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Impact and Potential of Sustainable Development Goals in Dimension of the Technological Revolution Industry 4.0 within the Analysis of Industrial Enterprises

Patrik Richnák [1] and Helena Fidlerová [2,*]

[1] Department of Production Management and Logistics, Faculty of Business Management, University of Economics in Bratislava, Dolnozemská cesta 1, 852 35 Bratislava, Slovakia; patrik.richnak@euba.sk
[2] Faculty of Materials Science and Technology in Trnava, Slovak University of Technology in Bratislava, Slovakia, Jána Bottu 2781/25, 917 24 Trnava, Slovakia
* Correspondence: helena.fidlerova@stuba.sk

Abstract: Sustainable technologies, including clean energy in manufacturing and green and reverse logistics, generate conditions for industry development and future growth with the implementation of Industry 4.0 technologies and innovations in the context of sustainable development goals (SDGs). The objective of the article is to identify and analyse the potential of sustainable technologies in synergy with Industry 4.0 innovations and renewable energy initiatives in manufacturing and logistics in the context of SDGs. Qualitative analysis was performed on 105 enterprises of various business sizes, in several regions of Slovakia, within various industry sectors, and within geographical coverage. Based on the summarised results, we can state that more than 82% of surveyed enterprises implement the SDGs. Currently, more than 70% of enterprises prefer environmental aspects in business management. Based on the results, we find a significant relationship between the environmental management of the enterprise in the context of SDGs and sustainability in production and logistics. Statistical analysis confirmed the relationship between the use of renewable energy technology in the industrial sector. A significant relationship was also demonstrated between sustainability in logistics activities in the industrial sector in waste separation and recycling; environmental certification; environmental training of employees; the use of renewable energy sources and the continuous reduction of CO_2 in all logistics activities. The results of the study indicate a significant relationship between green manufacturing, green logistics, reverse logistics and selected Industry 4.0 technologies: autonomous robots, renewable energy, advanced materials, virtual technologies, and simulation. We conclude the significant influence of environmental management on business production and logistics.

Keywords: renewable energy; sustainable development goals; sustainable technologies; Industry 4.0 innovation; Industry 5.0; industrial enterprises; statistical methods

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1. Introduction

Sustainable development as an integrated approach takes into consideration the environmental, economic, and social aspects of the future. Sustainability was first defined by the Brundtland Commission of the United Nations and defines sustainability as the ability to meet the present needs without compromising the ability of future generations to meet their own needs [1]. It is necessary for this win-win solution to ensure the involvement of sustainability in all spheres of human life. Achieving sustainability requires the support and action of all sectors of society, including industry. Sustainable development goals (SDGs) build a framework to achieve economic growth, social equity and environmental protection. Therefore, it is essential to study the level of SDGs awareness and interest to enhance activities considering sustainability by enterprises and individuals [2].

According to [3], the issue of socio-economic development is a complex phenomenon, and it is essential to deal with the natural environment and ecology and the existence of an impact of natural conditions for development. Authors [4] analysed environmental routines, policies and targets, implementation of environmental management systems, ISO 14001/EMAS certification, environmental reporting, environmental requirements inside the supply chain, the trend of GHG emissions and the trend of energy consumption for their environmental impact. For recording the progress can be used environmental sustainability index [5]. This is necessary to remind us of development in a sustainable way. Additionally, the interest in sustainability is growing in improving social sustainability in organizations [6]. On the other hand, we need to focus on economic advantages that play an often crucial role and search for positive effects of ecological and social improvement on the economy to satisfy all stakeholders, whereas the three dimensions of sustainability, environmental, social and economic, are part of mosaics on how to build future in all areas of life. In the manufacturing and logistics is a call for new changes from Industry 4.0 towards the new strategy of Industry 5.0, including society and the environment improvement leading to sustainable economic growth through technological improvements.

We find that previous research articles mostly focus on the description of the following concept of corporate social responsibility environmental aspects [4,5] or social aspects [6] and benefits of sustainability such as social enterprise [7]. It is worth mentioning here that most research is omitted the general scope of SDGs and their interaction with business, technology and logistics processes.

The main aim of the article is to reflect identified research gap and to identify the current state of sustainability in manufacturing and logistics in line with the SDGs in the context of Industry 4.0 technologies and innovations in industrial enterprises.

The article's structure is as follows: First, the article begins with the introduction section. Section 2 emphasises the theoretical background of the SDGs in the context of technological changes. Next, Section 3 describes the research methodology, the data collection tool, description of the research sample and research methods. Section 4 states four research questions, followed by the seven research hypotheses. The main issues are to develop the aim of the paper, an analysis and a discussion of the results using statistical methods. Finally, Section 5 considers the main conclusions, including insights regarding future trends and potential developments.

From our point of view, it is necessary to analyse and identify the strategic potential of changes in industry, new technological innovations in logistics, and production in the context of SDGs. This brings added value to the identification of future industrial development opportunities in the context of SDGs.

2. Theoretical Framework

Changes in the field of industry in recent years have marked a revolution in innovation or, at the same time, a changing view of sustainability issues in all spheres. Sustainability involving three pillars—economic, social and environmental—is a new challenge for future development. In recent years many researchers have analysed the benefits of sustainability for the environmental aspect across different regions [3], countries [4,5], social [6,7], and socio-economic aspects [8].

The universal standard for sustainability defined by the UN under the Agenda 2030 as SDGs in all areas was recognized by 193 countries in 2015 [9]. SDGs are a critical commitment for future development with an intention to drive collaboration and bring about systemic change in the world. Agenda 2030, with 17 SDGs and 169 targets providing guidelines and targets for all countries, industries and organisations, is a motivation to adopt sustainability in line with their own priorities.

In recent years, many international organizations, governments, and non-governmental organizations have committed themselves to achieve the SDGs through their annual reports. In the recent decade, researchers and practitioners have been diverted toward the integration of sustainability in industrial processes. On the other hand, despite before mentioned engagement, SDGs are unlikely to be met by 2030 [10,11].

Although all goals have their irreplaceable role, it is possible to identify those that have the greatest impact on the industrial area. We agree with [12] that the most relevant are Affordable and Clean Energy; Decent Work and Economic Growth; Industry, Innovation, and Infrastructure; Consumption and Production. It is as critical to consider the impact of industry on nature regarding Climate Action, Life Below Water and Life on Land. In the next part of the article are most relevant SDGs briefly introduced. *Affordable and Clean Energy (SDG7)* strives to ensure affordable, reliable, sustainable, and modern energy for all, with action needed at both international and national levels [13,14]. *Decent Work and Economic Growth (SDG8)* addresses sustainable and inclusive economic growth, as well as full and productive employment, emphasising decent work for all [15]. *Industry, Innovation, and Infrastructure (SDG9)* uses the field of industry to focus primarily on resource efficiency, modernisation to more environmentally friendly and clean technologies, and the development of intelligent energy and cost-saving technologies [16]. *Responsible Consumption and Production (SDG12)* considers the impact on the environment from consumption and production [17,18]. *Climate Action (SDG13)* calls on the world to take urgent action to combat climate change and its effects in all countries, also developing [19]. *Life Below Water (SDG14)* lays the foundations for integrated and sustainable ocean management activities [20]. This is closely related to industrial production as well as biodiversity protection and elimination of land degradation defined in *Life on Land (SDG15)* [21]. Specific SDGs are highly interdependent and have an impact on each other in close interactions in all areas of life. Companies often do not adequately recognise the interconnections among the goals and integrate only those goals that best align with their sustainability strategies [12]. The integrated nature of SDGs means that progress towards one of them is also linked through feedback to other goals and targets [22,23].

Although many researchers analysed the environmental [3–5] or social benefits [6–8] of sustainability and SDGs, only a few understand the general scope and pointed out their interaction with technologies and logistics innovations.

However, improvements in these issues are sharing and analysing new and implemented best practices integrating sustainability in enterprises to move forward to sustainable entrepreneurship [24] and supporting sustainability approaches towards sustainable innovation in the industry [25], green innovation in supply chain management [26], green transport [27], and eco design [28]. Authors [29,30] analyse the relation between sustainable development and industrial development.

Primarily industrial revolution Industry 4.0, with its changes in manufacturing, production and logistics, offers several challenges for all three dimensions of sustainability [12]. Key technologies driving Industry 4.0 are traceability [31], autonomous robots and human and robot interaction [32], drones, cyber-physical systems [33], cybersecurity, renewable energy, cloud technologies and simulation, big data analytics [34,35], blockchains, internet of things analytics [36], virtual and augmented reality [37,38], artificial intelligence [39], and mobile and cloud computing [40]. These technologies affect industry most intensively, and we can call them a technological revolution in the industry. The important trends that reflect sustainability are reverse logistics [41–44] and green logistics [45–47], which are often understood only partially as waste treatment or as part of the company's marketing strategy.

3. Materials and Methods

The data obtained in the presented study were used to identify the current state of sustainability in manufacturing and logistics in line with the SDGs regarding Industry 4.0 technologies and innovations in industrial enterprises. The collected data focus on sustainable development, implementation of the SDGs, enforcement of environmental management, and new technologies in production and logistics.

3.1. Research Methodology

The implementation of the research was conducted according to the research phases, which are illustrated in Figure 1. The specification of each phase is as follows:

1. *Definition of research issue*—identification of the current state of sustainability in manufacturing and logistics in accordance with the SDGs, in the context of Industry 4.0 technologies and innovations in industrial enterprises.
2. *Development of conceptual framework*—consisted of a literature review of the current state of the research issue in journals, reports and studies.
3. *Identification of research problem*—based on the review of previous literature and studies, the authors identified four research questions.
4. *Defining research hypotheses*—after formulating the research questions, null and alternative hypotheses were proposed.
5. *Determining research object*—the object of research was manufacturing enterprises in Slovakia. The research sample consisted of 105 manufacturing enterprises of various sizes and sectors.
6. *Questionnaire construction*—a standardised electronic questionnaire was used, which consisted of several parts. The first part dealt with classification questions: location of enterprises, geographical coverage of the enterprise, industry sector, and size of the enterprise. The second part of the questionnaire consisted of identification questions concerned with sustainability issues and the SDGs. The third part focused on production and logistics processes in the context of the Industry 4.0 technological revolution and the implementation of sustainability.
7. *Selection of data collection methods*—the following data collection methods were used: (Computer Assisted Web Interviewing), CATI (Computer Assisted Telephone Interviewing) and CASI (Computer Assisted Self Interviewing).
8. *Realisation of questionnaire research*—data collection was conducted anonymously in manufacturing enterprises in Slovakia. The respondents were production and logistics managers in enterprises from several industries.
9. *Descriptive analysis of collected data*—univariate descriptive statistics, bivariate descriptive statistics and multivariate descriptive statistics were used in this analysis.
10. *Inferential analysis of collected data*—in the statistical analysis, the null and alternative hypotheses were tested using correlation tests in the form of non-parametric 2-tailed Spearman's correlation test and Pearson's chi-square test of independence, while the strength of association was performed through Phi and Cramer's V coefficient and also the non-parametric Kruskal–Wallis test which is a one-way ANOVA for an independent variable that has more than two categories.
11. *Summary of survey data*—in conclusion, the most important findings from the descriptive and inferential analysis were summarised and then also a comparison was made with similar surveys conducted within the countries of the world between 2020 and 2022, thus enhancing the research's meaning and justification.
12. *Proposal for further research*—the research conducted is the basis for further, more in-depth research that would explore the identification of Industry 5.0 and its benefits in production and logistics processes, as it provides greener solutions compared to previous industrial transformations.
13. *Definition of research limits*—they consist of the representative sample of manufacturing enterprises, and the limitation of the conducted study is only to manufacturing enterprises operating in the Slovak Republic.

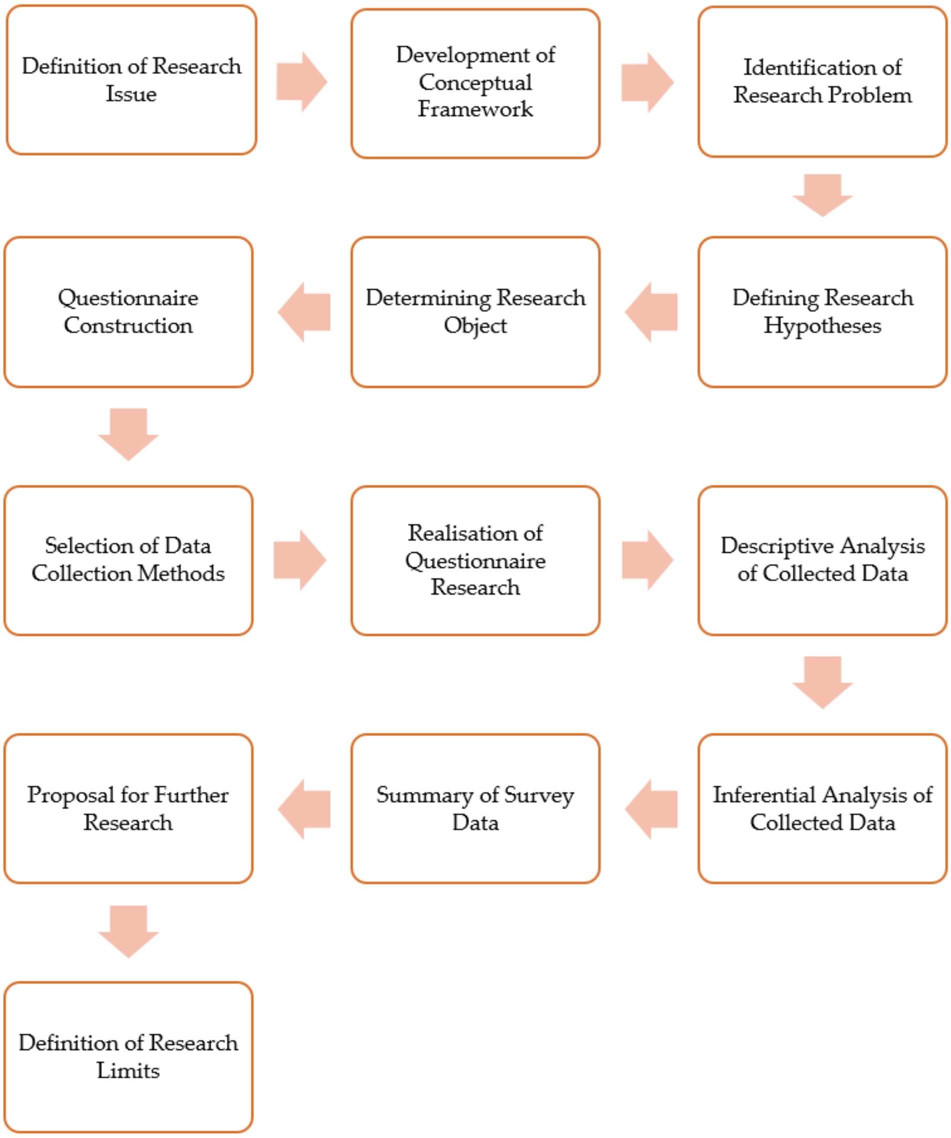

Figure 1. Visualisation of research methodology.

3.2. Description of Collection Tool

The primary data collection was carried out anonymously in manufacturing enterprises located in Slovakia. The questionnaire was conducted between April 2019 and February 2020. The respondents were producers and logistical managers in enterprises in several industrial sectors. The standardised electronic questionnaire was distributed through the following data collection methods: CAWI (Computer Assisted Web Interviewing), CATI (Computer Assisted Telephone Interviewing) and CASI (Computer Assisted Self Interviewing). The aim of collecting and analysing the data was to identify the actual state of sustainability and SDG implementation in a dimension of the technological revolution Industry 4.0.

Based on previous theoretical and empirical research realised by the authors Richnák and Gubová [48] analysed green and reverse logistics in the conditions of sustainable development in 165 enterprises in Slovakia; Fidlerová et al. [2] sustainable entrepreneurship and business opportunities recognition in 283 enterprises in an international context including 101 in Slovakia; Bajdor, Pawloszek and Fidlerová [49] analysed sustainability issues in small- and medium-sized Polish enterprises.

As a collection tool, the standardised electronic questionnaire was determined. The structure of the questionnaire consisted of three parts. The first part dealt with classification issues: the location of enterprises, geographical coverage of enterprise, industry sector, and size of the enterprise regarding the classification enterprise category (2003/361/EC). The second part of the questionnaire consisted of identification questions dealing with sustainability issues and SDGs. The third part dealt with manufacturing and logistics processes in the context of the technological revolution of Industry 4.0 and the implementation of sustainability. The questionnaire included various types of questions. In order to identify the respondents, closed multi-choice questions were used. For questionnaire construction, we used mostly scale questions with a Likert scale with options between 0 and 6 (value 0 stands for not implemented and value 6 stands for most implemented) since the even number of answers on the scale obliges respondents to the positive or negative end of the scale, leading to better data.

3.3. Description of Research Sample

Complex and in-depth studies in manufacturing enterprises considering the SDGs and their relations with manufacturing and logistics in the context of the ongoing Industry 4.0 revolution in the world and Slovakia are limited. Based on the identified research gap, we have analysed sustainability in manufacturing and logistics processes according to Industry 4.0 technologies in manufacturing enterprises in Slovakia. The subjects of research are manufacturing enterprises in Slovakia. The research sample was composed of 105 manufacturing enterprises of different sizes and sectors in Slovakia. The authors are aware of sample limitations in terms of geographic coverage and sample size. The aim of conducted analysis was a contribution to the identification of potential for further in-depth research in an international context.

The object of the quantitative research, which was realised in the form of the questionnaire survey, was small, medium-sized and large enterprises located in the Slovak Republic. The categorisation of enterprises is in accordance with the Commission Recommendation of 6 May 2003 on the definition of small, medium-sized and large enterprises (2003/361/EC), where we considered a small enterprise to be an enterprise with up to 50 employees and an annual turnover of up to EUR 10 million. We considered a medium-sized enterprise to be an enterprise with up to 250 employees and an annual turnover of up to EUR 50 million. We considered a large enterprise as a company with more than 250 employees and an annual turnover of more than EUR 50 million.

Based on the staff headcount, we have categorised the manufacturing enterprises into different categories. Out of the total number of respondents who participated in the survey, the largest number of manufacturing enterprises were in category of medium enterprise, accounting for 46.7% (49 enterprises). The second largest group of manufacturing enterprises were large enterprises, with a share of 45.7% (48 enterprises) participating in the research. Manufacturing enterprises were the least represented in the small enterprise category with 7.6% (8 enterprises). The structure of studied sample by enterprise category is shown in Table 1.

Table 1. Structure of studied sample by enterprise category.

Enterprise Category	Staff Headcount	Absolute Frequency	Relative Frequency [%]
Small enterprises	10–49 persons employed	8	7.6
Medium-sized enterprises	50–249 persons employed	49	46.7
Large enterprises	250 or more persons employed	48	45.7
Total		105	100

For identifying the research sample, the location of the enterprises was also included in the analysis. Based on the summarisation of the results from the questionnaire survey, the results are presented in Table 2. From the data, we conclude that the manufacturing enterprises in which the research was conducted are dominant in multinational markets (72.4%). Manufacturing enterprises operating in national markets were represented with a share of 20% (21 enterprises). The smallest and, at the same time, identical percentage representation with a share of 3.8% (4 enterprises) were both categories of manufacturing enterprises operating in regional markets and local markets.

Table 2. Structure of the studied sample by location of enterprises.

Location of Enterprises	Absolute Frequency	Relative Frequency [%]
Transnational	76	72.4
Regional	4	3.8
Local	4	3.8
National	21	20.0
Total	105	100

The quantitative research also subsequently identified the geographical coverage of enterprises. The Nomenclature of Territorial Units for Statistics (NUTS) was used to divide manufacturing enterprises by geographic location. According to NUTS 2, enterprises in the first place are dominated by enterprises in Western Slovakia. The second place belongs to the Bratislava Region, and the third place belongs to Central Slovakia. The least number of manufacturing enterprises participating in the survey was from Eastern Slovakia.

Of the manufacturing enterprises, most respondents were in the Bratislava Region (22 enterprises) with 21.0%. The second place was ranked by the Trenčín Region with 20% (21 enterprises). The third place was the Trnava Region, where manufacturing enterprises participated in the survey with a share of 17.1% (18 enterprises). The least number of manufacturing enterprises participating was from the Košice Region with 3.8% (4 enterprises). The participation of manufacturing enterprises by NUTS 2 and NUTS 3 is shown in Table 3.

Table 3. Structure of the studied sample by geographical coverage of enterprise.

NUTS 2	NUTS 3	Absolute Frequency	Relative Frequency [%]
Bratislava Region	Bratislava Region	22	21.0
Western Slovakia	Trnava Region	18	17.1
Western Slovakia	Trenčín Region	21	20.0
Western Slovakia	Nitra Region	11	10.5
Central Slovakia	Žilina Region	10	9.5
Central Slovakia	Banská Bystrica Region	9	8.6
Eastern Slovakia	Prešov Region	10	9.5
Eastern Slovakia	Košice Region	4	3.8
Total		105	100

The identification questions addressed industrial sector of the manufacturing enterprise. Table 4 provides the representation of the selected top industry sectors in view of absolute and relative frequency. The largest part of the research sample was represented by the mechanical engineering industry, with a share of 26.7% (28 enterprises). The automotive industry was also highly represented in the research sample with a share of 23.8% (25 enterprises) and the electrical engineering industry with a share of 20% (21 enterprises). Then, the mining industry was next in the ranking, with participation of manufacturing enterprises at 16.2% (17 enterprises). Manufacturing enterprises from the metallurgical industry were the least involved in the research, with 13.3% (14 enterprises).

Table 4. Structure of the sample studied by industry sector.

Selected Industrial Sector	Absolute Frequency	Relative Frequency [%]
Mining industry	17	16.2
Mechanical engineering industry	28	26.7
Automotive industry	25	23.8
Metallurgical industry	14	13.3
Electrical engineering industry	21	20.0
Total	105	100

3.4. Description of Research Methods

The elaboration of the subject matter required the application of several scientific and statistical methods. The method of analysing the current state of research in journals in international databases and non-impact journals, reports and studies has been used in theoretical analysis. Subsequently, a synthesis of these findings was performed. Through induction, deduction, abstraction, concretization, and intercomparison, we have developed a comprehensive theoretical and conceptual framework.

The statistical software IBM SPSS Statistics 20.0 (Statistical Package for Social Science) was used in data processing of quantitative research. First, one-dimensional descriptive statistics were used in the form of frequency analyses with the distribution of enterprises in terms of enterprise category, location of enterprises, geographical coverage, and industry sector. In data analysis, two-dimensional descriptive statistics were also used as contingency tables, which indicated the relations between the variables surveyed. Multivariate descriptive statistics were applied to present values regarding the midpoint. Subsequently, inferential statistics were used to evaluate the hypotheses that were established based on the research questions. In order to evaluate the statistical hypotheses, correlation tests in the form of non-parametric 2-tailed Spearman's correlation test and Pearson chi-square test of independence were used within the statistical software, where the strength of association was performed through Phi and Cramer's V coefficient. In data analysis, homogeneity of variance was first verified, which was tested through Levene's test. Based on the evaluation, non-parametric testing was used through the Kruskal–Wallis test, which is a one-way ANOVA, which was used for the evaluation. The significance level of the applied tests was α= 5% (confidence interval 95%).

4. Results and Discussion

Based on previous literature reviews and studies, the authors identified four research questions:

Research Question 1 (RQ1): What are the sustainability initiatives of manufacturing enterprises in production and logistics?
Research Question 2 (RQ2): What is the relationship between sustainable logistics activities and the industrial sector?
Research Question 3 (RQ3): What role do the selected sustainable technologies have in the industry sector regarding the environment?
Research Question 4 (RQ4): How do manufacturing enterprises perceive Industry 4.0 technologies in the context of sustainability?

4.1. Descriptive Analysis in Quantitative Research

First, descriptive analysis was used to interpret the data from the quantitative research, including univariate descriptive statistics, bivariate descriptive statistics and multivariate descriptive statistics. In identifying the most relevant knowledge about the subject, we were concerned with presenting the information that comprises the main part of the scientific problem. As mentioned above, the SDGs implementation will be analysed with selected industry sectors. Subsequently, sustainability in production and logistics processes in manufacturing enterprises was identified.

Figure 2 shows the SDGs implementation in enterprises in the selected industry sectors. Based on the results summarised in the bar chart, we conclude that the highest SDGs implementation is in the mechanical engineering industry (38.90%). The automotive industry also has a high percentage (26.40%). The SDGs are enforced in the electrical engineering industry enterprises at 22.20%. Sustainable development goals are least implemented in enterprises of the mining industry (16.70%) and enterprises of the metallurgical industry (13.80%). At the same time, based on the graphical visualisation of the data, we conclude that the SDGs are dominant in every type of industry that was part of the research sample.

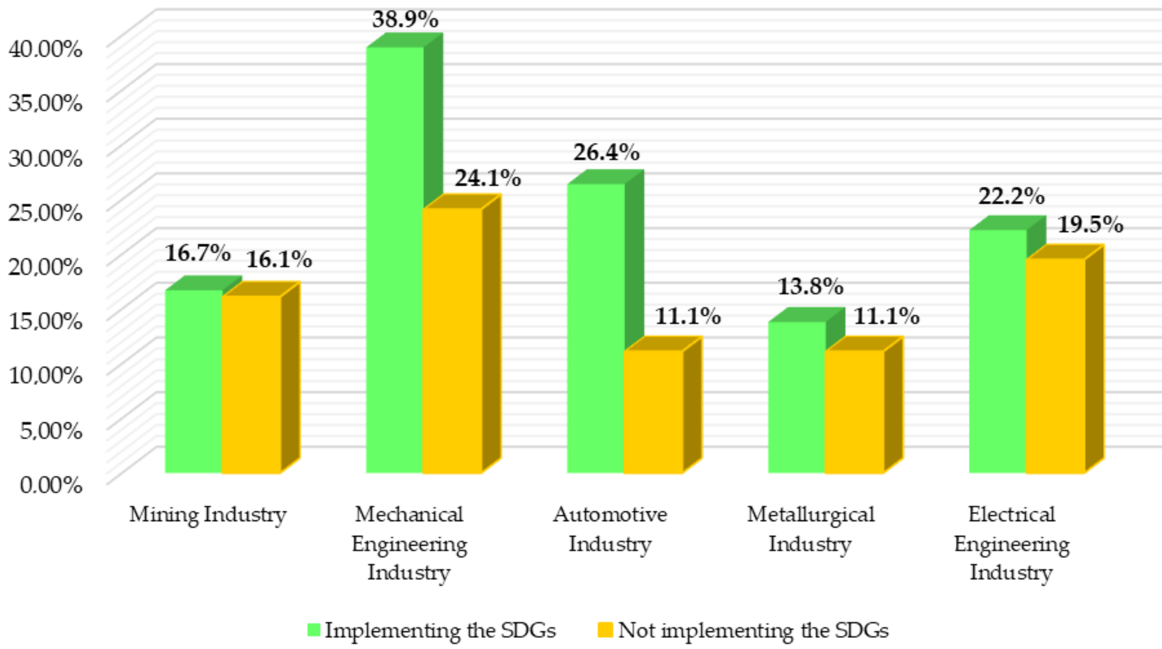

Figure 2. The data visualisation of SDGs implementation in selected industry sectors.

The sustainability in production and logistics processes is illustrated in Figure 3. It represents multivariate descriptive statistics in the form of a radar chart. This graph shows the mean values that emerged on a scale of 0 to 6, with the scale of 0 indicating that the manufacturing enterprises do not use SDGs in the production/logistics process and the scale of 6 indicating that the enterprises make high use of the production/logistics process. According to the data, the use of alternative transport modes in internal transport is of the highest importance weight (3.86) for manufacturing enterprises. Processes that also obtained high mean value values were: efficient use of external transport (3.72), efficient storage of materials and goods (3.64), use of renewable energy sources (3.59), and waste separation and recycling (3.47). The radar chart shows that the mean values are similar in the following processes: continuous CO_2 reduction in all logistics activities (2.75), working with suppliers to achieve the SDGs (2.7), and optimisation of the transport routes (2.67). Sustainability in production and logistics processes in manufacturing enterprises was obtained with the lowest average values for the processes: environmental certification (1.54) and supplier selection according to their environmental profile (1.14).

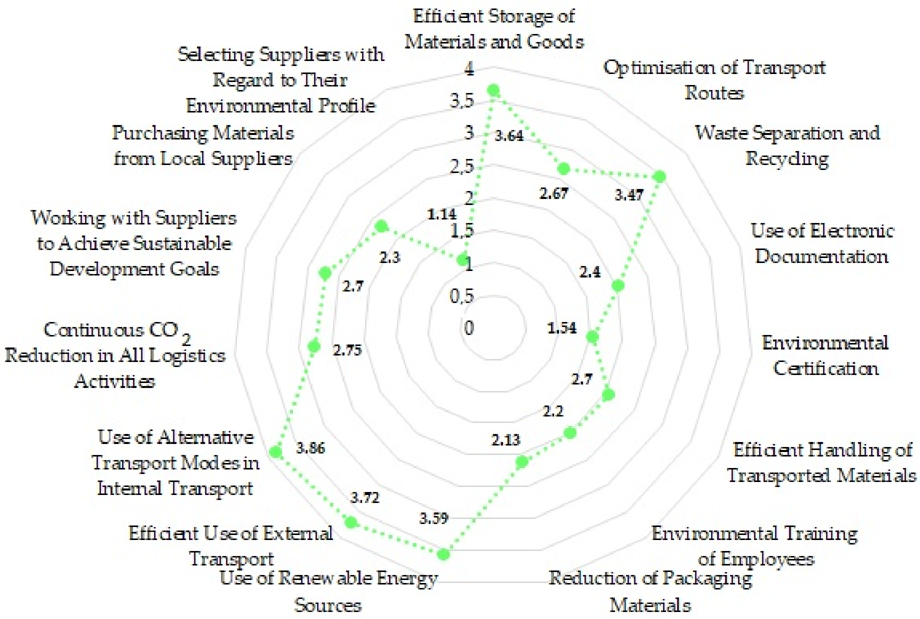

Figure 3. The data visualization about sustainability in production and logistics processes in manufacturing enterprises.

4.2. Evaluation of Research Questions

Considering the need for a better understanding of the issue and its deeper analysis, we used inferential statistics in addition to descriptive statistics. Next, the following null and alternative hypotheses were tested, applying tests of independence, comparison and correlation, and also the non-parametric Kruskal–Wallis test, which is a one-way ANOVA for the independent variable having more than two categories.

4.2.1. Research Question 1 (RQ1): What Are the Sustainability Initiatives of Manufacturing Enterprises in Production and Logistics?

Research Hypothesis 0 (RH_0): We assume that there is no significant difference between the environmental management of the enterprise, which is influenced by the SDGs, and sustainability in production and logistics. *Alternative Research Hypothesis (RH_A):* We assume that there is a significant difference between the environmental management of the enterprise that is influenced by the SDGs and sustainability in production and logistics.

Based on the null and alternative hypotheses testing, a significant difference was found between the environmental management of the enterprise that is influenced by the SDGs and sustainability in production and logistics. The results are interpreted in Table 5 below.

Table 5. Evaluation of null and alternative research hypotheses.

Spearman's Correlation Rho		Reducing Solid Waste	Minimising the Use of Dangerous Materials	Eliminating Air Emission	Reducing the Amount of Wastewater
Environmental management of the enterprise which is influenced by the SDGs	Correlation Coefficient	0.413 **	0.436 **	0.355 **	0.484 **
	Sig. (2-tailed)	0.000	0.000	0.000	0.000
	N	105	105	105	105

** Correlation is significant at the 0.05 level.

The null and alternative hypotheses were tested using a non-parametric 2-tailed Spearman's rank correlation test. Based on the results of the testing presented in Table 5, we conclude that there is a moderately significant relationship for reducing solid waste (r = 0.413); $p < 0.05$; minimising the use of dangerous materials (r = 0.436); $p < 0.05$, eliminating air emission (r = 0.355); $p < 0.05$, and reducing the amount of wastewater (r = 0.484); $p < 0.05$.

4.2.2. Research Question 2 (RQ2): What Is the Relationship between Sustainable Logistics Activities and the Industrial Sector?

Research Hypothesis 0 (RH_0): We assume that there is no significant difference between sustainability in logistics activities in the industrial sector. *Alternative Research Hypothesis (RH_A)*: We assume that there is a significant difference between sustainability in logistics activities in the industry sector.

Before the null and alternative hypotheses testing, the data were verified through a homogeneity test. Based on the results, we found that the homogeneity of the variance was disrupted in the sample under study. The assumption was tested using Levene's test. Therefore, the non-parametric Kruskal–Wallis test, which is a one-way ANOVA, was used to verify the null and alternative hypotheses.

Subsequently, the null and alternative hypotheses were tested. The results of the tests are shown in Table 6. Taking into account the value of statistical significance, there is a significant relationship between sustainability in logistics activities in the industry sector at the following options: waste separation and recycling ($\chi^2 = 14.717$, r = 0.005); environmental certification ($\chi^2 = 11.538$, r = 0.021); environmental training of employees ($\chi^2 = 19.657$, r = 0.001); use of renewable energy sources (χ^2= 12.139, r = 0.016); and continuous reduction in CO_2 in all logistics activities ($\chi^2 = 10.768$, r = 0.029). No significant relationship was identified in the other variables.

Table 6. Evaluation of null and alternative research hypotheses.

Kruskal–Wallis Test	Chi-Square	df	Asymp. Sig.
Efficient storage of materials and goods	4.709	4	0.319
Optimisation of transport routes	4.878	4	0.300
Waste separation and recycling	14.717	4	0.005
Use of electronic documentation	5.870	4	0.209
Environmental certification	11.538	4	0.021
Efficient handling of transported materials	7.060	4	0.133
Environmental training of employees	19.657	4	0.001
Reduction of packaging materials	2.416	4	0.660
Use of renewable energy sources	12.139	4	0.016
Efficient use of external transport	7.706	4	0.103
Use of alternative transport modes in internal transport	3.736	4	0.443
Continuous CO_2 reduction in all logistics activities	10.768	4	0.029
Working with suppliers to achieve sustainable development goals	8.332	4	0.080
Purchasing materials from local suppliers	6.188	4	0.186
Selecting suppliers with regard to their environmental profile	2.658	4	0.617

4.2.3. Research Question 3 (RQ3): What Role Do the Selected Sustainable Technologies Have in the Industry Sector Regarding the Environment?

1st Research Hypothesis 0 (RH_0): We assume that there is no significant difference between the use of renewable energy technology in the industrial sector. *1st Alternative Research Hypothesis (RH_A)*: We assume that there is a significant difference between the use of renewable energy technology in the industrial sector.

Testing of null and alternative hypothesis testing revealed a significant difference between the use of renewable energy technology in the industrial sector. The results of the testing are presented in Table 7.

Table 7. Evaluation of the null and alternative research hypotheses.

Spearman's Correlation Rho		Industrial Sector	Renewable Energy Technology
Industrial Sector	Correlation Coefficient	1.000	0.420 **
	Sig. (2-tailed)		0.024
	N	105	105
Renewable Energy Technology	Correlation Coefficient	0.420 **	1.000
	Sig. (2-tailed)	0.024	
	N	105	105

** Correlation is significant at the 0.05 level.

The presented null and alternative hypotheses were tested using a non-parametric 2-sided Spearman's rank correlation test. Based on the results of the testing, which are presented in Table 7, we conclude that there is a moderately significant relationship between the industry sector and renewable energy technology (r = 0.420); $p < 0.05$.

2nd Research Hypothesis 0 (RH_0): We assume that there is no significant difference between the use of environmentally friendly technology and advanced materials technology. *2nd Alternative research hypothesis (RH_A)*: We assume that there is a significant difference between the use of environmentally friendly technology and advanced materials technology.

Under the presented null and alternative hypothesis, a significant difference between the use of environmentally friendly technology and advanced materials technology was confirmed. The results of the tests are presented in Table 8.

Table 8. Evaluation of null and alternative research hypotheses.

Chi-Square Test	Value	df	Asymp. Sig.
Pearson Chi-Square	54.876	36	0.023
Likelihood Ratio	51.794	36	0.043
Linear-by-Linear Association	12.922	1	0.000
N of Valid Cases	105		

Pearson's chi-square test of independence was performed to evaluate the hypothesis. Based on the results of Table 8, we conclude that there is a significant relationship between the use of environmentally friendly technologies and advanced materials technology ($\chi^2 = 54.876$, $p = 0.023$).

Subsequently, the strength of association relationship between the use of environmentally friendly technologies and advanced materials technology was performed using Phi and Cramer's V coefficients. The results are presented in Table 9. From the results, we conclude that the Phi coefficient indicates a strong relationship (value = 0.723), and the Cramer V coefficient shows a moderate relationship (value = 0.295).

Table 9. Evaluation of the association.

Symmetric Measures		Value	Approx. Sig.
Nominal by Nominal	Phi	0.723	0.023
	Cramer's V	0.295	0.023
N of Valid Cases		105	

4.2.4. Research Question 4 (RQ4): How Do Manufacturing Enterprises Perceive Industry 4.0 Technologies in the Context of Sustainability?

1st Research Hypothesis 0 (RH_0): We assume that there is no significant difference between Industry 4.0 technologies and green manufacturing. *1st Alternative research hypothesis*

(RH_A): We assume that there is a significant difference between Industry 4.0 technologies and green manufacturing.

Before testing the null and alternative hypotheses, the data were verified through a homogeneity test. Based on the results, we identified that the homogeneity of variance was disrupted in the sample under study. The assumption was tested using Levene's test. Therefore, the non-parametric Kruskal–Wallis test, which is a one-way ANOVA, was used to verify the null and alternative hypotheses.

Subsequently, the null and alternative hypotheses were tested. The results of the testing are shown in Table 10. Taking into account the value of statistical significance, we can assume a significant relationship between the selected industry 4.0 technologies and green manufacturing under the options: autonomous robots (χ^2 = 16.079, r = 0.007); cyber-physical system (χ^2 = 20.845, r = 0.001); big data analytics (χ^2 = 19.150, r = 0.002); renewable energy (χ^2 = 13.911, r = 0.016); advanced materials (χ^2 = 15.329, r = 0.009); additive manufacturing (χ^2 = 20.507, r = 0.001); Internet of Things (χ^2 = 13.133, r = 0.022); and virtual technologies and simulation (χ^2 = 11.540, r = 0.042). For other Industry 4.0 technologies: cloud technologies, blockchain, cybersecurity, drones, augmented reality, artificial intelligence, and autonomous vehicles, no significant relationship was confirmed.

Table 10. Evaluation of null and alternative research hypotheses.

Kruskal–Wallis Test	Chi-Square	df	Asymp. Sig.
Autonomous robots	16.079	5	0.007
Cyber-physical system	20.845	5	0.001
Big Data Analytics	19.150	5	0.002
Cloud technologies	10.839	5	0.055
Blockchain	6.190	5	0.288
Renewable Energy	13.911	5	0.016
Advanced Materials	15.329	5	0.009
Cybersecurity	7.966	5	0.158
Drones	7.764	5	0.170
Augmented reality	3.630	5	0.604
Artificial intelligence	2.285	5	0.808
Additive manufacturing	20.507	5	0.001
Internet of Things	13.133	5	0.022
Virtual technologies and simulation	11.540	5	0.042
Autonomous vehicles	3.265	5	0.659

2nd Research Hypothesis 0 (RH_0): We assume that there is no significant difference between Industry 4.0 technologies and green logistics. *2nd Alternative research hypothesis (RH_A)*: We assume that there is a significant difference between Industry 4.0 technologies and green logistics.

First, the data were verified through a homogeneity test. The assumption was tested through Levene's test. Based on the results, the assumption of homogeneity was violated for the variables. Hence, the non-parametric Kruskal–Wallis test was further proceeded to use, which is a one-way ANOVA.

After testing the null and alternative hypotheses, the results were summarised in Table 11. Considering the value of statistical significance (at the significance level $\alpha = 0.05$), there is a significant relationship by the selected technologies Industry 4.0 and green logistics for opportunities: autonomous robots (χ^2 = 12.102, r = 0.033); renewable energy (χ^2 = 13.311, r = 0.021); advanced materials (χ^2 = 11.875, r = 0.037); additive manufacturing (χ^2 = 11.587, r = 0.041); virtual technologies and simulation (χ^2 = 12.178, r = 0.032); and autonomous vehicles (χ^2 = 22.210, r = 0.000). For the other Industry 4.0 technologies: cyber-physical systems, big data analytics, cloud technologies, blockchain, cybersecurity, drones, augmented reality, artificial intelligence, and internet of things, no significant relationships were identified.

Table 11. Evaluation of null and alternative research hypotheses.

Kruskal–Wallis Test	Chi-Square	df	Asymp. Sig.
Autonomous robots	12.102	5	0.033
Cyber-physical system	6.141	5	0.293
Big Data Analytics	7.859	5	0.164
Cloud technologies	7.616	5	0.179
Blockchain	4.011	5	0.548
Renewable Energy	13.311	5	0.021
Advanced Materials	11.875	5	0.037
Cybersecurity	4.781	5	0.443
Drones	10.855	5	0.054
Augmented reality	3.593	5	0.609
Artificial Intelligence	2.383	5	0.794
Additive manufacturing	11.587	5	0.041
Internet of Things	9.597	5	0.088
Virtual technologies and simulation	12.178	5	0.032
Autonomous vehicles	22.210	5	0.000

3rd Research Hypothesis 0 (RH_0): We assume that there is no significant difference between Industry 4.0 technologies and reverse logistics. *3rd Alternative research hypothesis (RH_A)*: We assume that there is a significant difference between Industry 4.0 technologies and reverse logistics.

The null and alternative hypotheses testing required verifying homogeneity of variance. The homogeneity of variance was examined by using Levene's test. After its evaluation, we concluded that homogeneity of variance was violated. Based on this fact, the non-parametric Kruskal–Wallis test, which is a one-way ANOVA, was used in further testing.

Table 12 indicates evaluation of the null and alternative hypotheses. The test results showed a statistically significant relationship (at the significance level $\alpha = 0.05$) between reverse logistics and the following selected Industry 4.0 technologies: autonomous robots ($\chi^2 = 12.925$, r = 0.024); big data analytics ($\chi^2 = 9.952$, r = 0.047); renewable energy ($\chi^2 = 13.033$, r = 0.023); advanced materials ($\chi^2 = 11.953$, r = 0.035); internet of things ($\chi^2 = 12.797$, r = 0.025); virtual technologies and simulation ($\chi^2 = 30.070$, r = 0.000). For Industry 4.0 technologies: cyber-physical system, cloud technologies, blockchain, cybersecurity, drones, augmented reality, artificial intelligence, additive manufacturing, and autonomous vehicles, no statistically significant relationship was indicated.

Table 12. Evaluation of null and alternative research hypotheses.

Kruskal–Wallis Test	Chi-Square	df	Asymp. Sig.
Autonomous robots	12.925	5	0.024
Cyber-physical system	5.392	5	0.370
Big Data Analytics	9.952	5	0.047
Cloud technologies	8.365	5	0.137
Blockchain	3.892	5	0.565
Renewable Energy	13.033	5	0.023
Advanced Materials	11.953	5	0.035
Cybersecurity	1.841	5	0.871
Drones	3.801	5	0.578
Augmented reality	3.837	5	0.573
Artificial Intelligence	2.592	5	0.763
Additive manufacturing	4.588	5	0.468
Internet of Things	12.797	5	0.025
Virtual technologies and simulation	30.070	5	0.000
Autonomous vehicles	5.649	5	0.342

Based on the summary of the evaluated descriptive and inferential analysis, we would like to emphasise the most interesting facts. The promotion of the SDGs is dominant in the automotive industry in addition to the mechanical engineering industry. The SDGs are least enforced in enterprises in the mining industry and in enterprises in the metallurgical industry. Sustainability in production and logistics processes is dominant in addition to the use of alternative transport modes in internal transport and other processes. Processes with high average values include efficient use of external transport, efficient storage of materials and goods, use of renewable energy sources and waste separation and recycling. The research question regarding the perception of sustainability in the context of Industry 4.0 technologies in manufacturing enterprises in Slovakia and the evaluation of the null and alternative hypotheses revealed the interaction between green manufacturing, green logistics and reverse logistics and the following Industry 4.0 technologies: autonomous robots, renewable energy, advanced materials and virtual technologies, and simulation.

5. Conclusions

The 2030 Agenda, with its 17 Sustainable Development Goals, presents a clear vision for industries and organisations to ensure economic, social and environmental well-being. Recently, the concept of Industry 4.0, which, together with its technologies, is set to make a systematic transition, has had a significant impact on enterprises. Another important strategic change in the corporate field is the orientation toward achieving goals in the context of sustainability, which is required by stakeholders (customers, clients, suppliers, and the public) and changes related to legislation. The synergy potential arising from the combination of these two megatrends is not clearly and comprehensively explored. For this reason, a research gap emerged that the authors wanted to fill. The subject issue aimed to identify the current state of sustainability in manufacturing and logistics in line with the SDGs in the context of Industry 4.0 technologies and innovations in industrial enterprises. The data collected concentrated on sustainable development, the implementation of the SDGs, the promotion of environmental management and new technologies in production and logistics.

The objects of the quantitative research, which was realised in the form of a questionnaire survey, were small, medium-sized and large manufacturing enterprises located in the Slovak Republic. Out of the total number of respondents who participated in the research, the largest number of manufacturing enterprises was in the medium-sized enterprise category. From the data, we conclude that the manufacturing enterprises in which the research was conducted were dominant in transnational markets, and their place of operation is Western Slovakia. Among the manufacturing enterprises, the respondents from the mechanical engineering industry were the most involved. Descriptive analysis shows that the greatest promotion of the SDGs is in the mechanical engineering industry in Slovakia. From the aggregated data, the use of alternative drives in internal transport was of the greatest importance for manufacturing enterprises. The inferential analysis confirmed several significant relationships through the statistical tests used. The relationship between the environmental management of the enterprise, which is influenced by SDGs, and sustainability in production and logistics was demonstrated. A significant relationship was also demonstrated between sustainability in logistics activities in the industrial sector in waste separation and recycling; environmental certification; environmental training of employees; the use of renewable energy sources and the continuous reduction of CO_2 in all logistics activities. Statistical analysis confirmed the relationship between the use of renewable energy technology in the industrial sector. A significant relationship was also demonstrated between the use of environmentally friendly technology and advanced materials technology. The results of the inferential analysis showed a significant relationship between green manufacturing and selected Industry 4.0 technologies—autonomous robots; cyber-physical systems; big data analytics; renewable energy; advanced materials; additive manufacturing; internet of things; virtual technologies and simulation. A significant relationship was also found between green logistics and selected Industry 4.0 technologies—autonomous robots; renewable energy; advanced materials; additive manufacturing; virtual technologies and simulation; and autonomous vehicles. Statistical analysis confirmed the relationship between reverse logistics and the following selected Industry 4.0 technologies—autonomous robots; big data analytics; renewable energy; advanced materials; internet of things; virtual technologies and simulation.

The attitude of enterprises in Slovakia towards the SDGs is changing, as it is not understood as a barrier to business competitiveness but as a potential competitive advantage in the domestic and foreign markets. The results of the evaluated hypotheses confirmed this, following the global trend of transition towards a circular economy. The evaluated hypotheses confirm the consistency with the intention of a circular economy in the form of waste minimisation, energy consumption, CO_2 reduction and overall reduction of the environmental level. Achieving sustainability in accordance with the principles of the circular economy is the basic vision of the Environmental Policy Strategy of the Slovak Republic until 2030. At the same time, for the Ministry of the Environment of the Slovak Republic, the circular economy is one of the pillars of the European Green Deal, which is intended to ensure faster and more efficient development of the circular economy among enterprises and to have a positive impact on consumer behaviour. It is the connection of new technologies that bring new business opportunities to the goals of sustainable development. We consider the industry sector to be the most important waste separation and recycling in accordance with the hierarchy of waste management, environmental certification and environmental training of employees. The important role and innovation potential has the use of renewable energy sources and continuous reduction in CO_2 in all logistics following the goal of affordable and clean energy. The synergistic effect is focused on achieving decent work, economic growth, and sustainable consumption and production in the context of a circular economy in enterprises.

When compared with similar surveys conducted in countries around the world between 2020 and 2022, we confirm the sense and justification of the research presented by the authors. Bai et al. [50] say that the circular economy can be an effective approach to integrating Industry 4.0 technologies into practice and business to improve sustainability. Their study explores the connection between Industry 4.0 technologies and the Sustainable Development Goals (SDGs). Fatimah et al. [51] conducted a survey in Indonesia where they examined the underlying issues and proposed an opportunity to develop a sustainable and smart nationwide waste management system using Industry 4.0 technologies. Maisiri et al. [52] identified factors that hinder the sustainable adoption of Industry 4.0 and strategies that promote the adoption of Industry 4.0 in the South African manufacturing industry. Strandhagen et al. [53] analysed sustainability challenges in supply chains in the shipbuilding industry in Norway, where they investigated how Industry 4.0 technologies can affect the sustainability of the industry under study. Chari et al. [54] investigated the extent of sustainability implementation and the implications of Industry 4.0 technologies through a nationwide quantitative survey in Sweden. The analysis showed that 71% of the evaluated projects included environmental aspects, 60% social aspects and 45% circular economy. In addition, 65% of the projects implemented Industry 4.0 technologies to increase overall sustainability. Ivascu [55] proposes a hierarchical framework for assessing the sustainability of the manufacturing industry in Romania as part of his research. Sustainability assessment captures the entire supply chain of an organization, including stakeholder interests and the direction of products after their end of life. Several improvements are identified that relate to Industry 4.0 technologies and their application in product value recovery. Raj et al. [56] explored how Industry 4.0 can contribute to sustainability by stimulating sustainable growth in the social, environmental and economic spheres and effectively contributing to the 2030 Agenda. The study contributes to a comprehensive overview of Industry 4.0 in the context of sustainable development in Malaysia. Indoria et al. [57] deal with sustainable manufacturing in the context of the SDGs using Industry 4.0 technologies in the steel industry in India is discussed. Yu et al. [58] investigated the role of Industry 4.0 in circular economy practices with supply chain capabilities and practices to enhance operational and economic performance in automotive companies in China. Satyro et al. [59] analysed sustainability in Industry 4.0 in multinational and national companies in the manufacturing sector in Brazil. The results of the study showed that the most expected benefits were an increase in the global competitiveness of the enterprises and an improvement in the quality of the production lines. Felsberger et al. [60] investigated the impact of Industry 4.0 implementation with a specific focus on digital transformation on the sustainability dimensions of the manufacturing industry in selected European countries.

The presented research results can be the basis for further analysis by the Ministry of the Environment of the Slovak Republic, the Ministry of Investment, Regional Development and Informatization of the Slovak Republic and the Ministry of Foreign and European Affairs of the Slovak Republic, which deal with and cover the 2030 Agenda and the SDGs in Slovakia. Furthermore, the conducted research can be an inspiration for Slovak industrial enterprises in initiating and adhering to the SDGs and creating a green and circular economy within their business processes. The conducted research is a basis for further, next research that would explore the identification of Industry 5.0 and its contribution to production and logistics processes, as it provides greener solutions and compared to previous industrial transformations, neither of which focused on ensuring environmental protection. Previous industrial revolutions have not demonstrated a decisive step towards realising the growing need for energy and achieving the SDGs. Against this background, a paradigmatic change from Industry 4.0 to Industry 5.0 is emerging. The transformation process of Industry into the Industry 5.0 is necessary for the dehumanisation of the industry in the future [61]. It is Industry 5.0 that creates new market opportunities and environmental aspects as well as the possibility of achieving the SDGs. Industry 4.0 primarily focuses on changing the industrial base through new technologies, but less importance is provided to the human and environmental aspects. The new strategy, Industry 5.0, aims to protect society and the environment through technological improvements that lead to economic growth and prosperity. The research presented has focused on sustainability in production and logistics following the SDGs, in connection with Industry 4.0 technologies and innovations. The results are the basis for the implementation of further upcoming research, which would be developed in a multicultural context to identify business processes in Industry 5.0. In this strategy, the interaction of humans and artificial intelligence is complemented by the issue of environmental consideration with processes for the use of renewable energy sources and waste elimination.

The limitations of the conducted research consist of the representative sample of manufacturing enterprises and the narrowing of the conducted study only to manufacturing enterprises operating in the Slovak Republic. Further research is to create an international perspective on the issue, including the questionnaire survey among enterprises operating in other European Union Member States.

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