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Exploring the Determinants of Industry 4.0 Development Using an Extended SWOT Analysis: A Regional Study

Katarzyna Szum and Joanicjusz Nazarko *

Faculty of Engineering Management, Bialystok University of Technology, Wiejska Street 45A, 15-351 Bialystok, Poland; k.szum@doktoranci.pb.edu.pl
* Correspondence: j.nazarko@pb.edu.pl

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Abstract: Researchers and practitioners argue that in the global context of the Fourth Industrial Revolution, also labelled Industry 4.0, the regional dimension of industrial development remains equally essential. A region that effectively implements the concept of Industry 4.0 can accelerate by enhancing the manufacturing energy efficiency, thus contributing to the goals of the "Green Deal" policy. Therefore, to support the policy-making process, it is necessary to develop analytical tools exploring the determinants of the Industry 4.0 development. This paper presents a methodology of strategic analysis of a region in terms of the Industry 4.0 development potential. The core of the methodology is an extended Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis. The study identifies regional strengths and weaknesses, external incentives and disincentives, internal opportunities and threats, and external opportunities and threats with regard to the development of Industry 4.0, related technologies and the potential of increasing manufacturing energy efficiency. The research procedure is exemplified by the case of Podlaskie Voivodeship in Poland. The results of this study demonstrate the robustness of the proposed approach. The elaborated methodology can be used by decision-makers in designing strategies for the development of fourth-generation industry at a regional level.

Keywords: Industry 4.0; Fourth Industrial Revolution; Green Deal; manufacturing energy efficiency; SWOT analysis; extended SWOT analysis; regional development; Podlaskie Voivodeship

1. Introduction

In recent years, global industry has been shaped by the Fourth Industrial Revolution, also known as Industry 4.0. Compared to previous revolutions, the current one stands out by a much faster pace of change and an impact that extends into all areas of human activity [1–3]. This new concept reshapes the way production companies do business by introducing digital technologies and modern organizational and management methods [2–5]. Effective implementation of the concept results in significant benefits, including increased production efficiency, improved process flexibility, and faster reaction to evolving customer needs [5,6]. However, Industry 4.0 is also associated with many challenges. Its successful implementation requires considerable financial resources, qualified managers, engineers and workers, openness to new solutions, and effective cooperation of the business sector, administration, and scientific community [7–9]. According to Schwab [1], raising awareness of ongoing changes, taking up challenges, and seeking opportunities will help to shape the course of industrial transformation. The complexity and topicality of Industry 4.0 make it an issue widely debated by scientists and researchers all over the world. Many countries have created strategic documents and programs dedicated to the fourth generation industry, such as the German "High Tech Strategy 2020", the Chinese "Made in China 2025", the American "Advanced Manufacturing Partnership" and the French "La Nouvelle France Industrielle" [10]. Poland included the fourth-generation industry as one of the key priorities of the national economic policy in the major strategic document Strategy for Responsible Development [11].

Researchers and national governments focus on specific companies or industrial sectors. Much less attention is given to the broader issue of the development of Industry 4.0 in subnational geographical areas. In the current era of globalization, it appears essential to address this development on a regional scale. A region that implements the concept of Industry 4.0 can enhance its socio-economic situation, improve its competitiveness, and contribute to achieving the goals set by the "Green Deal" policy [12]. Industry 4.0 presents an excellent opportunity for regions. However, it also poses an enormous challenge related to the diversity and complexity of the involved processes. Therefore, the analysis of regional environment is essential for the success of the implementation. The paper studies conditions for the development of Industry 4.0 on a regional scale, which is a significant issue for the sustainable industrial development of regions and creates substantial opportunities to enhance the manufacturing energy efficiency [4].

One of the principal tools of territorial strategic planning is Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis. It is universally applicable and relatively unsophisticated and understandable to managers [13,14], and at the same time, it enables a multidimensional, dynamic diagnosis of a region. This tool is frequently used in territorial strategic planning and foresight studies [15,16] but there are few instances in the literature of the use of SWOT analysis in the context of the regional development of Industry 4.0 [9,15,17–22]. Thus, a significant research gap has appeared. The primary scientific goal of this paper is to elaborate a SWOT-based methodology enabling the strategic evaluation of the determinants and potential of the Industry 4.0 development at a regional level.

Traditional SWOT analysis focuses on the internal and external environment of a studied object and identifies and investigates four types of factors, i.e., strengths, weaknesses, opportunities, and threats [23]. However, such analysis is not detailed, as it only focuses on the overall picture of a research problem [24]. Therefore, traditional SWOT analysis is often modified or combined with other methods by researchers [24–29]. The authors propose to apply a newly structured extended SWOT analysis [15,25] to assess the development potential of Industry 4.0 on a regional scale. The proposed way of making the analysis more comprehensive is to extend it by an additional division of factors based on their timewise occurrence [15,25,26]. The result is an eight-field SWOT matrix. Furthermore, a SWOT analysis should not only allow one to identify factors but also to determine their importance [15,25] A comprehensive view of a research problem can be achieved with the help of adequate methods and tools and appropriately modified traditional SWOT analysis.

The article presents a methodology for evaluating the potential of a region to develop fourth-generation industry. The methodology is based on the STEEPVL approach (Social, Technological, Economic, Environmental, Values, and Legal factors) [26,30–32] and extended SWOT analysis, which is tested on the example of Podlaskie Voivodeship in Poland. Factors for the eight-field model of SWOT analysis were identified based on a literature review, statistical data, and expert opinions. Representatives of businesses, scientific, and administrative institutions evaluated the importance of the factors using a seven-point Likert scale. The results of the study were subjected to a statistical analysis, which allowed us to determine key factors from the perspective of the development of Industry 4.0 in the region. The proposed methodology is a comprehensive approach to the development of Industry 4.0 on a regional scale. It may be used to design a regional strategy for the development of Industry 4.0.

The contribution of this paper is both theoretical and practical. Firstly, it presents a methodology for evaluating the potential of the region in terms of Industry 4.0 development. Secondly, it demonstrates an example of the practical application of the developed methodology.

2. Literature Review

2.1. Fundamentals of Industry 4.0

Over the centuries, global societies and economies have undergone significant transformations which influenced their functioning and development [33,34]. Such rapid and wide-ranging changes are referred to as revolutions [2,35]. The agrarian revolution initiated a sequence of global social and economic transformations, changing the lifestyle from nomadic to settled. This revolution offered different ways of obtaining food via new agricultural production methods [1,33]. Another string of transformations started in the second half of the eighteenth century, which turned into a series of industrial revolutions. The First Industrial Revolution was powered by the invention of the steam engine, which started the transition from manual to machine labor [1]. This discovery entailed a change in the previous methods of organization and division of labor. As an essential element of railway transport, steam machines also played a crucial role in the development of transportation [36,37].

The internal combustion engine and electricity are the symbols of the Second Industrial Revolution, which commenced in the second half of the 19th century [38,39]. The launch of the first production line and mass production prompted significant technological development [37,40]. The second half of the 20th century saw the development of programmable controllers, which indicated the start of the next revolution [39]. The Third Industrial Revolution birthed microprocessors, semiconductors, computer systems, microcomputers, and the internet. These inventions contributed to the automation of production processes and the development of transport and communication methods [37,39,41].

Industrial revolutions have common features. All of them start with a breakthrough invention, which triggers further changes. Usually, they occur at the turn of the century and take several years [42]. The time frames, nature and scope of the revolutions vary depending on underlying political, economic, and sociocultural conditions [9]. Some scientists believe that the current changes in the global industry are attributable to the Third Industrial Revolution [43]. According to Schwab, the exponential character of the changes and their influence on all areas of human life indicate the commencement of the next industrial revolution [1].

Many authors use the term “Industry 4.0” as a synonym for the Fourth Industrial Revolution, which is an English version of the German term “Industrie 4.0”. The term was coined in 2011 at the Hannover Messe while developing a strategy based on innovative technologies for German economic policy [44,45]. Shortly after, it appeared in the German High-Tech Strategy 2020 for the digitization of the German manufacturing sector [46]. Since then, Industry 4.0 became a priority for universities, research centers, and enterprises [47] as well as regions and countries [48]. Scientists and experts address the issue of fourth-generation industry at conferences and in numerous scientific articles [49]. Research efforts mainly focus on the context of the implementation of Industry 4.0 technologies in production companies [50,51] or investigate the readiness of companies of a country for the Fourth Industrial Revolution [17,52–54].

Aiming to demonstrate the growing interest in the subject of Industry 4.0, Web of Science and Scopus databases were used to conduct a study into the frequency of use of the term “Industry 4.0” and related terms. The associated terms were selected based on the literature review. The results are presented in Table 1.

Based on Table 1, the number of publications related to the topic of Industry 4.0 shows a growing trend. The most frequently used terms were “Industry 4.0” and “Industrie 4.0”. Compared to 2017, the increase in the number of papers containing these terms and published in the Scopus database in 2019 was almost threefold. It should be noted that the analysis focused on selected phrases only; meanwhile, issues related to fourth-generation industry may have been discussed using different terminology.

Table 1. Frequency of use of the term "Industry 4.0" and related terms in publications issued in 2017–2019 in Web of Science and Scopus databases.

Term	Web of Science			Scopus		
	2017	2018	2019	2017	2018	2019
Industry 4.0/Industrie 4.0	1017	1430	1629	1285	2249	3425
Fourth Industrial Revolution/4th Industrial Revolution/Industrial Revolution 4.0/Revolution 4.0/4IR	227	438	472	284	591	950
Digital transformation	242	450	607	378	771	1209
Smart Manufacturing/Intelligent Manufacturing/Smart Production	326	439	469	431	716	826

Despite the growing interest in Industry 4.0, no uniform definition has yet been accepted [3,55,56]. The Third Industrial Revolution resulted in many advanced solutions, which are widely used in production now. However, the Fourth Industrial Revolution is elevating the industry to a new digital level [9,57]. The speed of changes and their impact on all areas of human activity make it difficult to define the concept clearly [55]. Therefore, most authors focus on technology characteristics while defining Industry 4.0 [9,56]. Technologies 4.0 are based on discoveries of the Third Industrial Revolution; however, they are more advanced and integrated [58–60]. According to several authors, the fundamental components of Industry 4.0 are additive manufacturing, augmented reality, autonomous robots, Big Data, cybersecurity, the Cloud, the Industrial Internet of Things, horizontal and vertical integration, and simulation [57,61–63]. In their publication, Ustundag and Cevikcan mentioned Cyber-Physical Systems instead of cybersecurity [64]. Under the supportive infrastructure for technologies 4.0, the authors also classified mobile technologies, sensors and actuators, cybersecurity, real-time location systems (RTLS), and radio-frequency identification (RFID) [64]. Hermann, Pentek, and Otto indicated the Internet of Things, the Internet of Services, Cyber-Physical Systems, and Smart Factory as the four major components of Industry 4.0 [49]. Meanwhile, Yáñez [65] listed 20 technologies specific for Industry 4.0. Based on a literature review, Pfohl, Yahsi, and Kurnaz [66] identified over 40 technologies and concepts related to the issue of Industry 4.0.

Just as the concept of Industry 4.0, fourth-generation technologies are not clearly defined either. The pace and scope of the changes and their impact on all areas of human activity make it impossible to create uniform and lasting definitions. The concept of fourth-generation industry can be understood as the aim to build integrated and interconnected production systems by using advanced and digital technologies [60,67]. This smart production platform allows one to monitor, manage, and control the production process more effectively and easily [62,63]. This creates significant opportunities to improve the energy efficiency of the manufacturing industry and make manufacturing more environmentally friendly [4,68].

Although Industry 4.0 focuses on technology, the development of its concept is not confined to the technological dimension alone. Technology development involves scientific institutions, innovation support centers, educated and experienced personnel, and clear regulations on the protection of property rights. Innovation depends on the financial capacity of companies, which is contingent upon their capital, the involvement of private investors, and the ability to generate funds. It is also important to consider national and local authorities, which may either incentivize or inhibit processes. As all of these factors are interrelated, the analysis of requirements for the development of Industry 4.0 should consider not only technological conditions but also economic, political, legal, and social aspects [2,3,9]. An exhaustive literature review of Industry 4.0, its technologies, and related principles has been conducted by Oztemel and Gursev [3].

2.2. SWOT Analysis—Conceptual Framework

Traditional SWOT analysis is one of the methods most frequently used for strategic planning. The name of the method is an acronym for Strengths, Weaknesses, Opportunities, and Threats [28,69–72]. Figure 1 presents the matrix of traditional SWOT analysis.

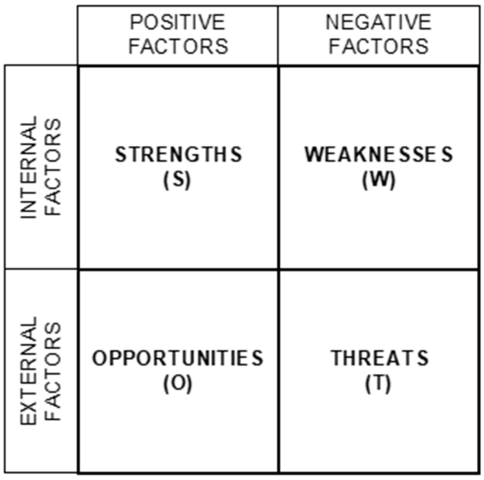

Figure 1. Traditional Strengths, Weaknesses, Opportunities, and Threats (SWOT) matrix [24].

Traditional SWOT analysis is a four-field matrix. Individual fields of the matrix are obtained by dividing the factors according to their source (internal and external) and the nature of their impact (positive or negative) [15]. Strengths and weaknesses are controllable factors that originate in the examined area. Opportunities and threats concern external aspects (environmental, legal, economic, etc.), which are outside the control of the object under analysis [24]. Factors may differ depending on the situation. Therefore, proper identification and classification of factors into appropriate groups is crucial for the analysis [72]. The popularity of SWOT analysis can be explained by its universal applicability, interpretive space, and relative simplicity [14,28,71]. It helps one to limit and organize information, which gives a comprehensive view of the situation and facilitates decisions on future actions [24]. Most publications use this analysis for companies and organizations, but it is also popular in research on national and regional issues [28].

The literature provides different views on the origin of SWOT analysis [14,24,28]. Most researchers claim that it was developed in the 1960s. However, different authors of the method and its place of origin are given. There are two predominant views. The first maintains that SWOT analysis came from satisfactory, opportunity, fault, threat (SOFT) analysis developed as part of a project conducted by Albert Humphrey at Stanford University [69,73,74]. The project involved several hundred enterprises and aimed to identify problems in strategic management processes and ways to eliminate them by creating an efficient change management system [75]. The presented method was called SOFT (satisfactory, opportunity, fault, threat) analysis. The second view maintains that the method was developed at Harvard Business School [72] during some classes. In both cases, no uniform definition was given for SWOT. Research shows a certain pattern of action, which coincides with the current form of the method [29].

A popular variant of SWOT analysis is the TOWS analysis (Threats, Opportunities, Weaknesses, and Strengths) proposed by Weinrich in 1982 [76]. He emphasized the importance of the external environment and suggested a change in the procedure for conducting the analysis. In this method, the analysis is carried out "from the outside to the inside", i.e., starting from the identification of opportunities and threats, then referring them to strengths and weaknesses. It allows determining the development strategies and choosing the most appropriate one [24,76]. The literature also provides a combination of both methods called TOWS/SWOT analysis. It consists of conducting both analyses and comparing their results [77,78].

Multidimensionality, simplicity, and integrative nature are the key advantages of SWOT analysis [24,72]. Despite its popularity, the traditional form of analysis has some limitations, which significantly affect the quality of results. These include, for example [28,71]:

- the inability to assess the importance of the identified factors;
- unspecified framework of analysis (which may include any number of factors);
- reliance on expert opinion.

Moreover, traditional SWOT analysis involves several risks [71]:

- describing factors too broadly;
- assigning factors to inappropriate groups;
- identifying factors subjectively;
- misinterpreting factors;
- basing the analysis on incomplete, outdated, or erroneous information.

Due to the existing limitations, SWOT analysis is often combined with other strategic management methods or analytical tools, which allows one to obtain a comprehensive view of the situation (Figure 2) [24,28].

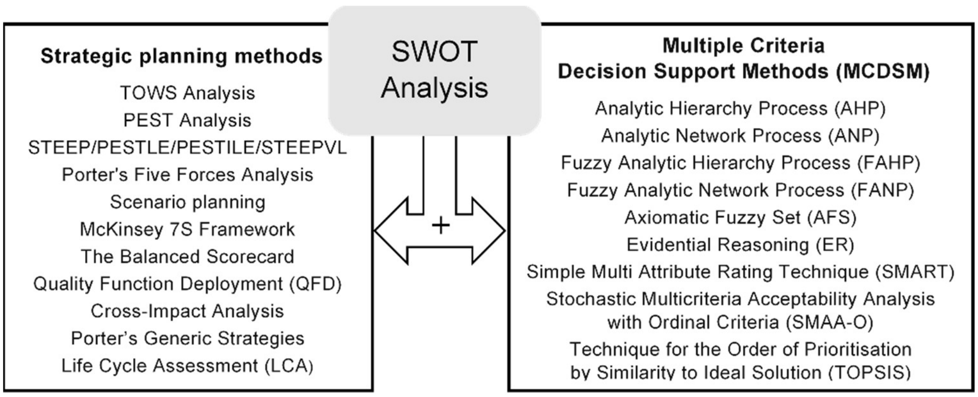

Figure 2. Selected methods and tools used in the literature in combination with SWOT analysis [24,28].

SWOT analysis allows the identification of a wide range of factors that are not qualitatively assessed. Therefore, all identified factors are assumed to be of equal value [28]. Combined with multicriteria methods to support decision-making (Figure 2), SWOT analysis enables the assessment and prioritization of factors. The Likert scale can also be used to prioritize factors. In this case, the identified factors are assessed using a three-, five-, or seven-point scale and the results are then statistically analyzed [26]. The importance of factors is valuable information, especially in the development of short-term strategies. Such an assessment allows the selection of the most important factors over the considered period. Combined with other strategic management methods (e.g., the PEST analysis (Political, Economic, Social, and Technological factors) and scenario method), SWOT analysis presents a broader and comprehensive outcome. An alternative way of making the analysis more detailed was presented by Sztando [25]. He proposed an additional division of factors by their timewise occurrence (existing and potential). This modification was first presented in a regional study of a local government unit [25]. The extension of the analysis by four additional dimensions reduces the risk of assigning factors to a wrong group.

2.3. SWOT Analysis in the Context of Regional Industry Development

Companies frequently use SWOT analysis at the initial stage of strategic assessment. However, the method can also be used for any other (organizational, institutional, sectoral, or conceptual) research area [15]. The analysis is also widely used in national and regional research as a starting point for the design of short- and long-term development strategies [18]. SWOT analysis can help to determine development directions for specific sectors of the national or regional economy, including the industrial sector. Fang et al. [19] used the method in this context, aiming to determine the industrial potential of the city of Yingkou in China. The authors identified factors for the four-field SWOT analysis and used them to establish four strategies for the industrial development of the city. Koshesh and Jarafi [20] analyzed the oil and gas sector in the Kurdistan region. Together with SWOT analysis, the authors also used PESTLE analysis (Political, Economic, Social, Technological, Legal, and Environmental factors), SPACE analysis (Strategic Position and Action Evaluation), FANP (Fuzzy Analytic Network Process), and FDEMATEL (Fuzzy Decision-Making Trial and Evaluation). Experts were involved in identifying and evaluating factors for the SWOT analysis. The variety of methods increased the accuracy of the results and made the study more comprehensive.

Kim and Park [21] used a modification of traditional SWOT analysis in a study addressing the development of the textile industry in Uzbekistan. As the fundamental limitation of traditional SWOT analysis, the authors indicated the inability of the method to assess the importance of factors and prioritize them. Consequently, they extended SWOT analysis by AHP analysis (Analytic Hierarchy Process), which consists of the comparison of variables in pairs. Factors of the SWOT–AHP analysis were selected, integrated, and classified based on the previously conducted SWOT analysis for the textile industry in Uzbekistan (Figure 3).

Figure 3. Model of the SWOT–AHP analysis [21].

In the four groups of SWOT analysis, the authors identified 16 factors (Figure 3). The factors were included in the questionnaire that was sent to representatives of textile companies from twelve regions of Uzbekistan. The study involved local, foreign, and joint venture companies. Next, the authors used software to determine the importance of the four groups of SWOT analysis and the weighting of factors in each group. The results of the study became the basis for creating alternative strategies for the development of the textile industry in Uzbekistan. The SWOT–AHP analysis made it possible to determine the importance of factors and their hierarchy, which significantly improved the quality of the conducted study. Additionally, the involvement of various types of companies allowed a practical view on the issue. The need to reduce the number of SWOT analysis factors due to the specificity of the AHP analysis is the major weakness of the approach [21].

Arbolino et al. [22] took a different approach while developing a methodology for monitoring the development of a sustainable industry on a regional scale. The authors combined SWOT analysis, Principal Components Analysis (PCA), and Hierarchical Cluster Analysis. They divided the regions into groups (clusters) with the same characteristics and described each group by specific variables. The proposed methodology was used in a study of Italian regions. Authors identified 34 indicators describing the Italian regional environment and separated them into three categories and six dimensions. The created composite index focused on the results of production systems considering the economic, ecological, socioeconomic, technological, and institutional contexts. Then, the factors were analyzed to identify the latent ones. As a result of cluster analysis, three groups of regions were identified, and a SWOT analysis was conducted for each group. Based on the features identified by statistical analyses of groups of regions, this approach allows identification of factors attributable to the four groups of the SWOT analysis [22].

In the literature, the extended SWOT analysis is rarely used in the context of territorial development of Industry 4.0. This issue is usually addressed using traditional SWOT analysis. For instance, Yılmaz [17] used the conventional approach in a study of the development of Industry 4.0 possibilities in Turkey. Based on a literature review and an analysis of reports and statistics on the Turkish industry, the author indicated the country's strengths, weaknesses, opportunities, and threats related to the implementation of Industry 4.0. However, Szum and Magruk [9] used STEEPVL analysis together with traditional SWOT analysis to study conditions for the development of Industry 4.0 in the Podlaskie Voivodeship. The authors identified factors using both analyses, local and foreign literature, statistical data, reports, and thematic yearbooks. This publication is an extension of these studies. It attempts to use a modified SWOT analysis to develop a methodology for the study and assessment of the region's potential to implement the assumptions of Industry 4.0.

3. Research Methodology

3.1. Identification of the Key Areas of the Regional Environment

This part of the study presents the proposed methodology, which is based on STEEPVL and extended SWOT analysis. The methodology intended for analyzing opportunities to develop Industry 4.0 in a region is depicted in Figure 4.

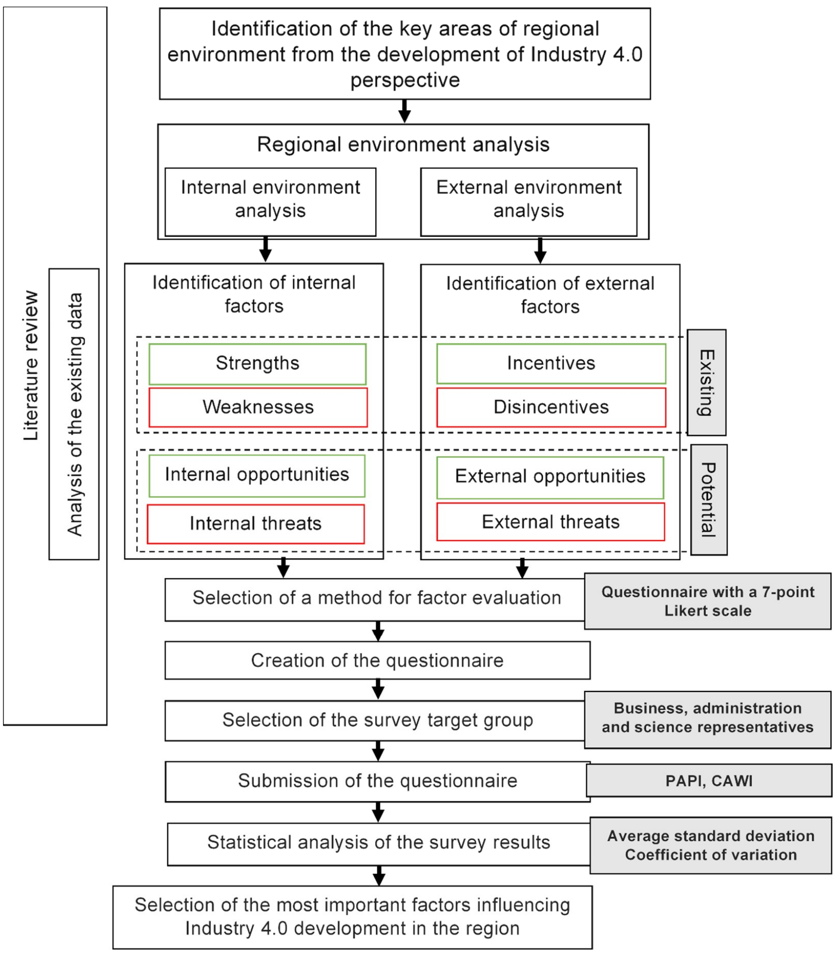

Figure 4. Research methodology implemented in the project.

The first stage of the research process was to identify the areas of the regional environment that are essential for the development of industry 4.0. An approach based on the STEEPVL method concept was used. STEEPVL analysis is essentially a heuristic method, which is used primarily to identify external factors (driving forces) affecting the development of the analyzed research area. The factors are located in several distinct fields of the regional environment [26,30–32]. Nedomlelová and Werner [79] used this approach in the study of the possibilities to develop Industry 4.0 in the Czech region of Ústí nad Labem. They limited their deliberations to four areas: research and development (R & D) and innovation, human resources and the labor market, education, and infrastructure. In their paper, they also analyzed the digitization of enterprises in the region as an important factor in the development of Industry 4.0, which can be considered the fifth important area of the regional environment. However, this study reviewed local and foreign literature to find four additional areas: industrial sector [80], business environment institutions [81,82], documents and initiatives supporting the development of industry [83,84], and location [85,86].

Figure 5 presents the nine identified areas, and Table 2 details the data analyzed in each of them.

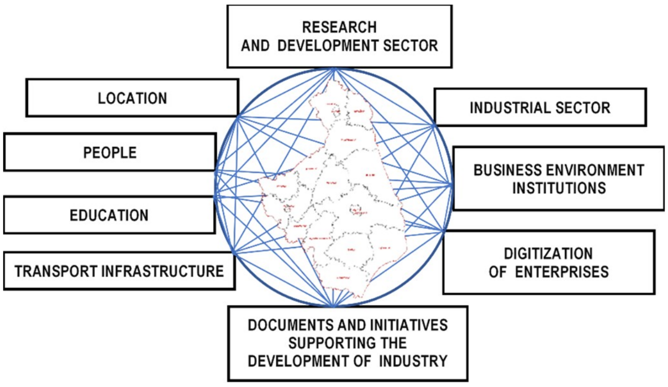

Figure 5. Areas of Industry 4.0 regional environment identified in the study.

Table 2. Data analyzed in nine identified areas of the regional environment.

Area	Analyzed Data
Location [85,86]	geographical location, distance from large markets, natural assets, natural resources, energy resources
People [79]	population size and structure, migration, residence structure, labor market
Education [79,87,88]	number of universities, number of people with higher education, graduate structure, education offer for Industry 4.0
Transport infrastructure [79,89]	quality and availability of transport infrastructure, transport routes running through the voivodeship
Research and development (R & D) sector [79,90]	number of R & D entities, expenditure on R & D activities, number of R & D personnel, degree of consumption of research equipment
Digitization of enterprises [79,80]	degree of use of computers and the Internet, the degree of use of digital technologies and services in enterprises
Industrial sector [80]	regional industry structure, industry energy intensity, economic indicators (remuneration, average employment, capital expenditure), industrial innovation (product and process innovations and improvements), local leaders, export structure, the attractiveness of the region for investments
Business environment institutions [81,82]	availability of business and innovation support institutions and the quality of their services
Documents and initiatives supporting the development of Industry 4.0 [83,84]	documents regulating issues related to I4.0, the cooperation of local units (enterprises, public administration units, and the scientific sector), innovation and entrepreneurship support initiatives

Nine areas were determined and analyzed (Figure 5). Then, based on the analysis of reports, yearbooks, and statistical data [91–100], quantitative and qualitative indicators were identified for each area (Table 2). The results achieved by the region were compared with other voivodeships to show the overall situation in the region against the national background. It allowed organizing the information, which is important considering the breadth of the Industry 4.0 issue and the multitude of processes taking place in the region.

3.2. Extended SWOT Analysis

The analysis of the identified indicators served as the basis for the SWOT analysis. To meet the goal of the study, the authors used an extended SWOT analysis, which is a modification of the traditional four-field SWOT analysis. It uses an additional criterion, i.e., the occurrence of factors depending on time. Factors are additionally classified into already existing and potential [101,102]. Such an analysis has been used to study regions. For instance, in the foresight project Nanotechnology for Podlaskie [26], it was used to analyze the possibilities of nanotechnology development in Podlaskie Voivodeship. Furthermore, the analysis was used in the Regional Economic Foresight of Mazowieckie Voivodeship [103–105].

Figure 6 depicts the groups of the extended SWOT analysis and Figure 7 presents the analysis matrix.

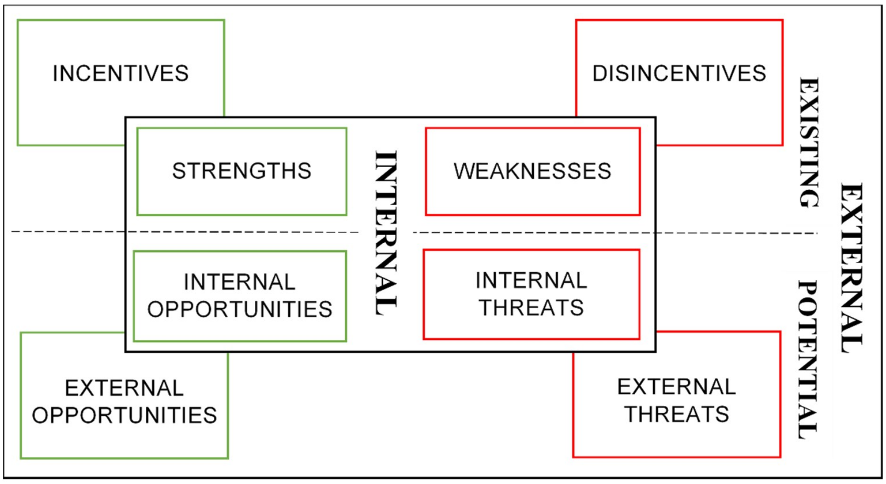

Figure 6. Groups in SWOT Plus [15,25,26].

	INTERNAL		EXTERNAL	
	POSITIVE	NEGATIVE	POSITIVE	NEGATIVE
EXISTING	STRENGTHS (S)	WEAKNESSES (W)	INCENTIVES (I)	DISINCENTIVES (D)
POTENTIAL	INTERNAL OPPORTUNITIES (IO)	INTERNAL THREATS (IT)	EXTERNAL OPPORTUNITIES (EO)	EXTERNAL THREATS (ET)

Figure 7. Matrix of the extended SWOT analysis [15,25,26].

According to Figures 6 and 7, the extended SWOT analysis consists of the division of factors by their source (internal, external), occurrence depending on time (existing and potential), and their nature (positive or negative) [15]. Such classification resulted in eight groups of factors [25]:

- strengths—positive factors, which originate in the studied area and exist during the study;
- weaknesses—negative factors, which originate in the studied area and exist during the study;
- incentives—positive factors, which originate in the external environment and exist during the study;
- disincentives—negative factors, which originate in the external environment and exist during the study;
- internal opportunities—positive factors, which may originate in the studied area;
- external opportunities—positive factors, which may originate in the external environment;
- internal threats—negative factors, which may originate in the studied area;
- external threats—negative factors, which may originate in the external environment.

The factors were identified based on a literature review and a comprehensive analysis of the socio-economic situation of the region:

- national and regional statistical yearbooks and studies containing data on the national and regional situation of: economy, demographics, industry, agriculture, trade, transport, and digitization;
- studies on the investment attractiveness of regions;
- reports on the implementation of national and regional strategy objectives;
- reports on research and development activity, innovation support centers, and business environment organizations.

The research tool was a two-part questionnaire, in which the first part concerned the profile of respondent (gender, age, education, and type of the represented organization). The second part included the factors identified using the SWOT analysis. This part asked the respondents to use a 7-point Likert scale (1—little influence, 7—great influence) to assess the impact of the factors on the development of Industry 4.0. Electronic or paper questionnaires were delivered to representatives of businesses as well as scientific and administrative institutions. The involvement of local actors allowed the obtaining of a comprehensive view of the research problem. It also helped to identify priority areas for the regional development of Industry 4.0. The results were statistically analyzed to obtain basic statistical measures: arithmetic means, standard deviations, and coefficients of variation. Average assessment of the importance of factors and the level of variability of the assessment values were used to create a hierarchy of factors and identify key factors for the development of Industry 4.0 in the region.

4. Case Study

4.1. Characteristics of the Region

The case study approach is extensively used as a research method in the area of management of technology and innovation [106]. It appears to be a valid investigation method, especially when a comprehensive, detailed study is required [107]. The study was designed as a theory testing, with a single case study embedded for exploratory and descriptive purposes [108].

Based on the literature review and the analysis of the social and economic situation in Podlaskie Voivodeship, a study was conducted to investigate the possibilities to develop Industry 4.0 in this region of Poland. The research method was an extended eight-field SWOT analysis. According to Figure 5, nine areas of the regional environment were analyzed: location, people, education, transport infrastructure, the R & D sector, digitization of enterprises, industrial sector, business environment institutions, and documents and initiatives supporting the development of Industry 4.0. These areas were identified during the review of local and foreign literature on the fourth-generation industry.

The identified areas were used for the analysis of the internal and external environments of the region. Selected socio-economic, economic, technological, and spatial indicators were discussed based on the European, national, and regional documents, reports and statistical data (Table 2).

Located in the northeastern part of the country, Podlaskie Voivodeship is one of the sixteen Polish provinces. The external border of the voivodeship is the eastern border of the country (with Lithuania) and the European Union (with Belarus). The region has significant spatial variations in population density. The capital of the region Bialystok is the only city with a population of over 200 thousand. The population of Podlaskie Voivodeship is over 1184 thousand, with a declining trend due to negative natural growth and intense migration. The region has nineteen universities, with the largest being the University of Bialystok and Bialystok University of Technology. In 2018, people with higher education constituted 27.4% of the total number of professionally active inhabitants [91].

Table 3 presents the selected characteristics of Podlaskie Voivodeship in the areas of Industry 4.0 regional environment.

Table 3. Selected characteristics of Podlaskie Voivodeship in the areas of Industry 4.0 regional environment.

Area	Factor		Value	Position in Poland
Location [92]	Podlaskie is located in the north-eastern part of Poland. The external border of the province is at the same time the eastern border of the country (with Lithuania) and the European Union (with Belarus)		N/A	N/A
People [93]	Population (thousand)		1184.5	14
	Economic age groups	Pre-working (%)	17.4	10
		Working (%)	62.2	4
		Post-working (%)	20.4	9
Education [93,94]	Students of higher education institutions (per 10 thousand population)		270	9
	Students of technical universities (per 10 thousand population)		72	8
	Number of people with higher education (%)		24.5	6
Transport infrastructure [94,95]	Railway lines (per 100 km^2 in km)		3.6	16
	Hard surface public roads [per 100 km^2 in km]		66.2	13
	Expressways (km)		61.2	12
	Motor vehicles [per 1000 population]		525	16
R & D sector [96]	Entities in Research and Development (R & D)		120	10
	Gross domestic expenditure on research and experimental development (GERD) per capita (in PLN)		220.6	9
	Funds from the sector of business enterprises financing R & D in intramural expenditures on R & D (%)		30.0	14
	Entities equipped with scientific and research equipment		40	12

Table 3. *Cont.*

Area	Factor		Value	Position in Poland
Digitization of enterprises [97]	Use of computers and the internet	Enterprises using computers (%)	94.8	12
		Enterprises with broadband access to the Internet (%)	92.9	13
		Employees using computers (%)	37.4	12
		Employees using computers with access to the Internet (%)	31.6	13
	Use of digital technologies	Sending orders via the internet (%)	32.3	8
		Receiving orders via the internet (%)	15.9	2
		3D printing (%)	1.6	12
		Industrial and service robots (%)	4.9	16
		Big Data analysis (%)	9.2	2
Industrial sector [98]	Average paid employment in the industry (in thousands)		53.9	16
	Average monthly gross wages and salaries in the industry (in PLN)		3461.5	14
	Investment outlays in the industry (in millions of PLN)		1993.3	15
	Expenditures on innovation activity for product and business process innovations in the industry (in millions of PLN)		328.1	15
	Share of net revenue from sales of new or improved products in net revenues from sales in the industry (%)		4.9	13
	Energy intensity of gross value added for manufacturing sector (kgoe/PLN)		0.39	14
Business environment institutions [99]	Number of innovation centers and business incubators		5	15
	Business supporting non-banking financial institutions		13	15
	Usage of services of business environment institutions by enterprises (%)		18.7	NA
Documents and initiatives supporting the development of Industry 4.0 [11,109]	European documents: Europe 2020 Strategy, Single Digital Market Strategy		N/A	N/A
	National documents: Long-term National Development Strategy 2030, Strategy for Responsible Development, National Regional Development Strategy		N/A	N/A
	Regional documents: Strategy for socio-economic development of Eastern Poland until 2020, Development Strategy of Podlaskie Voivodeship until 2020		N/A	N/A

Abbreviations: N/A—not applicable; NA—not available.

Podlaskie Voivodeship is characterized by a clean and diverse natural environment, which may foster the development of Industry 4.0. Four national parks are located there: Bialowieza National Park, Biebrza National Park, Narew National Park, and Wigry National Park. More than 45% of the voivodeship is covered by the EU Natura 2000 program. The region has great environmental values but itself is not rich in energy resources.

According to Table 3, compared to other voivodeships in Poland, Podlaskie had an inferior position in the majority of areas. The number of employed and the average monthly gross wages in the industry were much lower than the national average. The regional industry has low investment outlays and an inferior level of innovation. It is also characterized by low energy efficiency. This may be caused by the underdeveloped R & D sector. In 2018, the region had 120 entities in the R & D sector, of which only forty had scientific and research equipment. However, enterprises showed interest in using digital technologies and online services. The healthcare industry is expanding dynamically in the region. The Polish Eastern Medical Cluster connects universities, innovative enterprises, hospitals, and health centers.

In comparison with the rest of the country, Podlaskie Voivodeship has a relatively poorly developed transport infrastructure with a rare road and railway network. There is high inequality in terms of the accessibility of municipalities to urban centers. Railroad infrastructure is of low quality but is being currently modernized. Currently, three international transport projects are being implemented through the region—Via Baltica, Via Carpatia, and Rail Baltica. A great advantage for regional enterprises could be the proximity of Eastern markets (Belarus, Ukraine, Russia).

The situation of the region in terms of higher education and scientific staff is quite favorable. There are three significant universities in Bialystok, the capital of the Podlaskie Voivodeship. Bialystok University of Technology has great educational and research potential in the fields of Industry 4.0 technology.

The region has moderately numerous innovation support institutions, including industrial parks, science and technology parks, technology transfer centers, and business incubators [9,100,110]. These institutions offer material and financial support to foster knowledge transfer, commercialization of research, and the cooperation between businesses and science centers [9]. Activities of business environment institutions include events and competitions aimed at developing the innovativeness of regional companies. Cooperation of business, science and administration is particularly visible in special economic zones and cluster structures. Currently, three clusters are involved in activities related to the development of the concept of Industry 4.0—the Polish Construction Cluster, Metalworking Cluster, and InfoTECH Technology Cluster. The most important regional structures are involved in the activities related to the launch of the Northeastern Industry Center of the Future.

At the European, national, and regional level, there are documents and regulations that directly or indirectly relate to the issues of Industry 4.0. They create a framework to support the development of "Industry 4.0" from European and national funds.

4.2. Extended SWOT Analysis of the Region

Based on the analysis of Podlaskie Voivodeship, the potential for the development of "Industry 4.0", a list of its strengths and weaknesses, incentives, and disincentives of its environment, as well as related internal and external opportunities and threats has been generated by an expert panel. The experts were selected deliberately based on their competence and experience. The study included 39 experts from the region. They represented universities (30% or 12), enterprises (30% or 12), public foundations (17.9% or 7), technology parks (10% or 4), academic incubators (7.7% or 3), and a technology transfer center (2.6% or 1). The brainstorming technique has been used to identify SWOT factors. The analysis of the areas of Industry 4.0 regional environment produced factors for eight dimensions of the extended SWOT analysis (Tables 4 and 5).

After critical analysis, aggregation, and systematization of the proposals, 77 factors in total were identified by the expert panel:

- 11 strengths (S) and 15 weaknesses (W);
- 10 incentives (I) and 8 disincentives (D);
- 12 internal opportunities (IO) and 6 external opportunities (EO);
- 5 internal threats (IT) and 9 external threats (ET).

Table 4. SWOT analysis of Podlaskie Voivodeship in the context of the development of Industry 4.0 (existing factors).

	Existing Factors	
	Internal Factors	**External Factors**
	Strengths	**Incentives**
Positive Factors	S1: A strong support network for innovation and entrepreneurship S2: A group of innovative and competitive enterprises S3: The cooperation of enterprises in clusters S4: Activities and initiatives which increase knowledge among regional entrepreneurs S5: Relatively low labor costs S6: High potential of human resources in the region (many people with higher education) S7: A well-developed higher education system S8: Promotion of energy production from renewable sources in the region S9: Exceptional natural conditions of the region S10: The cooperation between regional universities and foreign education centers S11: Geographical location (the eastern border of the country and the EU, closeness to the capital city)	I1: EU innovation policy I2: EU cohesion policy I3: National support policy for the development of Industry 4.0 I4: Availability of funds (European and national) for the development of innovation I5: Tax breaks for entrepreneurs I6: Pushing for the implementation of energy-efficient green technologies I7: Creating a support network for entrepreneurs interested in implementing Industry 4.0 (the Future Industry Platform) I8: Worldwide popularity of the Industry 4.0 I9: Self-improvement trend I10: The availability of international research and publications dealing with issues related to Industry 4.0
	Weaknesses	**Disincentives**
Negative Factor	W1: Low attractiveness of the region for investment W2: The advantage of less technologically advanced sectors in the regional economy W3: Low competitiveness and innovation of the regional industry W4: Low use of digital technologies in regional enterprises W5: Low levels of entrepreneurship W6: Low investment outlays in the regional industry W7: Low wages in the industrial sector W8: Weakness of the regional R & D sector W9: Low energy efficiency of basic industries W10: Low expenditure on research and development in regional enterprises W11: Emigration of competent staff from the region W12: Low quality and availability of transport infrastructure W13: Lack of assumptions for Industry 4.0 in regional strategic documents W14: Negative demographic trends (negative population growth, aging population) W15: Limited energy resources of the region	D1: Negative economic image of the region D2: Inflexible education system D3: Unclear and unstable legislation D4: The brain drain of Industry 4.0 technology specialists to high-income regions D5: A negative image of entrepreneurs in Polish society D6: High costs of implementing new energy-efficient technologies D7: Industrial espionage in cyberspace D8: A long and complicated process of commercialization

Abbreviations: S—strength; W—weakness; I—incentive; D—disincentive; EU—the European Union; R & D—research and development.

Table 5. SWOT analysis of Podlaskie Voivodeship in the context of the development of Industry 4.0 (potential factors).

	Potential Factor	
	Internal Factors	**External Factors**
Positive Factors	**Internal Opportunities**	**External Opportunities**
	IO1: Increasing use of energy-efficient green technologies in the local industry IO2: A growing number of spin-offs and spin-outs in the region IO3: The improvement of the cooperation effectiveness among businesses, science, and administrative institutions IO4: The development of the regional R & D sector IO5: The potential of the regional ICT sector IO6: The improvement of the quality of technical infrastructure IO7: The improvement of the quality and availability of transport infrastructure IO8: Adapting regional policy to the challenges of the Fourth Industrial Revolution IO9: The creation of regional policy instruments supporting the development of innovation IO10: The radical increase in energy production from renewable sources IO11: The launch of the North-Eastern Center of the Future Industry Competence IO12: New fields of education at regional universities that meet the needs of the digital revolution	EO1: The finalization of the international transport corridors running through the region EO2: The inflow of international investors EO3: The external transfer of energy-efficient technologies to local industry EO4: Creating new forms of assistance for young entrepreneurs EO5: The establishment of the European Business Cooperation Network EO6: The simplification of commercialization procedures
Negative Factor	**Internal Threats**	**External Threats**
	IT1: Increased labor costs IT2: Increased unemployment IT3: Increased competition among entrepreneurs IT4: Further outflow of competent staff from the region IT5: Insufficient renewable energy resources in the region	ET1: Growing differences between regions ET2: Stagnation of the national economy ET3: Withdrawal of countries from the EU ET4: The fall of the Eurozone ET5: Reduction of the EU financial support ET6: International conflicts ET7: New legal restrictions on digital technologies ET8: The lack of public acceptance of digital technologies ET9: The shortage in energy supply (disturbances in electricity supply, higher energy prices)

Abbreviations: IO—internal opportunity; IT—internal threat; EO—external opportunity; ET—external threat; R & D—research and development; ICT—information and communication technologies; EU—the European Union.

Table 4 presents the existing factors (strengths, incentives, weaknesses, and disincentives) which characterize the Podlaskie Voivodeship in the context of the development of Industry 4.0.

Table 5 presents the potential factors (internal opportunities, external opportunities, internal threats, and external threats) which characterize the Podlaskie Voivodeship in the context of the development of smart manufacturing. They explain the aspects that may potentially have a positive or negative impact on the development of Industry 4.0 in the region.

4.3. Assessment of Factor Importance

The next stage of the research process was an expert assessment of the importance of the influence of individual factors. The evaluation was performed by the same group of experts using a purposefully designed research questionnaire. The survey was conducted using PAPI (Paper and Pencil Interviewing) and CAWI (Computer-Assisted Web Interviewing) methods. Experts were asked to use a 7-point Likert scale (1—little influence, 7—great influence) to assess the impact of particular SWOT analysis factors on the development of Industry 4.0 in Podlaskie Voivodeship.

Due to the construction of the survey, in which the respondents indicated their assessment of the significance of a certain factor in comparison with others from a given group, classical statistical measures were determined, i.e., arithmetic means (AM) of the assessment scores, standard deviation (SD) of these assessment scores, coefficients of variation (CV), as well as positional measures. The statistical evaluation of the results obtained by means of classical measures only slightly deviated from those obtained employing positional measures. Therefore, a decision was made to use classical measures in the description of results. The results of the statistical analysis helped to determine factors with the greatest and the least impact on the development of Industry 4.0. The value of the coefficient of variation for various factors is in the range of 18–31% and indicates a fairly high concordance of experts' evaluation.

Tables 6 and 7 present the results of the statistical analysis of the highest- and lowest-rated factors within each of the eight groups of SWOT analysis.

Table 6. Variability measures for factor assessment of the SWOT analysis.

Group	TGA	Highest-Rated Factors				Lowest-Rated Factors			
		Factor	AM	SD	CV	Factor	AM	SD	CV
Strengths	4.90	**S1**	5.35	1.20	22%	**S11**	3.53	1.09	31%
		S2	5.30	1.07	20%	**S4**	4.68	1.33	28%
		S6	5.15	1.31	25%	**S10**	4.80	1.26	26%
Incentives	5.10	**I4**	5.78	1.27	22%	**I9**	4.20	1.25	30%
		I2	5.60	1.14	20%	**I8**	4.45	1.27	29%
		I6	5.50	1.21	22%	**I10**	4.50	1.33	30%
Weaknesses	5.22	**W6**	5.63	1.02	18%	**W14**	4.38	1.04	24%
		W8	5.60	1.23	22%	**W12**	4.68	1.38	30%
		W9	5.58	1.00	18%	**W13**	4.88	1.17	24%
Disincentives	5.03	**D6**	5.80	1.09	19%	**D5**	4.18	1.26	30%
		D4	5.55	1.21	22%	**D7**	4.60	1.24	27%
		D3	5.20	1.43	28%	**D2**	4.90	1.42	29%

Abbreviations: S—strength; W—weakness; I—incentive; D—disincentive; AM—arithmetic mean; SD—standard deviation; CV—coefficient of variation, TGA—total group average.

Table 7. Variability measures for factor assessment of the SWOT analysis, cont.

Group	TGA	Highest-Rated Factors				Lowest-Rated Factors			
		Factor	AM	SD	COV	Factor	AM	SD	COV
Internal opportunities	5.35	**IO1**	5.80	0.92	16%	**IO11**	4.98	1.11	22%
		IO5	5.58	0.97	17%	**IO9**	5.10	1.13	22%
		IO4	5.53	1.17	21%	**IO7**	5.13	1.15	22%
External opportunities	5.57	**EO2**	5.85	0.96	16%	**EO5**	5.20	1.00	19%
		EO3	5.83	0.95	16%	**EO4**	5.35	1.18	22%
Internal threats	5.17	**IT4**	5.90	1.07	18%	**IT2**	4.20	1.22	29%
		IT1	5.40	1.29	24%	**IT3**	5.18	1.24	24%
External threats	4.91	**ET9**	5.63	1.27	23%	**ET4**	3.78	1.13	30%
		ET5	5.48	1.39	25%	**ET3**	3.80	1.43	31%
		ET7	5.45	1.27	23%	**ET6**	4.63	1.36	29%

Abbreviations: IO—internal opportunity; IT—internal threat; EO—external opportunity; ET—external threat; AM—arithmetic mean; SD—standard deviation; COV—coefficient of variation, TGA—total group average.

Among the strengths that have the greatest importance for the development of Industry 4.0 in the voivodeship, the highest scores were given to a strong support network for innovation and entrepreneurship—S1 (5.35)—and a group of innovative and competitive enterprises—S2 (5.30) (Table 6). The respondents had a strong agreement regarding the high ratings of these factors. Another important factor was the high potential of human resources in the region—S6 (5.15). The lowest importance was assigned to the geographical location (the eastern border of the country and the EU, closeness to the capital city)—S11 (3.53). The average score for this factor differed significantly from the rest and was lower than the total group average by 1.37. The respondents also had the least agreement regarding the assessment of this factor.

The arithmetic means of incentives ranged from 4.20 to 5.78. The strongest incentive was the availability of funds (European and national) for the development of innovation—I4 (5.78). Despite the high average value of assessment for this factor, it had a relatively large standard deviation (1.27). Another highly rated factors were the EU cohesion policy—I2 (5.60)—and pushing for the implementation of energy-efficient green technologies—I6. According to the respondents, the least significant factors were the self-improvement trend—I9 (4.20)—the worldwide popularity of the Industry 4.0—I8 (4.45)—and the availability of international research and publications dealing with issues related to Industry 4.0—I10 (4.50).

The average values of assessment in the group of weaknesses ranged from 4.38 to 5.63. The most important factors were low investment outlays in the regional industry—W6 (5.63—weakness of the regional R & D sector—W8 (5.60)—and low energy efficiency of basic industries—W9 (5.58). The latter factor had the lowest deviation of assessment values from the average (1.00) and the lowest coefficient of variation (18%). Negative demographic trends—W14 (4.38)—low quality and availability of transport infrastructure—W12 (4.68)—and the lack of assumptions for Industry 4.0 in regional strategic documents—W13 (4.88)—were perceived as less important for the development of Industry 4.0 in the region. The least consistency of the assessment was observed concerning the second factor, which had a coefficient of variation of 30%.

Assessment of factors in the group of disincentives ranged from 4.18 to 5.80. Respondents considered that the highest importance for the development of Industry 4.0 in the region was attached to the high costs of implementing new energy-efficient technologies—D6 (5.80)—the brain drain of Industry 4.0 technology specialists to high-income regions—D4 (5.55)—and unclear and unstable legislation—D3 (5.20). Industrial espionage in cyberspace—D7 (4.60)—and the inflexible education system—D2 (4.90)—received the lowest scores. The first of these factors had the highest standard deviation (1.50). A negative image of entrepreneurs in Polish society was perceived as the least significant—D5 (4.18). Assessment values of this factor were the most diverse, with a coefficient of variation of 30%.

According to Table 7, the assessment values of internal opportunities were between 4.98 and 5.80. This group of factors had the smallest deviations of 0.92–1.23 from the average. The importance of the increasing use of energy-efficient green technologies in the local industry was emphasized—IO1. The arithmetic mean of assessment values for this factor was 5.80. High scores were also given to factors of the potential of the regional information and communication technologies (ICT) sector—IO5 (5.58)—and the development of the regional R & D sector—IO4 (5.53). The analysis of the coefficients of variation for these factors (16%, 17%, and 21%, respectively) showed a relative agreement in the assessment of the respondents. The least important factor was the launch of the North-Eastern Center of the Future Industry Competence—IO11 (4.98).

Among the external opportunities, the inflow of international investors—EO2 (5.85)—and the external transfer of energy-efficient technologies to the local industry—EO3 (5.83)—received the highest scores regarding the impact made on the development of Industry 4.0 in the voivodeship. Assessment values of these factors had a low coefficient of variation (16%). The lowest importance was attached to the establishment of the European Business Cooperation Network—EO5. Evaluation of this factor slightly deviated from the average (1.00) and had a low differentiation (19%). According to the respondents, creating new forms of assistance for young entrepreneurs also had little importance—EO4 (5.35). However, the coefficient of variation (22%) was slightly higher than for the previous factor.

Average values of internal threat factors were in the range of 4.20–5.90. According to the respondents, the further outflow of competent staff from the region—IT4—and increased labor costs—IT1—had the most significant negative impact on the development of Industry 4.0 in the region. The averages of these factors amounted to 5.90 and 5.40, respectively. The increased unemployment—IT2—was perceived as the least important. The average of assessment for this factor was below the total group average and differed considerably from the rest of the results. Moreover, this factor had the highest coefficient of variation (29%).

The group of external threats had nine factors. Arithmetic means of factor assessment values ranged from 3.78 to 5.63. The shortage in energy supply—ET9 (5.63)—and the reduction of the EU financial support—ET5 (5.48)—were perceived as the greatest threat to the development of Industry 4.0 in the region. New legal restrictions on digital technologies—ET7 (5.45)—were perceived as having less importance. Respondents perceived the fall of the Eurozone—ET4 (3.78)—and the withdrawal of countries from the EU—ET3 (3.80)—as negligible external threats to the development of Industry 4.0. The respondents had the least agreement on the assessment of these factors, with the coefficient of variation of 30% and 31%, respectively.

According to Tables 6 and 7, external and internal opportunities have the highest importance for the development of Industry 4.0 in the region. Arithmetic averages of the factors for these groups were 5.57 and 5.35, respectively. Below the average were incentives (5.10), disincentives (5.03), external threats (4.91), and strengths (4.90).

5. Discussion of the Results

While few studies focus on the impact of regional circumstances on the development of Industry 4.0, it appears that there is a growing interest in this issue [9,79,84,111]. This paper is part of this trend. It proposes a new methodology of strategic analysis of a region in terms of the Industry 4.0 development potential. The core of the concept is the extended SWOT analysis, which explores an additional dimension, i.e., the occurrence of factors depending on time. Extension of the SWOT factors classification according to the typology: the region's strengths and weaknesses, external incentives and disincentives, internal opportunities and threats, and external opportunities and threats, enabled better recognition of the potential of the voivodeship and its environment in the development of Industry 4.0.

Industry 4.0 technologies should be particularly suitable for implementation in regions that have insufficient energy resources, especially renewable ones. High energy efficiency of the fourth generation technologies [112] will lead to an increase in the productivity of regional industry without exploiting additional energy resources. They are also a unique opportunity for the development of industry in regions with low environmental pollution, accelerating their development without the simultaneous degradation of the environment [4,112]. These premises are reflected in the results of the SWOT analysis for Podlaskie Voivodeship.

The results of the study suggest a moderately favorable environment for the development of Industry 4.0 in Podlaskie Voivodeship. Nevertheless, the implementation of the required assumptions is an enormous challenge for the region's economy. A relatively strong support network for innovation and entrepreneurship, fairly innovative and competitive enterprises, and the high potential of human resources in the region are the driving forces behind the development of Industry 4.0. The voivodeship also promotes the concept and offers assistance for its implementation. The conducive environment in the region results from the incentives to entrepreneurs and the availability of financial support provided under the EU cohesion policy. However, financial and technological barriers limit the transformation processes. Low investments in regional industry and the weak R & D sector impede the development of Industry 4.0 in the region. Innovation among regional entrepreneurs is limited by the high costs of new technologies and complicated commercialization procedures.

According to the experts, existing internal and external opportunities are the priority measures for the development of Industry 4.0. The region should take measures to improve the innovativeness of regional enterprises by increasing the use of energy-efficient green technologies in the local industry, leveraging the potential of the regional ICT sector, and to develop the R & D sector. In the opinion of the authors, the launch of the North-Eastern Center of the Future Industry Competence would have a significant influence on the success of these measures. It should be noted, however, that this factor received low scores in the survey. Such a perception of the Center should be a premise for the reconstruction and better promotion of its offer. The inflow of foreign investors and external transfer of energy-efficient technologies to the local industry would create significant opportunities for the implementation of the concept in the region. When planning activities leading to the implementation of the concept, the region should consider the potential further outflow of competent staff from the region and the possibility of increasing labor costs. Furthermore, consideration should be given to the shortage in energy supply and the reduction of the EU financial support as these factors would reduce the possibility to implement Industry 4.0 in the region.

Findings from the research presented in this paper correspond to the analysis carried out in the work of Nedomlelova et al. [79] and indicate the serious constraints of outlying regions in implementing the concept of Industry 4.0 as a way to accelerated socio-economic development.

The authors also want to indicate the possible negative effects of the implementation of the concept of Intelligent Manufacturing identified in the literature, which should be taken into account when creating a strategy for the development of Industry 4.0 in a region [113]. For example, the paper of Sony [114] indicates such negative effects as: (i) the negative impact of data sharing in a competitive environment; (ii) total implementation of Industry 4.0 is necessary for success; (iii) handling employees and trade union apprehensions; (iv) need for highly skilled labor; (v) socio-technical implications of Industry 4.0; (vi) cybersecurity and high initial cost. Additionally, the work of Oláh et al. [115] indicates the negative impact of Industry 4.0 on environmental sustainability as a result of air pollution, poor discharge of waste, and the intensive use of raw materials, information, and energy.

6. Conclusions

Industry 4.0 has a significant impact on the global economy. In the Fourth Industrial Revolution, technology is fundamental for building the competitiveness of enterprises, countries, and regions [9,102,116]. Industry 4.0 is critical in the context of the "Green Deal" policy and regional sustainable development and creates substantial opportunities to enhance manufacturing energy efficiency [4]. Effective implementation of Industry 4.0 in a region would improve its socioeconomic performance and strengthen its competitiveness. The effectiveness of the implementation of Industry 4.0 in a region is associated with a wide range of factors. These include not only the technological readiness of regional companies but also the variety of social, economic, ecological, and legal aspects [9,68,117–119]. The implementation of assumptions for the development of Industry 4.0 in a region requires an analysis of several areas [9] mentioned in this paper. Appropriate regional development strategies can be designed using key factors identified in the internal and external environments of the region.

There are inevitable limitations in the presented study. First, Industry 4.0 is developing intensively, but not all conditions for its implementation have yet been sufficiently recognized. Secondly, SWOT analysis, despite its usefulness and many advantages, has some limitations that are indicated in the literature [28,71]. That is why the SWOT results should always be a subject of critical reflection before they are used in building a development strategy. One of the ways to reduce the weaknesses of a SWOT analysis is to apply it in combination with other methods [24,28,72]. The third limitation concerns the recruitment of experts. It should be noted that all experts came from the studied region. This could lead to a one-sided and homogenous judgment of the assessed issues. Finally, the examination was based on a case study, which limits the generalization of findings.

Therefore, future research should first be aimed at developing a hybrid method combining the extended SWOT analysis with MCDSM (Multi Criteria Decision Support Methods) and, secondly, at a geographical diversification of experts. Moreover, it would be interesting to examine how the specificity of different industries and sizes of enterprises influence a regional Industry 4.0 development strategy.

The contribution of this publication is two-fold. First, it presents a methodology based on the strategic perspective (extended SWOT analysis) intended for the assessment of the potential of a region to implement the Industry 4.0 framework. The combination of the extended SWOT analysis and quantitative evaluation allowed us to identify factors that influence the development of Industry 4.0 as well as to prioritize them. The involvement of representatives from enterprises, and scientific and administrative institutions enabled a comprehensive view of the research problem. Second, the paper presents a practical example of the application of the proposed methodology. In the opinion of the authors, this publication may serve as a source of information for those involved in creating regional development strategies for Industry 4.0 as well as all people interested in this topic. The implications for decision-makers suggest that a deep understanding of the regional determinants of the Industry 4.0 development is needed to create regional development strategies for Industry 4.0. In the opinion of the authors, this publication may serve as a source of information for those involved in this process as well as all people interested in this topic.

In the authors' opinion, the conducted research confirms the effectiveness of the developed methodology and the possibility of its future implementation in wider scale research.

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