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Industry 4.0 and Social Development in the Aspect of Sustainable Development: Relations in EC Countries

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Abstract:

Purpose: *The aim of this paper is to focus on the analysis and assessment of the level of development of Industry 4.0, the social development in the context of the implementation of the concept of sustainable development and to determine the relationship of these phenomena in EU countries.*
Design/Methodology/Approach: *Due to the fact that both Industry 4.0 and social development are complex issues, the research uses taxonomic measures based on the TOPSIS method, which replace the multi-feature description of the studied objects by a single aggregate size, which greatly facilitates their analysis. For the purposes of this article, an attempt was made to construct a synthetic measure of the development of Industry 4.0, as well as a synthetic measure of social development in the context of implementing the concept of sustainable development based on a previously selected set of diagnostic variables. The research also used the so-called threshold method to classify EU countries into homogeneous typological groups. In addition, a correlation analysis was carried out in order to examine whether there is a correlation between the analysed phenomena.*
Findings: *The results of the research indicate that there is a moderate variation in the level of social development in the EU countries in the context of implementing the concept of sustainable development and a significant variation in the level of development of Industry 4.0. The analysis showed that there is a very high positive correlation between the two.*
Practical Implications: *Modern economies are faced with the need to meet the challenges resulting from the fourth industrial revolution, for which the emergence of Industry 4.0 is significant. The changes resulting from the implementation of the concept of Industry 4.0 concern not only industry and its enterprises, but also affect the overall shape of socio-economic processes.*
Originality/value: *Social development considered in connection with the development of Industry 4.0 a relatively new economic category, still not well described in the literature. The way they are combined in the article is a relatively new proposal, important from the point of view of each of these areas.*

Keywords: *Industry 4.0, social, sustainable development, taxonomic analysis, TOPSIS method.*
JEL classification: *C4, I1, I2, I3, M21, D04.*
Paper Type: *Research study.*

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1. Introduction

Modern economies are faced with the need to meet the challenges resulting from the fourth industrial revolution, for which the emergence of Industry 4.0 is significant. The changes resulting from the implementation of the concept of Industry 4.0 concern not only industry and its enterprises, but also affect the overall shape of socio-economic processes (Potočan *et al.*, 2020). In particular, a clear link between Industry 4.0 and the theme of sustainability emerges (Bonilla *et al.*, 2018; Bressanelli *et al.*, 2018; Müller *et al.*, 2018). In relation to the theme of sustainability, analyses concerning only two of the sustainability pillars found in literature: environmental and economic (De Sousa Jabbour *et al.*, 2018; Almada-Lobo, 2015; Hansmann *et al.*, 2012; Gibson, 2006). An enduring challenge is also the implementation of the concept of sustainable development, which assumes the possibility of transforming society as well as its various spheres of functioning in such a way as to secure resources and enable future generations to benefit from the achievements of others.

It should be noted that economic growth, social progress and environmental order are treated as interdependent phenomena, which implies the need to solve problems on the sustainable development path in a synergistic way (Barska and Jędrzejczak-Gas, 2019), including also the idea of the development of Industry 4.0. Undoubtedly, the new technologies that make up Industry 4.0 have a huge potential and may become the engine of sustainable development, also in the social dimension. Due to the fact that Industry 4.0 refers not only to technology, but also requires the involvement of human resources in order to effectively manage the creation of added value, the literature refers to social issues (Buhr, 2017; Windelband, 2017; Lorenz *et al.*, 2015). It should be remembered that its development requires the involvement of human resources, which significantly affects not only the labour market, but other social issues.

The social aspects related to Industry 4.0 remain an important but poorly recognised subject of the study at present, therefore the academic discussion on Industry 4.0, the analysis of its content and its detailed description as well as the explanation of its possible future developments deserve more attention (Glas and Kleemann, 2015). Piccarozzi *et al.* (2018, p. 18) indicate that "the transition to Industry 4.0 is very challenging and sustainability issues must be considered as a part of it, in that Industry 4.0 and sustainability are linked two-fold. This relationship could also be a very interesting topic for further investigation. […] Therefore, there is much scope for more contributions to further consider the two economic and environmental pillars that have already been taken into account, as well as the third pillar of sustainability, the social aspect of it". The question therefore arises as to the relationship between the level of development of Industry 4.0 and social development, in particular social development in the context of its sustainability.

As a consequence, the aim of this paper is to start filling this gap, focusing on the main analysis and assessment of the level of development of Industry 4.0 and the level of social development in the context of the implementation of the concept of sustainable development and to determine the relationship between these phenomena in EU countries. The specific objectives are:

– listing EU countries by the level of analysed phenomena,
– Classification of EU countries into homogeneous typological groups according to the level of analysed phenomena,
– analysis of statistical relations between the analysed phenomena.

The perspective proposed in this article combines aspects of Industry 4.0 with social development and, at the same time, takes account of sustainable development issues. The genesis for the formulation of research questions is the integration of two important and current research areas covering Industry 4.0 and social development. However, linking these two issues, indicated as important development goals of most countries of the world, does not only mean another attempt to make research on sustainable development more detailed. The considerations and results of the research presented in the article concern much more complex and interdisciplinary issues.

Therefore, the following research questions can be put forward:

– How does the development of Industry 4.0 in the EU countries relate to social development in the context of implementing the concept of sustainable development?
– How are the EU country classifications presented in relation to these relations and what changes have taken place in the period of 2014-2018?
– Is there a link between the development of Industry 4.0 and social development in the context of implementing the concept of sustainable development?

Due to the fact that both Industry 4.0 and social development are complex categories, the research uses taxonomic measures based on the TOPSIS method, which replace the multi-feature description of the studied objects by a single aggregate size, which greatly facilitates their analysis. For the purposes of this article, an attempt was made to construct a synthetic measure of the development of Industry 4.0, as well as a synthetic measure of social development in the context of implementing the concept of sustainable development[1] based on a previously selected set of diagnostic variables. The research also used the so-called threshold method to classify EU countries into homogeneous typological groups. In addition, a correlation analysis was carried out in order to examine whether there is a correlation between the analysed phenomena. The main criterion for the selection of variables was their completeness and availability for all surveyed objects (EU countries) in the years 2014-2018. The source of data describing the development of Industry 4.0 and areas of social development in individual EU countries was Eurostat and World Bank databases. The survey covered 28 EU Member States.

The article is therefore intended to contribute to filling the cognitive gap that has arisen. Given the very limited empirical literature on the subject, both the study and its results should be treated as exploratory analysis.

2. Literature Review

2.1 Social Development as One of the Pillars of the Concept of Sustainable Development

The idea of sustainable development emerged at a time when attention was drawn to the rapid and unrestrained rate of population growth, with uncontrolled use of natural resources, increasing environmental degradation and unrestrained growth in consumption. In addition, deepening disproportions between highly developed and developing countries in terms of the quality of life of their inhabitants became important (Barska and Jędrzejczak-Gas, 2019). Therefore, the idea is a response to the growing public awareness of the emerging threats in a context of systematic economic growth and limited natural resources. Sustainable development is a development that seeks to improve the quality of life and ensure the welfare of the current generation, but at the same time does not jeopardise the possibilities of meeting the needs of future generations.

This can only be achieved by integrating economic development, environmental protection and social justice measures (Burny *et al.*, 2019, Hou and Al-Tabbaa, 2014). It should be noted that the term sustainable development is not uniformly defined. It appeared in 1987 in a report of the World Commission on Environment and Development entitled *Gro Harlem Brundtland Report*. The report defines "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundland, 1987). The Brundland report postulated that economy and nature should be understood as integrated system components and that economic and environmental goals should be linked to social goals. The concept of sustainable development assumes a change in the current way of thinking and consists in including the natural environment in the social and economic development of a region, country or the whole world, without reducing the current level of civilizational development (Skowronski, 2006). The concept of economic development according to the idea of sustainable development is of double importance, reflecting both the real growth of income in the country and the improvement of other important elements of social welfare. It should be noted that economic growth, social progress and environmental governance are treated as interdependent phenomena, which implies the need to solve problems on the sustainable development path in a synergic way (Barska and Jędrzejczak-Gas, 2019).

The concept of sustainable development combines spatial, economic and social planning, allowing for better coordination of activities and increasing their effectiveness. In the literature on the subject, these aspects are referred to as the so-called 'governance', which can group from 3 sets of indicators, e.g. economic, social and environmental, to 5, e.g. economic, social, environmental, institutional and spatial (Burny *et al.*, 2019).

The policy implemented in accordance with the concept of sustainable development is focused on the following elements: innovativeness and efficiency of the economy, development of human capital, development of transport, energy security and environment, an efficient state, development of social capital, regional development, sustainable development of villages, agriculture and fisheries and development of the national security system (Ladysz, 2015). Social development is an important base of sustainable development. It is a transition from treating economic growth as a condition for building welfare into economic growth as a condition for building social welfare. All "activities that foster such development have started to be referred to as "good development" or “human-centred social development” (Krzyminiewska, 2013).

UNDP defines social development as a process of expanding human choices that lead to a long and healthy life, acquiring knowledge and maintaining a decent standard of living (UNDP 1990), and according to the idea of sustainable development is to take place with rational use of environmental resources. The concept of sustainable development assumes the possibility of transforming the society as well as its various areas of functioning in such a way as to secure resources and enable future generations to benefit from the achievements of others. The aim is to create a kind of symbiosis between man, his artificial environment and the threatened biocenosis and biotope (Rosicki, 2010). The concept of social development therefore means beneficial quantitative, qualitative and structural changes taking place in the society of a given country.

Social development is therefore defined as an expansion of the freedoms and opportunities for people to lead a life that they value and have reason to value. This is an expansion of choice (UNDP, 2012). Social development is an important tool for the implementation of sustainable development, hence the pursuit of social development fosters sustainable development. Midgley (2017) concisely noted that "The concept of sustainable development has been well received in social development circles and reported on many social development projects, especially at the community level". Sustainable development must be based on improving people's quality of life, which means that it should be designed to increase people's ability to meet their socio-economic needs without harming the environment (Mupedziswa, 2012). The social aspects of sustainable development are summed up in terms of social sustainability, whose importance now seems to exceed consensus and concreteness. This is often described indirectly by related ideas such as social justice or stability or is shortened to proposals for measures, indicators and policy objectives, for example poverty reduction (Ketschau, 2017).

Speaking of social development, we refer to the concept of social change, which is defined as a process of structural transformation of the social system. This defines the direction of the course of social change, which means that the research of change must take into account transformations in various successive time frames, although these do not have to create integrated systems, i.e., a change occurring in one sphere does not have to cause changes in another. This principle has been retained in the studies carried out for the purposes of this article, because different years have been considered. The assessment of social change is carried out by individuals, communities, institutions for which the situation may transfer into the adoption of life strategies, taking action in different areas. The processes occurring as a result of social change may increase the chances of an individual and his or her community for a favourable location in the social space or limit these chances (Krzyminiewska, 2013).

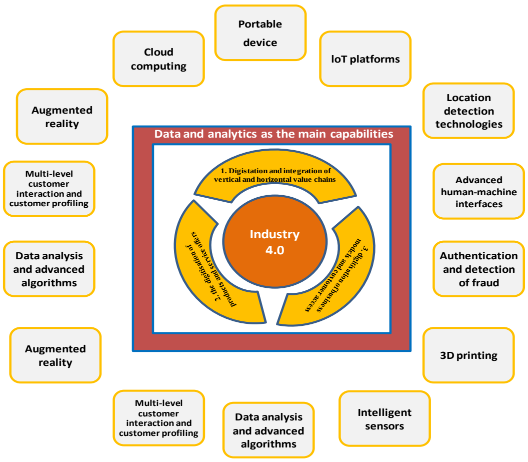
2.2 The Concept of Industry 4.0

Industry 4.0 is an issue increasingly discussed not only in business circles and in the area of economic policy, but also in scientific discourse, as evidenced by the rapidly growing number of publications in renowned scientific journals (Ślusarczyk, 2018). Becoming this new idea popular has led many researchers to try to define it. The author of the term Industry 4.0 is German physicist Kagermann (2015a), who claims that Industry 4.0 is "a network of autonomous production resources, capable of controlling themselves in response to various situations, self-configuring, knowledge-based, sensor-based and spatially dispersed, and with appropriate planning and management systems". According to Kagermann (2015b), the main goal of Industry 4.0 as a concept is to achieve the strategic advantage of "mass customization", i.e., through a higher degree of production of products tailored to the individual needs of customers, but at the cost of mass production. At the Hanover Fair in 2011, the term was used for the first time and the term Industry 4.0 was adopted as a name for the general direction of change in industrial policy by the European Commission promoting the idea of strengthening industrial competitiveness. This idea has become a central pillar of the German industry strategy ("High-Tech Strategy 2020 for Germany"), which aims to make the German economy a global leader in technological innovation (Issa *et al.,* 2018; Müller *et al.*, 2018; Rao and Prasad 2018; Androniceanu 2017; Pereira and Romero 2017). The initiative taken by the German government was intended to bring about a structural change in the way the industrial sectors of the EU economies think and operate. Similar initiatives have been developed in other EU countries, e.g. in the UK (Innovate UK, including Digital Catapult), France (Nouvelle France Industrielle), Sweden (Produktion 2030), Italy (Fabbrica Intelligente), Belgium and the Netherlands (Made Different), Spain (Industria Conectada 4.0), Hungary (IPAR 4.0 National Technology Platform) and Austria (Produktion der Zukunft) and the USA (Industry Connected 4.0), as well as in China (Made in China, 2025).

Industry 4.0 assumes that in the future companies will operate in a global network that incorporates their infrastructure and production equipment, their storage systems, into a cyber-physical production system (CPS). In the production environment, the systems will create intelligent storage machines and systems and devices capable of automatic information exchange, automatic activation of actions and self-controlapproach forms the basis for improving production processes, which include manufacturing processes, engineering, materials management, supply chain and life cycle management. These solutions are suitable for intelligent factories - companies of the future that produce intelligent products that are unique, can be created by the manufacturer at any time, they know their history, status and there are alternative manufacturing options for them to achieve the target state in terms of customer requirements. In smart factories, manufacturing systems are vertically integrated into business processes, while companies collaborate horizontally from the moment an order is placed until the final product is manufactured (Alcácer and Cruz-Machado, 2019; Castelo-Branco *et al.*, 2019; Chiarello *et al.*, 2018; Dalenogare *et al.*, 2018; Kagermann *et al.*, 2013).

In the literature, the Industry 4.0 concept is most often reduced to four key components (Rao and Prasad 2018; Sanders *et al.*, 2016; Jovanović *et al.*, 2015; Schmidt *et al.*, 2015; Kagermann *et al.*, 2013): cyber-physical systems, Internet of Things (IoT), Internet of Services (IoS) and smart factory. A graphical presentation of the pillars of the Industry 4.0 concept is shown in Figure 1.

Figure 1. *The essence and technology of the Industry concept 4.0*



Source: *Own study based on PwC. 2017. Przemysł 4.0 czyli wyzwania współczesnej produkcji, form: https://www.pwc.pl/pl/publikacje/2017/przemysl-4-0.html.*

In this category, for example, Alekseev *et al.* (2018) provide a general definition of Industry 4.0 affirming that Industry 4.0 is "totality of the spheres of economy in which the fully automatic production processes are based on the artificial intellect and Internet with the help of which machines interact and create new machines without human participation". In the same way, Pan *et al.* (2015) state that Industry 4.0 represents "the ability of industrial components to communicate each other" and Kovács and Kot (2016) affirm that "the essence of Industry 4.0 conception is the introduction of network-linked intelligent systems, which realize self-regulating production: people, machines, equipment and products will communicate to one another". Burritt and Christ (2016) propose considering Industry 4.0 as "an umbrella term used to describe a group of connected technological advances that provide a foundation for increased digitization of the business environment". Sanders *et al.* (2016), on the other hand, introduce the theme of the impact of Industry 4.0 on production dynamics and state that “Industry 4.0 significantly influences the production environment with radical changes in the execution of operations. In contrast to conventional forecast based production planning, Industry 4.0 enables real-time planning of production plans, along with dynamic self-optimization”. Industry 4.0 is a change-oriented customization of production according to customer needs. It can therefore be seen as an important step towards the digitisation of industry. Brettler et al. (2014) emphasise that Industry 4.0 is an approach reflecting intelligent shop floor product and process management based on digitisation. Among the key features of Industry 4.0 the literature most frequently mentions (Oztemel and Gursev, 2020; Baldassarre *et al.,* 2017; Liao *et al.,* 2017):

- Intelligent industrial and service robots (collaborative and autonomous robots),
- Analytical systems (big data) with machine learning,
- Cloud computing,
- Simulation systems (digital twin) - use of computer simulation techniques to create a digital model of the factory and processes for the training of operators,
- Industrial Internet of Things,
- Extended and virtual reality,
- Incremental production - use of 3D printing in prototyping and production of expensive or components that are difficult to produce.

To sum up, many definitions of Industry 4.0 (Müller *et al.,* 2017) are proposed in the literature, due to the fact that the concept can be described and explained at micro levels - within a company, mezzo levels - within a sector or macro levels - in the economic dimension. The element connecting the different definitions is the integration of people, machines and advanced communication and information technologies, enabling real-time interaction between the key components of an enterprise (manufacturing or service), sector and economy (Młody and Weinert, 2020). 4.0 technologies belong to an open set because of the combinations of solutions and their derivatives permanently developed by manufacturers and users (Batkovskiy *et al.,* 2019).

The idea of Industry 4.0 fits perfectly into the European economic model. It will make it possible to maintain a sustainable industry, develop workers' qualifications, support the energy transformation and adapt to a high level of personalization. The implementation of industrial robots and information and communication technologies will facilitate the integration of work - from the design process through procurement, logistics to the production of the final product, whose quality will be the result of combining the work of programs supporting and optimizing production and people who will become "quality guards" on automated production lines (Stolarczyk, 2017). This will also allow Europe to successfully compete with other regions in the world.

3. Research Methods

The assessment of the social development of EU countries in the context of the implementation of the concept of sustainable development and the evaluation of the development of Industry 4.0 in the EU countries was carried out on the basis of linear ordering methods.

The first stage of the research consisted in constructing a synthetic, taxonomic measure of social development in the context of implementing the concept of sustainable development in individual EU countries. Due to the multi-faceted nature of social development, it was necessary to use a significant number of measures. However, bearing in mind that an excessive number of variables may cause disruption or even locking the possibility of effective object classification (Młodak, 2006), a set of 34 potential diagnostic variables was proposed. These variables were divided into five thematic groups:

1) Poverty: X1 - People at risk of poverty or social exclusion, X2 - People at risk of income poverty after social transfers, X3 - Severely materially deprived people, X4 - People living in households with very low work intensity, X5 – Indicator of poverty risk at work, X6 - At risk of poverty or social exclusion rate for elderly (65+), X7 - Median relative income of elderly people, X8 - Income share of the bottom 40% of the population.
2) Health: X9 - Healthy life years at birth, X10 - Healthy life years at age 65, X11 - Share of people with good or very good perceived health , X12 - Infant mortality rate, X13 - Life expectancy by age, X14- Death rate due to chronic diseases.
3) Labor market: X15 - Employment rate , X16 - Long-term unemployment rate, X17 - Youth unemployment rate, X18 - Overall employment growth, X19 - Employment rate of older workers, X20 - Unemployment rate, X21 - Labour productivity per person employed and hour worked.
4) Education: X22 - Tertiary educational attainment rate, X23- Employment rates of recent graduates, X24 - Adult participation in learning , X25 - Young people neither in employment nor in education and training , X26 - Early leavers from education and training.
5) Demography: X27 - Overcrowding rate, X28 - Population density, X29 - Population change, X30 - Women per 100 men, X31 - Live births and crude birth rate number, X32 - Immigration persons, X33 - Emigration persons, X34 - Old-age-dependency ratio.

The second stage of research consisted in the construction of a synthetic, taxonomic measure of the development of Industry 4.0 in individual EU countries. As a result of substantive and formal analysis of variables - 17 subindices were proposed, reflecting the level of development of Industry 4.0 in EU countries: Y1 - % People ICT in employment aged 15-74, Y2 - Electronic Information Sharing, Y3 - Social media uptake, Y4 - SMEs selling online, Y5 - Selling online cross-border, Y6 - High-technology exports, Y7 - Patent applications, nonresidents, Y8 - Patent applications, residents, Y9 - Enterprises with a website, Y10 - Electronic information sharing, Y11 - Business enterprise R&D expenditure in high-tech sectors, Y12 - Scientific and technical journal articles, Y13 - Researchers in R&D, Y14 - Research and development expenditure, Y15 - Total R&D appropriations, Y16 - Big data, Y17 - Cloud uptake.

It should be noted that the diagnostic variables used do not fully reflect the level of development of Industry 4.0 in individual EU countries. This is largely due to the limited availability of data, as well as the difficult measurability of the analysed phenomenon. Being aware of the imperfections of the used variables, they should be treated as some approximation of the level of development of Industry 4.0. The following steps have been taken to implement both research phases:

In order to obtain the final set of diagnostic variables, the discriminatory capacity of the variables and their capacity (degree of correlation with other variables) were examined. When selecting the variables, it is required that individual observations show adequate variability, because a poorly differentiated variable provides small analytical value. It has been assumed that from the set of potential variables the features for which the value of the classic coefficient of variation is lower than the arbitrarily determined critical threshold value of this coefficient at the level of 10% will be eliminated. Due to too low variability, four characteristics relating to the level of social development were eliminated from the set of partial variables - X9, X13, X15 and X30. However, no variables were eliminated from the set of variables describing the level of development of Industry 4.0.

Pearson correlation coefficients were used to assess the informative value. For each subject subgroup of variables characterizing social development, the analysis of correlation coefficient matrixes was carried out, and then variables exceeding the threshold value (most often set by researchers at r*=0.7) were eliminated. Thus, the variables X1, X2, X8, X16, X17, X23, X32 were eliminated from the set of potential decision variables describing social development. Table 1 presents the final set of variables describing social development in the context of implementing the concept of sustainable development, on the basis of which synthetic measures for individual EU countries were constructed.

***Table 1**. Indicators on the basis of which the synthetic measure of social development in the context of implementing the concept of sustainable development was constructed*

Sym bol	Variable	Unit of measure	Variable characteristics
Poverty			
X3	Severely materially deprived people	percentage	The indicator measures the share of severely materially deprived persons who have living conditions severely constrained by a lack of resources. They experience at least 4 out of 9 following deprivations items: cannot afford 1) to pay rent or utility bills, 2) keep home adequately warm, 3) face unexpected expenses, 4) eat meat, fish or a protein equivalent every second day, 5) a week holiday away from home, 6) a car, 7) a washing machine, 8) a colour TV, or 9) a telephone. The indicator is part of the multidimensional poverty index.
X4	People living in households with very low work intensity	percentage of total population aged less than 60	The indicator is defined as the share of people aged 0-59 living in households with very low work intensity. These are households where on average the adults (aged 18-59, excluding students) work 20% or less of their total work potential during the past year. The indicator is part of the multidimensional poverty index.

X5	In work at-risk-of-poverty rate % of employed persons aged 18 or over	percentage of employed persons aged 18 or over	Individuals (18-64) who are classified as employed according to their most frequent activity status and are at risk of poverty.
X6	At risk of poverty or social exclusion rate for elderly (65+)	percentage	The sum of elderly (65+) who are: at-risk-of-poverty or severely materially deprived or living in (quasi-)jobless households (i.e. with very low work intensity) as a share of the total population in the same age group.
X7	Median relative income of elderly people	persons aged 65 years and over compared to persons aged less than 65 years	The indicator is defined as the ratio between the median equivalised disposable income of persons aged 65 or over and the median equivalised disposable income of persons aged between 0 and 64.
Health			
X10	Healthy life years at age 65	number of years	The indicator Healthy Life Years (HLY) at age 65 measures the number of years that a person at age 65 is still expected to live in a healthy condition. HLY is a health expectancy indicator which combines information on mortality and morbidity.
X11	Share of people with good or very good perceived health	percentage of population aged 16 or over	The indicator is a subjective measure on how people judge their health in general on a scale from "very good" to "very bad". It is expressed as the share of the population aged 16 or over perceiving itself to be in "good" or "very good" health.
X12	Infant mortality rate	per 1000 live births	Infant mortality rate is the number of infants dying before reaching one year of age, per 1,000 live births in a given year.
X14	Standardised death rate due to chronic diseases	number per 100 000 persons aged less than 65	The indicator measures the standardised death rate of chronic diseases. Chronic diseases included in the indicator are malignant neoplasms, diabetes mellitus, is chaemic heart diseases, cerebrovascular diseases, chronic lower respiratory diseases and chronic liver diseases. Death due to chronic diseases is considered premature if it occurs before the age of 65. The rate is calculated by dividing the number of people under 65 dying due to a chronic disease by the total population under 65.
Labor market			
X18	Overall employment growth	percentage change on previous period (based on persons)	The indicator 'employment growth' gives the change in percentage from one year to another of the total number of employed persons on the economic territory of the country or the geographical area.
X19	Employment rate of older workers	percentage of total population	The employment rate of older workers is calculated by dividing the number of persons in employment and aged 55 to 64 by the total population of the same age group.
X20	Unemployment rate	total, percentage of labour force	Unemployment rate is the number of unemployed people as a percentage of the labour force, where the latter consists of the unemployed plus those in paid or self-employment. Unemployed people are those who report that they are without work, that they are available for work and that they have taken active steps to find work in the last four weeks.
X21	Labour productivity per person employed and hour worked	percentage of EU27 (from 2020) total (based on million purchasing power standards), current prices	Labour productivity per hour worked is calculated as real output per unit of labour input (measured by the total number of hours worked). Measuring labour productivity per hour worked provides a better picture of productivity developments in the economy than labour productivity per person employed, as it eliminates differences in the full time/part time composition of the workforce across countries and years.

Education			
X22	Tertiary educational attainment rate	percentage of population aged 30 to 34	The indicator is defined as the percentage of the population aged 30-34 who have successfully completed tertiary studies (e.g. university, higher technical institution, etc.).
X24	Adult participation in learning	percentage of population aged 25 to 64	The indicator measures the share of people aged 25 to 64 who stated that they received formal or non-formal education and training in the four weeks preceding the survey (numerator). The denominator consists of the total population of the same age group, excluding those who did not answer to the question 'participation in education and training'.
X25	Young people neither in employment nor in education and training	percentage of the total population in the same age group	The indicator young people neither in employment nor in education and training (NEET) provides information on young people aged 15 to 24 who meet the following two conditions: (a) they are not employed (i.e. unemployed or inactive according to the International Labour Organisation definition) and (b) they have not received any education or training in the four weeks preceding the survey. Data are expressed as a percentage of the total population in the same age group, excluding the respondents who have not answered the question 'participation to education and training' and in change over 3 years (in % points).
X26	Early leavers from education and training	percentage of the population aged 18-24 with at most lower secondary education and not in further education or training	The indicator is defined as the percentage of the population aged 18-24 with at most lower secondary education and who were not in further education or training during the last four weeks preceding the survey.
Demography			
X27	Overcrowding rate	percentage	This indicator is defined as the percentage of the population living in an overcrowded household. A person is considered as living in an overcrowded household if the household does not have at its disposal a minimum of rooms equal to: - one room for the household; - one room by couple in the household; - one room for each single person aged 18 and more; - one room by pair of single people of the same sex between 12 and 17 years of age; - one room for each single person between 12 and 17 years of age and not included in the previous category; - one room by pair of children under 12 years of age.
X28	Population density	people per sq. km of land area	Population density is midyear population divided by land area in square kilometers. Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship-except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin.
X29	Population change	percentage	Annual population growth rate for year t is the exponential rate of growth of midyear population from year t-1 to t, expressed as a percentage . Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship.
X31	Live births and crude birth rate	per 1 000 persons	Live births are the births of children that showed any sign of life. The crude birth rate is the ratio of the number of live births during the year to the average population in that year. The value is expressed per 1 000 persons.
X33	Emigration persons	per 1 000 persons	Emigrant is a person undertaking an emigration. Emigration is the action by which a person, having previously been usually resident in the territory of a Member State, ceases to have his or her usual

			residence in that Member State for a period that is, or is expected to be, of at least 12 months.
X34	Old-age-dependency ratio	per 100 persons	This indicator is the ratio between the number of persons aged 65 and over (age when they are generally economically inactive) and the number of persons aged between 15 and 64. The value is expressed per 100 persons of working age (15-64).

Source: *Own study based on Eurostat and World Bank databases.*

Similarly, the analysis of the matriY of correlation coefficients of variables characterizing the development of Industry 4.0 was performed and variables eYceeding the threshold value (r*=0.7) were eliminated. Thus, from the set of potential decision making variables describing the development of Industry 4.0 the following variables were eliminated: Y1, Y2, Y5, Y11, Y12, Y13, Y15.

The final set of variables on the basis of which synthetic measures of the development of Industry 4.0 for individual EU countries were constructed is presented in Table 2.

Table 2. *Indicators on the basis of which the synthetic measure of industry development was constructed 4.0*

Symbol	Variable	Unit of measure	Variable characteristics
Y3	Social media uptake	percentage of enterprises	Enterprises using two or more of the following social media: social networks, enterprise's blog or microblog, multimedia content sharing websites, wiki based knowledge sharing to ols.
Y4	SMEs selling online	percentage of enterprises	Enterprises selling at least 1% of turnover online.
Y6	High-technology exports	number for 10,000 enterprises	Enterprises exporting high-technology exports. High-technology exports are products with high R&D intensity, such as aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery.
Y7	Patent applications, nonresidents	number per million inhabitants	Patent applications are worldwide patent applications filed through the Patent Cooperation Treaty procedure or with a national patent office for exclusive rights for an invention--a product or process that provides a new way of doing something or offers a new technical solution to a problem.
Y8	Patent applications, residents	number per million inhabitants	Patent applications, residents product or process that provides a new way of doing something or offers a new technical solution to a problem.
Y9	Enterprises with a website	percentage of enterprises	Enterprises who have website.
Y10	Electronic information sharing	percentage of enterprises	Enterprises who have ERP software package to share information between different functional areas
Y14	Research and development expenditure	percentage of GDP	Gross domestic expenditures on research and development (R&D), expressed as a percent of GDP. They include both capital and current expenditures in the four main sectors: Business enterprise, Government, Higher education and Private non-profit. R&D covers basic research, applied research, and experimental development.
Y16	Big data	percentage of enterprises	Enterprises analysing big data from any data Source.
Y17	Cloud uptake	percentage of enterprises	Enterprises purchasing at least one of the following cloud computing services: hosting of the enterprise's database, accounting software applications, CRM software, computing power.

Source: *Own study based on Eurostat and World Bank databases.*

Then for each variable its nature was determined (way of influencing the analysed phenomenon). It could be a stimulant, destimulant or nominant. In the case of variables related to social development in the context of implementing the concept of sustainable development, the following variables were included in the stimulant set: X10, X11, X18, X19, X21, X22, X23, X24, X28, X29, X31, X32, while the destimulant set included the following variables: X1, X2, X3, X4, X5, X6, X7, X8, X12, X14, X16, X17, X20, X25, X26, X27, X33, X34. None of the variables were nominative. On the other hand, in the case of variables showing the level of development of Industry 4.0, all variables were included in the stimulant set. In the case of variables of a destimulant character, they were transformed into stimulants. It is from the many transformations proposed in the literature (Kolenda 2006; Walesiak 2006) that the following ones will be applied in this study:

$$x_{ij}^{S} = -x_{ij} \tag{1}$$

where:
x_{ij}^{S}– the value of the jth variable in the ith object transformed into a stimulus,
x_{ij} – value of jth variable in ith object.

Once the nature of the variables has been determined, a standardisation process was carried out for them by means of unitarisation and using the following formula (Strahl 1998, p. 272):

$$z_{ij} = \frac{x_{ij} - min\, x_i}{max\, x_i - min\, x_i} \tag{2}$$

where:
z_{ij}– normalized values of the j-th variable in the i-th object,
x_{ij} – value of jth variable in ith object,
$min\, x_i$– minimum value of j-th variable,
$max\, x_i$– maximum value of j-th variable.

The classic TOPSIS method (Technique for Order Preference by Similarity to an Ideal Solution) was used in order to list the EU countries by the level of social development in the context of implementing the concept of sustainable development and by the level of development of Industry 4.0. Unlike the Hellwig's development pattern method (most often used by researchers), this method takes into account the Euclidean distance from both the pattern and the counterweight. Synthetic meters were constructed according to the following steps (Hwang and Yoon, 1981; Lai *et al.,* 1994; Wysocki, 2010):

1. For the standardised features, the coordinates of the model units - the pattern (z_{0j}^{+}) and anti-pattern of development (z_{0j}^{-}):

$$z_{0j}^{+} = \max_i\{z_{ij}\};\ z_{0j}^{-} = \min_i\{z_{ij}\} \tag{3}$$

z_{ij}– standardised values of the jth variable for the ith object

2. Euclidean distances of each object from the pattern and anti-pattern were calculated:

$$d_{i0}^{+} = \sqrt{\sum_{j=1}^{m}\left(z_{ij} - z_{0j}^{+}\right)^{2}}; \qquad d_{i0}^{-} = \sqrt{\sum_{j=1}^{m}\left(z_{ij} - z_{0j}^{-}\right)^{2}} \tag{4}$$

3. Synthetic measurement values have been calculated:

$$s_i = \frac{d_{i0}^{-}}{d_{i0}^{+} + d_{i0}^{-}} \tag{5}$$

$s_i \in [0; 1]$, $\max_i\{s_i\}$ – best object, $\min_i\{s_i\}$ – worst object.

For the sake of completeness of the analysis of the TOPSIS method's measures, EU countries were grouped in terms of social development in the context of the implementation of the concept of sustainable development and in terms of the level of development of Industry 4.0 using the so-called threshold method into four classes (Wysocki, 2010):

Group I (very high level): $z_i \geq \bar{z}_i + S_{z_i}$

Group II (high level): $\bar{z}_i + S_z > z_i \geq \bar{z}_i$

Group III (medium level): $\bar{z}_i > z_i \geq \bar{z}_i - S_{z_i}$

Group IV (low level): $z_i < \bar{z}_i - S_{z_i}$

where $\bar{z}_i$ it is the arithmetic mean of the meter value and S_{z_i} is a standard deviation.

The final stage of the research consisted in checking the relationship between social development in the context of implementing the concept of sustainable development and industrial development 4.0 in EU countries. For this purpose, a correlation analysis was carried out. In order to mitigate the negative impact of possible outliers on the results of the correlation analysis, the non-parametric Spearman's rank correlation coefficient was used.

4. Empirical Results

An analysis of the synthetic values of the measures shows that there is a moderate variation in the level of social development in the EU in the context of implementing the concept of sustainable development and a significant variation in the level of development of Industry 4.0.

The average value of the synthetic measure of social development in the years 2014-2018 was about 0.51. The highest level of this measure was identified in the following countries: Sweden, the Netherlands, Ireland, Denmark, Luxembourg, Finland. The lowest values were found in Romania, Bulgaria, Greece, Croatia, Italy and Latvia. In the same period the average value of the synthetic measure of the development of

Industry 4.0 was about 3.8, which indicates that in the EU the level of development of Industry 4.0 is lower than the level of social development. The highest level of development of Industry 4.0 was identified in countries such as Germany, Denmark, the Netherlands, Finland, Sweden and the United Kingdom. The countries with the lowest scores were Romania, Latvia, Poland, Hungary, Bulgaria, Italy and Greece (Table 3).

In the analysed period, the value of the coefficient of variation calculated for synthetic measures of social development was at the level of about 18%, while in the case of synthetic measures of the development of Industry 4.0 the value ranged between 33% and 36%. So it can be concluded that the diversity of EU countries in the case of Industry 4.0 is much higher than in the case of social development. This is also confirmed by the fact that the ratio of the maximum to minimum measure in the case of social development is about 2, while in the case of Industry 4.0 it is as much as about 4. Synthetic measures of social development throughout the analysed period were characterised by left-handed asymmetry, which means that most EU countries achieved a level of social development higher than average. A completely different situation was noted in the case of the level of development of Industry 4.0 - synthetic measures in the entire analysed period were characterised by right-handed asymmetry, which means that most EU countries achieved a level of development of Industry 4.0 lower than the average.

Analysing the value of synthetic measures for individual EU countries, it can be seen that many countries that have achieved high measures of social development have also achieved high measures of development of Industry 4.0 (Sweden, the Netherlands, Denmark, Finland). In turn, many countries that achieved low measures of social development also achieved low measures of development of Industry 4.0 (Romania, Bulgaria, Greece, Hungary). These data may therefore indicate that there is a correlation between social development in the context of sustainable development and the development of Industry 4.0. On the basis of the synthetic values of the measures, the rankings of EU countries were created in terms of the level of social development in the context of the implementation of the concept of sustainable development and the level of development of Industry 4.0. In particular years, no significant differences were observed between the ranks of particular countries. However, it should be noted, that during the period under examination, the increase in social development and improvement of its position in the ranking was recorded by countries such as: Ireland, Malta, Cyprus and Czech Republic. In turn, a decrease in the level of social development, as compared to other EU countries, and consequently a decrease in the position in the ranking was recorded by countries such as Luxembourg and France.

As far as the level of development of Industry 4.0 is concerned, Germany is the undisputed leader in the EU. It took first place in all the years under study. Next are Denmark and the Netherlands (2nd or 3rd position) then Sweden and Finland (4th or 5th position). No EU country has recorded either a significant increase or a significant decrease in the level of development of Industry 4.0 during the period considered. Some positive developments and therefore an improvement in the ranking was noted, inter alia, by Cyprus, France, Latvia and Spain. On the other hand, some negative changes and therefore a decrease of the ranking position were noted, inter alia, by Croatia, Slovenia (Table 4).

For the sake of completeness of the analysis of the TOPSIS measures, EU countries were grouped in terms of similarity of the level of social development in the context of implementation of the concept of sustainable development and in terms of the level of development of Industry 4.0 (Table 5). In the subsequent years of the period analysed, the results of the grouping are very similar - both in the case of social development and in the case of the development of Industry 4.0. In only a few cases, countries changed the group, and this was a change by only one rank, i.e. from Group I to Group II. There was no case for a country to change its rank by two, e.g. from Group IV to Group II.

When analysing the results of grouping by the level of social development, it can be observed that in all the analysed years the most numerous group was the one characterized by a high level of development (II), while the least numerous was the one characterized by a very high level of development (I). Only 4 countries qualified to the group with a very high level of development (in 2018 - 3 countries), these were Sweden, the Netherlands (in all the studied years) and Denmark and Ireland. About 43% of all EU countries qualified for the group with a high level of social development in the following years, of which about 80% were in this group in all the years surveyed. In the group with a medium and low level of development there were about 21-28% and 18-21% of EU countries respectively, with the majority of countries being in these groups for all the years under study. It is worrying that as many as 6 EU countries were in the group with a low level of development.

When analysing the results of grouping by level of development of Industry 4.0, it can be seen that in all the years under examination the most numerous group was the one characterized by an average level of development (III), then high (II) and very high (I) level of development. The group characterized by a low level of development (IV) was the least numerous. The countries that were in the group with the highest level of development of Industry 4.0 and are leaders in this area in the EU are primarily: Germany, Denmark, Finland, the Netherlands and Sweden. It should be noted that these countries are also in the group with a very high or high level of social development in the context of sustainable development, which may indicate a link between the two categories. On the other hand, the group with the lowest level of development of Industry 4.0 included countries from Central and Eastern Europe, i.e. Hungary, Latvia, Poland, Romania and Bulgaria. These countries were also in the group characterized by a low or medium level of social development in the context of sustainable development, which may also indicate a relationship between the two categories.

Table 3. *Synthetic measures - the level of social development in the context of implementation of the concept of sustainable development and the level of development of Industry 4.0.*

Kraje UE	Synthetic measure – social development						Synthetic measure – development of Industry 4.0					
	2014	**2015**	**2016**	**2017**	**2018**	**2014-2018**	**2014**	**2015**	**2016**	**2017**	**2018**	**2014-2018**
Austria	0,5721	0,5607	0,5744	0,5516	0,5426	0,5603	0,4944	0,4417	0,4424	0,4360	0,4554	0,4540
Belgium	0,5787	0,5618	0,5705	0,5503	0,5354	0,5593	0,5008	0,4844	0,4838	0,4915	0,4929	0,4907
Bulgaria	0,3456	0,3588	0,3386	0,3463	0,3368	0,3452	0,2766	0,2507	0,2501	0,2441	0,2447	0,2532
Croatia	0,4085	0,3889	0,3854	0,3797	0,3883	0,3902	0,3314	0,3137	0,2832	0,2719	0,2800	0,2960
Cyprus	0,5187	0,5414	0,5767	0,5635	0,5563	0,5513	0,2908	0,3131	0,3397	0,3353	0,3239	0,3206
Czech Republic	0,5594	0,5600	0,5719	0,5654	0,5598	0,5633	0,3827	0,3746	0,3271	0,3478	0,3664	0,3597
Denmark	0,6315	0,6297	0,6437	0,6068	0,5742	0,6172	0,5857	0,5840	0,5544	0,5584	0,5844	0,5734
Estonia	0,5145	0,5276	0,5119	0,5214	0,5077	0,5166	0,3146	0,3071	0,3022	0,3231	0,3148	0,3124
Finland	0,5976	0,5844	0,5905	0,5728	0,5655	0,5822	0,5572	0,5292	0,5215	0,5401	0,5576	0,5411
France	0,5743	0,5515	0,5598	0,5376	0,5196	0,5486	0,3597	0,3519	0,3685	0,3682	0,4008	0,3698
Germany	0,5398	0,5520	0,5550	0,5378	0,5259	0,5421	0,6704	0,6538	0,6371	0,6113	0,6080	0,6361
Grece	0,3627	0,3455	0,3557	0,3523	0,3585	0,3549	0,3164	0,2681	0,2872	0,2839	0,2886	0,2888
Hungary	0,4306	0,4281	0,4572	0,4307	0,4540	0,4401	0,2034	0,1882	0,1972	0,2095	0,2112	0,2019
Ireland	0,6080	0,6149	0,6332	0,6199	0,6378	0,6228	0,4879	0,4921	0,5147	0,5108	0,5051	0,5021
Italy	0,4273	0,4102	0,4275	0,4091	0,3865	0,4121	0,2842	0,2501	0,2736	0,2757	0,2673	0,2702
Latvia	0,4114	0,4221	0,4179	0,4088	0,4111	0,4143	0,1529	0,1524	0,1789	0,1840	0,2210	0,1778
Lithuania	0,4719	0,4550	0,4594	0,4446	0,4550	0,4572	0,3877	0,3626	0,3679	0,3791	0,3982	0,3791
Luxemburg	0,6344	0,6039	0,6000	0,5717	0,5539	0,5928	0,4246	0,3718	0,4392	0,4536	0,4301	0,4239
Malta	0,5890	0,5692	0,5705	0,5835	0,5824	0,5789	0,4212	0,4076	0,4024	0,4034	0,3902	0,4050
Netherlands	0,6352	0,6318	0,6457	0,6273	0,6188	0,6318	0,5861	0,5598	0,5632	0,5630	0,5629	0,5670
Poland	0,4890	0,4861	0,5020	0,4950	0,4812	0,4907	0,1930	0,1722	0,1879	0,1911	0,2055	0,1899
Portugal	0,4704	0,4779	0,4918	0,4995	0,4889	0,4857	0,3430	0,3236	0,3456	0,3422	0,3408	0,3390
Romania	0,3443	0,3210	0,3231	0,3336	0,3096	0,3263	0,1861	0,1633	0,1610	0,1589	0,1698	0,1678
Slovakia	0,4895	0,4958	0,5072	0,4965	0,4861	0,4950	0,3412	0,3081	0,2997	0,2925	0,2985	0,3080
Slovenia	0,5401	0,5402	0,5514	0,5438	0,5506	0,5452	0,3886	0,3721	0,3686	0,3505	0,3711	0,3702
Spain	0,4589	0,4613	0,4734	0,4683	0,4612	0,4646	0,3428	0,3310	0,3456	0,3762	0,3784	0,3548
Sweden	0,6661	0,6566	0,6697	0,6479	0,6314	0,6543	0,5676	0,5312	0,5246	0,5171	0,5277	0,5336
United Kingdom	0,6026	0,5928	0,5923	0,5738	0,5435	0,5810	0,5194	0,5006	0,4935	0,4983	0,5113	0,5046
MIN	0,3443	0,3210	0,3231	0,3336	0,3096	0,3263	0,1529	0,1524	0,1610	0,1589	0,1698	0,1678
MAX	0,6661	0,6566	0,6697	0,6479	0,6378	0,6543	0,6704	0,6538	0,6371	0,6113	0,6080	0,6361
SR	0,5169	0,5118	0,5199	0,5086	0,5008	0,5116	0,3897	0,3700	0,3736	0,3756	0,3824	0,3782
MED	0,5293	0,5408	0,5532	0,5377	0,5228	0,5437	0,3712	0,3573	0,3568	0,3594	0,3748	0,3648
V	0,1801	0,1810	0,1842	0,1761	0,1751	0,1780	0,3472	0,3622	0,3433	0,3375	0,3295	0,3419
A	-0,1729	-0,5786	-0,6170	-0,5158	-0,3166	-0,5355	0,3145	0,2770	0,2024	0,1872	0,0591	0,2079
Q1	0,4518	0,4483	0,4589	0,4411	0,4548	0,4529	0,3087	0,2974	0,2862	0,2819	0,2865	0,2942
Q2	0,5839	0,5655	0,5756	0,5686	0,5581	0,5711	0,4912	0,4631	0,4631	0,4726	0,4742	0,4723

MIN - minimum value; MAX - maximum value; SR - average value; MED - median; V - coefficient of variation; A - asymmetry coefficient; Q1 - first quartile; Q3 - third quartile.

Source: *Own elaboration.*

Table 4. *Ranking position - the level of social development in the context of implementation of the concept of sustainable development and the level of development of Industry 4.0*

EU member state	Position in the ranking – social development						Position in the ranking – development of Industry 4.0					
	2014	2015	2016	2017	2018	2014-2018	2014	2015	2016	2017	2018	2014-2018
Austria	11	10	9	11	12	10	8	9	9	10	9	9
Belgium	9	9	11	12	13	11	7	8	8	8	8	8
Bulgaria	27	26	27	27	27	27	24	23	24	24	24	24
Croatia	25	25	25	25	24	25	19	18	22	23	22	21
Cyprus	15	14	8	10	8	12	22	19	17	18	18	18
Czech Republic	12	11	10	9	7	9	14	11	18	16	16	15
Denmark	4	3	3	4	5	4	3	2	3	3	2	2
Estonia	16	16	16	16	16	16	21	21	19	19	19	19
Finland	7	7	7	7	6	6	5	5	5	4	4	4
France	10	13	13	15	15	13	15	15	13	14	11	14
Germany	14	12	14	14	14	15	1	1	1	1	1	1
Grece	26	27	26	26	26	26	20	22	21	21	21	22
Hungary	22	22	22	22	22	22	25	25	25	25	26	25
Ireland	5	4	4	3	1	3	9	7	6	6	7	7
Italy	23	24	23	23	25	24	23	24	23	22	23	23
Latvia	24	23	24	24	23	23	28	28	27	27	25	27
Lithuania	19	21	21	21	21	21	13	14	14	12	12	12
Luxemburg	3	5	5	8	9	5	10	13	10	9	10	10
Malta	8	8	12	5	4	8	11	10	11	11	13	11
Netherlands	2	2	2	2	3	2	2	3	2	2	3	3
Poland	18	18	18	19	19	18	26	26	26	26	27	26
Portugal	20	19	19	17	17	19	16	17	16	17	17	17
Romania	28	28	28	28	28	28	27	27	28	28	28	28
Slovakia	17	17	17	18	18	17	18	20	20	20	20	20
Slovenia	13	15	15	13	10	14	12	12	12	15	15	13
Spain	21	20	20	20	20	20	17	16	15	13	14	16
Sweden	1	1	1	1	2	1	4	4	4	5	5	5
United Kingdom	6	6	6	6	11	7	6	6	7	7	6	6

Source: *Own elaboration.*

Table 5. *Classification of EU countries into typological groups according to the level of social development in the context of sustainable development and the level of industrial development 4.0*

Group	Level of development	EU member state					
		2014	2015	2016	2017	2018	2014-2018
Level of social development							
I	very high	SE, NL, DK, LU	SE, NL, DK, IE	SE, NL, DK, IE	SE, NL, DK, IE	SE, NL, IE	SE, NL, DK, IE
II	high	BE, CZ, DE, FR, CY, MT, AT, SI, FI, GB, IE	BE, CZ, DE, FR, CY, MT, AT, SI, FI, GB, LU, EE	BE, CZ, DE, FR, CY, MT, AT, SI, FI, GB, LU	BE, CZ, DE, FR, CY, MT, AT, SI, FI, GB, LU, EE	BE, CZ, DE, FR, CY, MT, AT, SI, FI, GB, LU, EE, DK	BE, CZ, DE, FR, CY, MT, AT, SI, FI, GB, LU, EE
III	average	ES, LT, HU, PL, PT, SK, EE, IT	ES, LT, HU, PL, PT, SK, LV	ES, LT, HU, PL, PT, SK, EE, IT	ES, LT, HU, PL, PT, SK	ES, LT, HU, PL, PT, SK	ES, LT, HU, PL, PT, SK
IV	low	BG, EL, HR, RO, LV	BG, EL, HR, RO, IT	BG, EL, HR, RO, LV	BG, EL, HR, RO, LV, IT	BG, EL, HR, RO, LV, IT	BG, EL, HR, RO, LV, IT
Level of industrial development 4.0							
I	very high	DE, DK, FI, NL, SE	DE, DK, FI, NL, SE	DE, DK, FI, NL, SE, IE	DE, DK, FI, NL, SE, IE	DE, DK, FI, NL, SE, GB	DE, DK, FI, NL, SE
II	high	AT, BE, LU, MT, GB, IE	AT, BE, LU, MT, GB, IE, CZ, SI, GB	AT, BE, LU, MT, GB,	AT, BE, LU, MT, GB, LT, ES	AT, BE, LU, MT, LT, IE, FR	AT, BE, LU, MT, GB, LT, IE,
III	average	HR, CY, EE, EL, IT, PT, SK, BG, CZ, FR, LT, SI, ES	HR, CY, EE, EL, IT, PT, SK, BG, FR, LT, ES	HR, CY, EE, EL, IT, PT, SK, BG, CZ, FR, LT, SI, ES	HR, CY, EE, EL, IT, PT, SK, CZ, FR, SI	HR, CY, EE, EL, IT, PT, SK, CZ, SI, ES	HR, CY, EE, EL, IT, PT, SK, BG, CZ, FR, SI, ES
IV	low	HU, LV, PL, RO,	HU, LV, PL, RO,	HU, LV, PL, RO,	HU, LV, PL, RO, BG	HU, LV, PL, RO, BG	HU, LV, PL, RO,

AT – Austria, BE – Belgium, BG – Bulgaria, HR – Croatia, CY – Cyprus, CZ – Czech Republic, DK – Denmark, EE – Estonia, FI – Finland, FR – France, DE – Germany, EL – Grece, HU – Hungary, IE – Ireland, IT – Italy, LV – Latvia, LT – Lithuania, LU – Luxemburg, MT – Malta, NL – Netherlands, PL – Poland, PT – Portugal, RO – Romania, SK – Slovakia, SI – Slovenia, ES – Spain, SE – Sweden, GB – United Kingdom.

Source: *own elaboration.*

The results presented above indicate that there may be a relationship between the level of social development in the context of implementing the concept of sustainable development and the level of development of Industry 4.0. Therefore, in order to examine whether there is a relationship between these phenomena, and what is its nature if there is one (positive or negative; very high, high, moderate or weak), a correlation analysis was conducted (Table 6).

Table 6. *Spearman's Rank Correlation Factor values between synthetic measures of social development in the context of the implementation of the concept of sustainable development and synthetic measures of the level of development of Industry 4.0*

Description	2014	2015	2016	2017	2018
Correlation coefficient	0,8320	0,8528	0,8352	0,8287	0,7685

Source: *Own elaboration.*

The analysis carried out showed that there is a very high positive correlation relationship between the categories concerned. In the analysed period we can speak about a very high degree of correlation at the level of significance of $p < 0.05$. The critical value of Spearman's ranked correlation at the level of materiality $\alpha = 0.05$ and for 28 observations is 0.3754. The calculated values of the correlation coefficient in the whole analysed period varied between 0.7685 and 0.8528 and in the years 2014-2018 significantly exceeded the critical value, which allows us to conclude the significance of the correlation coefficient at the level of materiality 0.05.

5. Discussion

The issue of assessing the level of advancement in the process of implementing sustainable development in EU countries has been discussed by many scientists. One of the key positions on how to measure is presented by Bell and Morse (2000; 2001; 2012; 2013). Sustainable development is indeed a complex phenomenon, which makes it particularly difficult to compare and assess the progress of EU Member States in achieving its objectives (Grzebyk and Stec, 2015). In the literature, we will mainly find research on the analysis of various issues related to sustainable economic development of countries, including the works of Brown (2011), Imran *et al.* (2014), Chen *et al.* (2014) and others. Although there are different indicators and rankings to measure and monitor progress on sustainability at the macro level, the benefits for stakeholders and policy makers are still limited due to the lack of predictive models (Pérez-Ortiz *et al.*, 2014). The literature studies show that the results of research on various aspects of sustainable development, including its social dimension, are presented above all at the level of individual countries, for example Roszkowska and Karwowska (2014), Roszkowska and Filipowicz-Chomko (2016), Ivanova (2015), Kotykova and Albeshchenko (2017), Prasad (2008), Ray (2008), Chua **et al.** (2010), Bibó (2015), Kumar (2017).

Researchers Grzebyk and Stec (2015) conducted research aimed at establishing a synthetic measure of the level of sustainable development in relation to EU countries, taking into account three elements; economic, social and environmental. The results of their research indicate continuous progress in the implementation of the concept of sustainable development in EU Member States. Although there may be a gradual convergence of EU Member States in terms of their sustainable development levels, in their view most countries still show sustainable development indicators below the EU average. In turn, the problem of classifying EU countries in terms of socio-economic development in terms of sustainable development was addressed by Mazur-Wierzbicka (2012), Tusińska (2012), Pawlas (2015). Pérez-Ortiz *et al.* (2014) conducted their research using threshold models (in this case, logistic regression and vector-bearing machines) and a new decision rule. The adopted methodology is used to monitor progress in the implementation of sustainable development, including its socio-economic dimension in different EU countries, in a similar way to that used in the rankings.

Finally, the logistical regression-based decomposition method is used to interpret the model, providing valuable information on the most relevant indicators for ranking the endpoint variable. Researchers are less likely to study only the social dimension of sustainable development in EU countries. One example is the study by Bluszcz (2016), which classified EU countries in terms of social development in the context of sustainable development. The research of the quoted author was carried out using a much smaller number of indicators (only 5) than presented in the article, where 34 indicators were used, out of which 23 were left after standardization, which significantly limits the possibility of comparing the results from them, they also concern different time perspectives.

However, one should note a certain convergence in the ranking prepared by the authors of this article for the year 2014 - the leaders were Sweden, the Netherlands and Luxembourg, while the lowest position in the ranking was taken by Romania, which was in the ranking just after Bulgaria. However, the classification carried out by Bluszcz (2016), which also refers to the year 2014, made it possible to identify three leaders: Ireland, Cyprus and Sweden, while Bulgaria was on the last position in the ranking, followed by Romania. The arithmetic mean of the level of synthetic indicators illustrating the social development of EU countries in the study by Bluszcz (2016) was 0.6064, which means that 15 countries were classified above the average, and 13 countries achieved a level of social development below the European average (Ivy 2016), while in relation to the studies presented in this article, this measure of variation was 0.5169. However, the indicators adopted for the assessment of social development in the context of sustainable development have not been studied in relation to Industry 4.0, they also concern other time perspectives, so that comparisons with our study are limited.

Social development considered in connection with the development of Industry 4.0 is a relatively new economic category, still not well described in the literature. The way they are combined in the article is a relatively new proposal, important from the point of view of each of these areas. It results from mutual permeation of not yet fully operationalized and empirically verified research directions. It should be emphasized that the test of EU countries on social development in the context of sustainable development in the aspect of Industry 4.0 should be considered as a precursor study.

As Industry 4.0 does not refer to technology only, involvement of human resources is required in order to effectively manage the creation of added value, thus significantly affecting not only the labour market but other social issues. When analysing the social effects of Industry 4.0, e.g. in relation to the labour market, it can be seen that the fear of negative effects prevails in the evaluations on this subject so far (Buhr, 2017; Windelband, 2017; Lorenz *et al.*, 2015). As a result of the study, in the years 2014-2018 a moderate spatial differentiation of EU countries due to the level of social development and large in terms of Industry 4.0 has been shown.

In the distinguished clusters of countries, high level of development of Industry 4.0 is accompanied by relatively high values of indicators related to social development factors. Our research shows a significant, positive relationship between the level of social development in the context of sustainable development and the level of development of Industry 4.0, which would indicate that fears of negative consequences of the development of Industry 4.0 for social development in the context of sustainable development are too pessimistic. The results presented are therefore an invitation to further research and discussion on the issues raised.

It is worth emphasizing that when preparing new solutions to improve social development and Industry 4.0, it is not possible to take into account and analyse only individual indicators, but it is necessary to make multi-faceted syntheses covering as much as possible all the drivers, stimuli and effects of changes taking place in EU countries.

6. Conclusions

The considerations and research results presented in the article concern a complex and interdisciplinary issue. The combination of two areas, indicated as one of the most important development objectives of the EU, i.e. social development in the context of the implementation of the concept of sustainable development and Industry 4.0, has been considered important. In the face of unstable and complicated conditions of the development of modern economies, attempts at operationalization of both concepts and the search for opportunities to measure them are now gaining new meaning. It is worth noting that the overriding goal of both social development and activities related to Industry 4.0 is a high quality of life for current and future generations. In terms of sustainable development, it is important to assess the level of diversity in the EU countries.

The aim of the article was accomplished by determining diagnostic variables describing social development in the context of sustainable development and the development of Industry 4.0, building synthetic measures of development, drawing up a ranking of EU countries on their basis and dividing them into typological classes, as well as studying statistical relationships between the analysed phenomena. The analysis made it possible to draw wider conclusions about changes in the level of social development in the EU in the context of Industry 4.0. The results of the research indicate that there is a moderate variation in the level of social development in the EU in the context of implementing the concept of sustainable development and a significant variation in the level of development of Industry 4.0. This is due not only to an increase in social levels in these countries, but unfortunately also to a decrease in some of the old Member States, such as France, Luxembourg and Italy. In the case of the level of development of Industry 4.0, the undisputed leaders in the EU are Germany, Holland and the Scandinavian countries i.e. Denmark, Sweden and Finland. No EU country has experienced either a significant increase or a significant decrease in the level of development of Industry 4.0 during the period considered.

In many cases, the high ranks for social development were at the same time matched by the high positions in the area of Industry 4.0. This concerned mainly the most economically developed countries of Northern and Western Europe. However, in the case of countries located in Central and Eastern Europe and partly Southern Europe, the opposite situation was observed.

The results obtained allowed for a positive verification of the research hypothesis concerning the existence of dependencies between the complex factors describing social development and Industry 4.0. At the current stage of implementation of the concept of sustainable development in the EU countries, the dependency for each country is strong. The distribution of the synthetic value of the measure of social development in relation to the synthetic indicator of Industry 4.0 shows that the higher developed countries in the area of Industry 4.0 had a higher level of social development. The preparation and use of the synthetic indicator for assessing social development and industry 4.0 is an internationally innovative project. As previously presented, discussions on social development in EU countries have been going on for many years in economic (social) sciences. Despite the popularity of this issue, however, no systematic research has been carried out to demonstrate the interdependence between social development and Industry 4.0. The study has therefore made a new contribution to the state of the existing knowledge and at the same time has not closed the possibility of undertaking further research. The study also fits in with the global trends of new ways of measuring social development and Industry 4.0. The research carried out is not free from limitations which may affect the results obtained and the conclusions drawn from them. It should be stressed that a key constraint on the survey was issues related to access to the necessary data, in particular with regard to indicators describing the development of Industry 4.0.

In conclusion, the research carried out confirms the need for further benchmarking in relation to EU countries. The proposals to use selected variables describing social governance and Industry 4.0 presented in the article can also be extended to other measures that will take into account the economic dimension of sustainable development. This is an important direction for further research.

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Notes:

1 In the study, using the term social development, we have in mind social development in the context of sustainable development.