scale and the construction of an integral quality indicator, qualimetry provides the opportunity for an objective comparison of scientific and technological parks among themselves, identifying their strengths and weaknesses and making informed strategic decisions to improve their competitiveness and efficiency.

The main advantage compared to the above -considered straightforward methods of multi-criteria assessment is that qualimetry methods do not require the labor-intensive process of determining the weights of indicators by expert means and thus significantly increases the adequacy of calculations.

To determine a single assessment scale, it is proposed to apply nonlinear normalization using the error function (error function – erf), which provides a more flexible and adequate display of the weight of various indicators in the overall assessment. Unlike linear normalization, which equally scales all values in a fixed range (for example, from 0 to 1), nonlinear normalization allows you to pay more attention to those values that are critical for assessing quality, and smooth out the impact of anomalous or too high indicators that can distort the results.

The error function, which has a sigmoid shape, is especially useful in conditions where the indicators have a nonlinear effect on the final quality – for example, when an additional increase in the indicator after a certain level no longer provides a significant increase in overall efficiency. Thus, the use of the erf function allows for the specificity of the parameters being assessed, increases the accuracy and validity of the integral quality indicator, and facilitates a fairer comparison of science and technology parks within the framework of multi-criteria analysis. As a result, an adaptive scale is formed that better reflects the real value of individual characteristics of the object of assessment.

The error function has applications in various fields of activity and scientific fields. Oldham et al. (2008) presents a fundamental review of special functions, including the error function erf (x) and its complement erfc (x). Their analytical properties, graphs, derivatives, limits and series are described. The publication is of a reference nature and is intended for engineers, mathematicians working with applied problems.

Ersoy (2021) proposes new rational approximations of the error function, intended to improve the accuracy of numerical calculation of erf (x) at low computational costs. The article contains a mathematical justification of the methods, their comparison with classical approximations and numerical examples.

Howard (2022) presents a method for constructing analytical approximations of the error function with arbitrarily high accuracy. The author uses decomposition into piecewise rational functions with control of absolute and relative error.

Demidov (2023) covers solutions of classical equations of mathematical physics, including the heat equation. The error function is considered as part of the analytical solution of the problem of temperature distribution in an infinite medium.

Various functional dependencies have found application in various research areas in such works (Kupriyanov et al., 2023; Khomiak et al., 2024b; Dyadyura et al., 2024). For example, the authors (Cherniak et al., 2024; Trishch et al., 2024) suggest approaches to qualimetrics assessment security production processes. Security efficiency, accuracy and reliability are key aspects to achieve quality results (Fedorovich et al., 2024; Hrinchenko et al., 2019; Trishch et al., 2019). Articles authors (Hovorov et al., 2025; Khomiak et al., 2025, 2024a) are combined research quality, reliability and efficiency critically important technical systems – energy infrastructure.

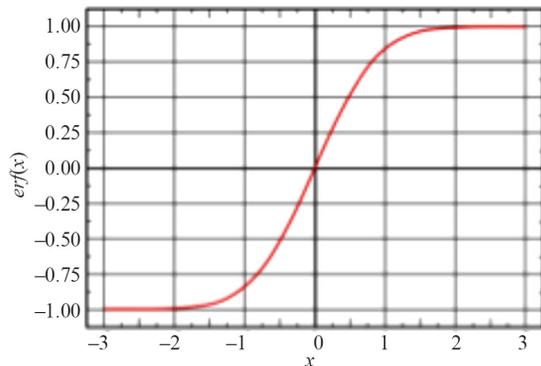
The error function has the following form (1):

$$\operatorname{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt, \quad (1)$$

where:  $x$  is the upper limit of integration. This is the argument of the error function, that is, the number for which the  $\operatorname{erf}(x)$  value is calculated. The larger the value of  $x$ , the closer the result of  $\operatorname{erf}(x)$  to one.

$t$  is the integration variable. This is an auxiliary variable over which the integration is performed. It is **internal** and

does not appear in the final answer – after the integral is calculated, it “disappears”. Figure 3 shows a graphical representation of the function errors (1).



**Figure 3.** Graphical view of the error function (source: compiled by the authors)

From the graphical view of the error function, it is clear that the OX axis is limited by an interval of approximately  $(-3; 3)$ , within which the most significant change in the function values occurs. However, in the context of assessing the quality of scientific and technological progress, the indicators used for analysis (e.g., the number of patents, the volume of attracted investments, the number of startups that entered the market, etc.) have different units of measurement, scales, and value ranges. In order to effectively apply the error function to such heterogeneous data, it is necessary to adapt it by scaling the O X axis.

This process involves transferring each real indicator to a corresponding normalized range corresponding to the interval  $(-3; 3)$ , taking into account the minimum, maximum, and target (reference) values of each indicator. Such a transformation can be carried out by introducing scaling parameters (e.g., mean and standard deviation or estimation limits), which allow data from different scales to be compared in one integrated environment.

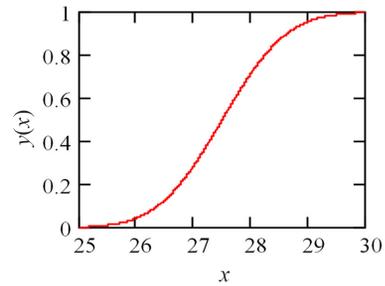
Thanks to this adaptation, the error function becomes a universal tool for normalization – it allows to reduce the influence of outliers, increase the significance of critical values and better reflect the real “value” of each indicator in the overall evaluation system. Thus, it is possible to correctly integrate heterogeneous criteria into a single multi-criteria indicator of the quality of scientific and technological progress, maintaining logical and mathematical consistency in the model.

As a result of the transformation of function (1), using the method of dividing segments in a given ratio, we obtain the function (2):

$$y(x_i) = \frac{1}{2} + \frac{1}{2} \operatorname{erf} \left( -2 + 4 \frac{x_i - a_i}{b_i - a_i} \right), \quad (2)$$

where  $\operatorname{erf}(x)$  is the error function,  $a_i$  is the minimum value of the  $i$ -th STP indicator,  $b_i$  is the maximum value of the  $i$ -th STP indicator;  $x_i$  is the actual value of the  $i$ -th STP indicator. Note that the function  $y(x)$  at point  $a$  takes a value close to zero, and at point  $b$  – close to one. The graphical

form of function (2) for numerical values  $a = 25$  and  $b = 30$  is shown in Figure 4.



**Figure 4.** View of function (2) provided that  $a = 25$  and  $b = 30$

The methodology for multi-criteria assessment of scientific and technological progress consists of several steps:

1. It is necessary to define an assessment matrix that takes into account the combination of the above criteria. In the absence of legislative or regulatory documents, it is recommended to use expert assessments.
2. It is necessary to determine  $x_i$  – the actual value of the  $i$  – that indicator of scientific and technological progress.
3. It is necessary to determine the limit values for each criterion ( $a_i$  is the minimum value of the  $i$ -th indicator,  $b_i$  is the maximum value of the  $i$ -th indicator). For this stage, it is recommended to use expert assessments. They may be different, depending on the objectives of the analysis.
4. It is necessary to determine the assessment of the  $i$ -th indicator of scientific and technological progress on the dimensionless scale OY in the range  $(0, 1)$ , using Equation (2).
5. To obtain a complex (multi-criteria) indicator, it is proposed to use one of the averaging methods, for example, the arithmetic mean.

## 4. Results

The proposed methodology was tested based on the activities of eight Polish scientific and technological progress institutes. Table 3 presents quantitative information for the first and second stages of calculations.

The complete system of indicators of the NTP activity consists of six blocks: general characteristics of parks, indicators of tenants, services, qualifications, franchise activities of parks, as well as indicators of the creation of a park network. Using step 3, the limit values for each indicator were determined ( $a_i$  is the minimum value of the  $i$ -th indicator,  $b_i$  is the maximum value of the  $i$ -th indicator). The results are presented in Table 4.

Using the fourth stage of the methodology, we determined the assessment of the  $i$ -th indicator of scientific and technological progress on the dimensionless scale OY in the range  $(0, 1)$ , using Equation (2). The results of applying nonlinear normalization using function (2) are presented in Table 4. Using the fifth stage of the methodology, we determined the complex indicator. The results are presented in Table 5.

**Table 3.** Information on quantitative indicators of scientific and technological progress (source: compiled by the authors)

No	Indicators	Measure unit	Elbląski Park Technological	The Science and Technology Park Poland-East in Suwałki	Tarnobrzieski Park Industrial-Technological	Olsztynski Park Science and Technology	Park Naukowo-Technologiczny w Ełku	Kielecki Park Technological	Puławski Park Naukowo-Technologiczny sp. z oo	Białostocki Park Science and Technology
General characteristics of science and technology parks, $x_i$										
1	How many years has the park been operating on the market?	Years	13.00	20,00	10.00	11.00	12.00	17.00	9.00	13.00
2	Office space in the park	m <sup>2</sup>	2,000,	2520,00	2,000.00	4517,71	280,00	16,437.00	1,438.00	2721,48
3	The occupancy rate of the park's office space	%	95.00	85.00	90.00	88.84	90.00	97.00	78.00	74.17
4	Number of laboratories operating in the park	Number	3.00	3.00	1.00	20.00	1.00	5.00	5.00	10.00
5	Degree of laboratory space occupancy	%	100.00	71.00	100.00	75.88	78.00	95.00	47.00	100.00

**Table 4.** Limit values of indicators of the general characteristics of scientific and technological progress (source: compiled by the authors)

No	General characteristics of science and technology parks, $x_i$	
$i$	$a_i$	$b_i$
1	0	20
2	0	16,437.00
3	0	97.00
4	0	20.00
5	0	100.00

**Table 5.** Numerical values of the estimates of the  $i$ -th indicator of scientific and technological progress (source: compiled by the authors)

Name of the Science and Technology Park							
Elbląski Park Technological	The Science and Technology Park Poland-East in Suwałki	Tarnobrzieski Park Industrial-Technological	Olsztynski Park Science and Technology	Park Naukowo-Technologiczny w Ełku	Kielecki Park Technological	Puławski Park Naukowo-Technologiczny sp. z oo	Białostocki Park Science and Technology
0.80	1.00	0.50	0.61	0.71	0.98	0.39	0.80
0.02	0.02	0.02	0.10	0,00	1.00	0.01	0.03
1.00	0.98	0.99	0.99	0.99	1.00	0.96	0.93
0.02	0.02	0.01	1.00	0.01	0.08	0.08	0.50
1.00	0.88	1.00	0.93	0.94	0.99	0.43	1.00
Complex indicator. (Arithmetic mean)							
0.568	0.580	0.504	0.726	0.530	0.810	0.374	0.652
Place							
5	4	7	2	6	1	8	3

Unlike existing methods for assessing the state of functioning of socio-technical systems, which are often based on complex mathematical models, the proposed use of the error function has an important advantage – its simplicity and accessibility due to integration into the Microsoft environment Excel. This means that the process of data normalization and construction of an integral quality indicator can be implemented without developing specialized software, using standard office tools, which significantly facilitates the implementation of the methodology in practice.

Due to this, the approach becomes maximally universal and adaptive. It can be used to assess objects of different nature – from technological processes and products to the level of knowledge management or innovative activity in different sectors of the economy. Given the simplicity of implementation, these mathematical dependencies can be integrated into internal regulatory documents of enterprises, institutions or organizations in the form of a regulated procedure for assessing the state of operation. This allows you to create a unified system of its control and improvement, which does not depend on subjective judgments and is suitable for automation. In the future, such a model can serve as a basis for creating corporate or industry assessment standards, with the possibility of scaling at the regional or national level.

## 5. Discussion

The results of the complex evaluation of STP performance using non-linear normalization of indicator values confirmed the validity of this approach. Simultaneously, the multi-criteria evaluation theory is expanded, moving to a new, higher stage. The advantages of the new approach manifest in a significant reduction of calculation costs and an increase in evaluation adequacy. By their nature, STPs are large, complex socio-economic systems. The condition for their existence is continuous development, which must be goal-oriented (or directional). This can be achieved if there is an ability to determine the state of development at a desired point in time. Until now, such an opportunity was not offered; this methodology fills that gap. Both the scientific and practical significance of such a methodology are confirmed by the results obtained. Another advantage is that standard computing tools can be used to determine the index reflecting the STP performance results. This significantly facilitates the implementation of the proposed methodology.

## 6. Conclusions

Science and technology parks play a special role in the knowledge-based economy, as they create conditions for the commercialization of innovations, facilitating interaction between entrepreneurs, scientific institutions, etc. In this regard, issues of their functioning are given much attention in scientific research. At the same time, many important issues remain unresolved, including a quantita-

tive assessment of the state of functioning of science and technology parks (STP). At the same time, without this, it is impossible to compare the results of the activities of individual parks, it is impossible to study their impact on the results of enterprises, etc. The assessment of the state of activity of scientific and technical parks as complex socio-technical systems is based on a system of indicators that reflect all the main aspects of the functioning of parks. Two approaches to such an assessment are possible – linear and nonlinear.

The essence of the first is that the importance of the indicator does not depend on its value. In this case, the weights of the indicators are additionally determined by experts. This affects both the labor intensity and the adequacy of the calculations. The nonlinear approach used in the article allows avoiding the use of expert assessments, and the importance of the indicator is determined by the degree of nonlinearity of the functional normalization. In addition, nonlinearity corresponds to the fundamental theory of qualimetry, which is based on the fact that there are no linear dependencies in nature.

The method has been tested on the example of eight scientific and technological parks in Poland. Calculations show that it is universal, so it can be used to assess the condition of objects of different nature. The application of the proposed methodology is currently limited by the fact that there is no universally accepted system of indicators reflecting STP performance. Further research should be developed in two main directions: first, the formation of a unified system of indicators reflecting STP performance; and second, a deep and comprehensive analysis of their impact on company performance.

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