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SHAPING THE DIGITAL POTENTIAL OF THE LARGE ENTERPRISE SECTOR FOLLOWING THE IMPLEMENTATION OF THE EUROPEAN DIGITAL DECADE STRATEGY

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Purpose: The article aims to identify changes in the intensity of large enterprises using modern technological solutions due to the regulations in force in the field of gaining digital sovereignty by implementing the European Digital Decade strategy.
Design/methodology/approach: During the research process, data collected from Eurostat were compiled. They concerned the sector of large enterprises operating in the European Union in the years 2014-2022. The research procedure was carried out using the PCA and VIKOR methods, and the ICT dissemination index.
Findings: The research results indicate that there are significant inequalities in the level of digitization and intensity of technology use among large enterprises. Entities located in Cyprus, Malta, Luxembourg, and Estonia have the greatest digital potential. In turn, the smallest technological resources were gathered by enterprises in France, Italy, Germany, Poland, and Spain. Based on the determined indicator of the dissemination of modern technologies, differences in the level of ICT implementation were found. Leaders in the implementation of modern technologies, i.e., Germany, France, and Estonia, were indicated.
Research limitations/implications: Further research should focus on analyzing the use of technological resources for sustainable development, delays in the implementation of ICT technologies, the use of quantum technologies, and the levels of achieving digital sovereignty of entities.
Practical implications: The research results provide business and state managers with information that can be used in the development and implementation of digital transformation strategies to increase digital potential and achieve digital sovereignty.
Originality/value: The authors contribute to research on the digital transformation of large enterprises. They develop a technology diffusion index that provides information about the level of ICT use.

Keywords: digital potential, ICT, Digital Compass, Europe's Digital Decade strategy.

Category of the paper: Research paper.

1. Introduction

Nowadays, enterprises are subordinated to the environment, and in particular to the determinants resulting from the economic state of the country in which they operate. One dimension of the operating environment of entities is the technological environment including a developed and modern technological infrastructure. This also applies to the high degree of availability of information and communication technology (ICT) devices and tools that enable the collection, processing, analysis, storage, sharing, and transfer of data and information (Hossain et al., 2023, p. 11).

Dynamic changes taking place in the operating environment of entities affect the transformations taking place in their business models (BM) (Caputo et al., 2021, p. 494). To a large extent, they reflect the implementation of modern ICT solutions aimed at increasing the competitiveness of enterprises. Therefore, one of the fundamental stimulants affecting the environment and contributing to the development of large enterprises is the ongoing transformation focused on the so-called new economy. This is considered a possible composition of currently generated macroeconomic factors related to the development of modern technologies (MT). Digital transformation (DX) is analyzed from the perspective of an event that contributes to a thorough and strategic restructuring within the existing operations of the organization (Hanelt et al., 2021).

During the intensification regarding the development of the new economy resulting from the digitization process, the prevalence of modern technological solutions being used by large enterprises located in the European Union (EU) countries is strongly differentiated. Although the level of digitization is an important factor determining the competitive advantage of enterprises and the position of a given country in international structures, there is a digital gap between them in the EU (Arbeláez-Rendón et al., 2023, p. 10; de Clercq et al., 2023, p. 6). To compensate for the disproportions resulting from the level of digital intensity, the "Road towards a digital decade" program was introduced. It is part of the European Digital Decade (EDD) strategy, which defines the four overriding goals of digitization regulated in the Digital Compass for 2030: Europe’s Way in the Digital Decade, and a continuation of the Europe Fit for the Digital Age strategy.

This study aims to present the level of use of technological resources at the disposal of large enterprises in the territory of the 27 EU countries (EU27) to determine the digital potential and the possibility of shaping and using them to obtain technological independence.

Given the above, the main assumption of the conducted analyses is to find an answer to the general research question: to what extent has the advancing digital revolution influenced the implementation of the digital transformation and the effectiveness of using digitization tools among large enterprises as users of new technologies? The main research question was developed with the following four specific questions: 1. What modern technologies are used by large enterprises operating in the EU? 2. What are the directions for using new technologies and digital solutions in large enterprises? 3. What is the level of digitization of the EU's large enterprise sector? 4. What are the territorial differences in the level of digitization of the EU's large enterprise sector?

However, the main purpose of the article is to identify changes in the intensity of large enterprises using modern technological solutions due to the regulations in force in the field of gaining digital sovereignty by implementing the European Digital Decade strategy.

Based on the indicated aim and research question, a hypothesis was formulated, which assumes that large enterprises gradually carry out digital transformations. This is characterized by a diverse pace and scope of diffusion of modern technologies, which they adapt through the adopted policy of the EU digital single market, in terms of gaining digital sovereignty, seeing in them a strategic opportunity to achieve a market advantage and the ability to function in a changing, dynamic and uncertain environment.

Taking into account the above thesis, an analysis of statistical data obtained from the Statistical Office of the European Communities (Eurostat) database was carried out using the desk research technique. To interpret the results, principal component analysis (PCA) and the VIKOR multi-criteria decision optimization method were used, and it was proposed to determine a technology dissemination index, which was verified using the Statistica, RStudio, MATLAB&Simulink, and MS Excel statistical packages.

The issues considered in this article have not been the subject of research for the digital potential and the large enterprise sector so far. For this reason, it intends to supplement the information in the research already carried out on the digital transformation of enterprises operating in the EU.

2. Literature review

2.1. Creating digital independence of enterprises

The currently observed dynamic and continuous changes taking place in the environment oblige enterprises to systematically improve business processes. The accelerating pace and unpredictability of transformations in the operating environment of entities mean that their success and survival in new market conditions are determined by their potential and adaptive skills. As a consequence, a competitive and technological advantage in the market is gained by entities that, while operating in the global economy, renew their BM (Reis et al., 2018) and modify their development strategy, taking into account the ongoing DX processes. Therefore, it should be noted that the functioning of enterprises in the old economy was based on achieving the scale effect, while in the digital economy, it comes down to the implementation of the network effect (Shapiro, Varian, 2007). Thus, the digital economy is considered a type of new economy based on using the Internet and the implementation and proper application of modern technological solutions that determine the progressive phenomenon of digital transformation.

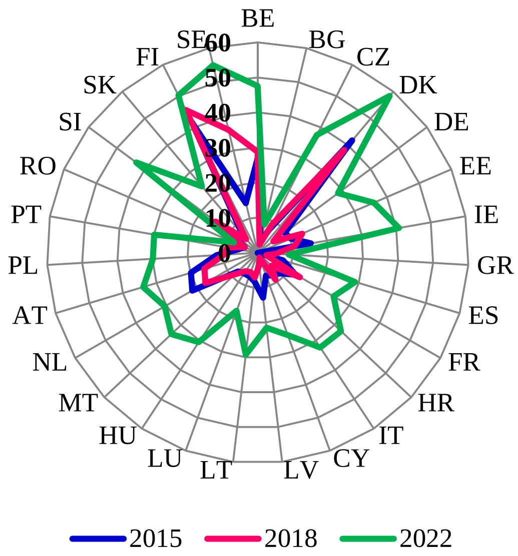
Digitization and the resulting processes related to the dissemination of using new digital technologies are also of key importance in achieving the competitiveness of enterprises (Kraus et al., 2022; Mergel et al., 2019; Westerman et al., 2011; Loske and Klumpp, 2022; Luo et al., 2023). Nevertheless, the pace of digital adoption is not the same in all organizations (Reis, Melão, 2023, p. 3). This is related, among others, to the lack of financial resources for the implementation of digitization, investment difficulties, and unfavorable conditions in adapting the BM.

Progressive DX obliges enterprises to constantly develop and implement newer and much more advanced ICT solutions (Wang, 2013). Its fundamental goal is to digitize the economy, industries, businesses, consumers, objects, and things. The transformation of the aforementioned structures is possible following the dynamic development of ICT, the Internet, and emerging transformational technologies. These include primarily: 1. Internet access (Barrero et al., 2021), 2. mobile technologies (Peris-Ortiz et al., 2020; Viete, Erdsiek, 2020), 3. social media (Nadziakiewicz, 2018; Tourani, 2022), 4. artificial intelligence (AI) (Soni et al., 2020); (Mishra, Tripathi, 2021), 5. virtual reality (VR) and augmented reality (AR), (Farshid et al., 2018; Jolink, Niesten, 2021; Bellalouna, 2021), 6. big data (BDA) (Acciarini et al., 2023; Peng, Bao, 2023; Piccarozzi, Aquilani, 2022), 7. cloud-based applications and services (CC), (Godavarthi et al., 2023; Marston et al., 2011), 8. automation and robotisation, (Siderska, 2020; Ribeiro et al., 2021), 9. ubiquitous connectivity (hyperconnectivity), (Arruda Filho et al., 2022; Gaines, 2019), 10. multi-channel and omni-channel models of product and service distribution, (Ailawadi, Farris, 2017; Thaichon et al., 2023), 11. Internet of Things (IoT) and Internet of Everything (IoE), (Nalajala et al., 2023; Peter et al., 2023; Kumar et al., 2019; Langley et al., 2021; Sestino et al., 2020).

The above-mentioned ICT technologies have evolved from the concept of the digital revolution (Toffler, 1985), the development of the digital economy (Tapscott, 1996), the network society (Castells, 2000) and the phantom of what is now known as virtual reality (Lem, 1964).

The development of ICT technology is related to the dynamic development of the Internet, which functions with the help of the "world wilde web" or web (www) information system, enabling digital information processing. Thus, the intensified development of the Internet initiated the DX process through Web1.0, 2.0, 3.0, 4.0, 5.0 applications (Mazurek, 2020).

The intensity and scope of MT use provides information about the level of technological development of the organization and the stage of advancement of business processes. A very high digital intensity index (DII according to Eurostat), the scale of which was 11.3% in 2015 (no data from 2014), 10.1% in 2018, and 29.7% in 2022, was achieved by large enterprises operating in the EU (see Fig. 1).



where: AT – Austria, BE – Belgium, BG – Bulgaria, HR – Croatia, CY – Cyprus, CZ – Czechia, DK – Denmark, EE – Estonia, FI – Finland, FR – France, DE – Germany, GR – Greece, HU – Hungary, IE – Ireland, IT – Italy, LV – Latvia, LT – Lithuania, LU –Luxembourg, MT – Malta, NL – Netherlands, PL – Poland, PT – Portugal, RO – Romania, SK – Slovakia, SI – Slovenia, ES – Spain, SE – Sweden.

Figure 1. Highest level of digital intensity of large EU enterprises in 2015-2022 (% value).

Source: Own elaboration based on Eurostat data.

Depending on the operating environment and available resources, enterprises have a set of technological solutions, which is referred to as digital potential. Currently, an important premise for the implementation of such improvements to increase the potential is a total of six technologies, including four so-called SMAC (Social, Mobile, Analytics, and Cloud) ones (Nayyar et al., 2021; Sedera et al., 2022; Gopichand, 2016) and two consisting of BDA and communication using IoT.

The scope of application and implementation of new ICT technologies affects the achievement of digital sovereignty by enterprises, which is considered an alternative to digital colonialism (Young, 2019). The term sovereignty from the perspective of technology has so far been used to characterize various forms of independence, control and autonomy in the field of digital technologies (DT), BM and content (Bauer, Erixon, 2020, p. 8). Thus, digital sovereignty indicates the ability of states, international organizations and each user to exercise their rights and influence digital platforms and technological enterprises in accordance with their own social and development needs (Zygmuntowski, 2021, p. 27).

The EU's intention is to achieve digital sovereignty by implementing digital strategies that will enable the creation of a sustainable business environment equipped with appropriate technological resources.

2.2. European Digital Decade Strategy

DX provides the basis for carrying out fundamental and strategic transformations in the way businesses operate. At the same time, it obliges managers to change, renew, modify, or implement new so-called digital BMs. Therefore, managers should constantly familiarize themselves with digital solutions, because soon they may not be able to cope with the process of communicating with suppliers and customers effectively and efficiently (Paiola, 2018). Thus, the development of DT in enterprises operating in the EU is an important research issue, especially due to the recognition of its significant diversity.

The issue of digitization of the economy, enterprises and society in the EU is also one of the priority projects for the implementation of the EDD and DC 2030 strategies. As part of DX, on March 9, 2020, the European Commission (EC) adopted a program indicating the basic goals that should be achieved by 2030. They concern four key issues: 1. digitally-skilled population and highly-skilled digital staff, 2. secure, efficient and sustainable digital infrastructure, 3. digital transformation of enterprises, 4. digitization of public services (European Commission, 2021, p. 2). Based on the presented document, by 2030, 75% of enterprises operating in the EU should use CC, AI and BDA technologies. Moreover, over 90% of small and medium-sized entities are required to achieve at least a basic level of the indicator regarding the use of digital technologies. The strategy also assumes doubling the number of technology start-ups (so-called unicorns, with a value of at least USD 1 billion) (European Commission, 2021, p. 15).

In terms of gaining digital sovereignty, the program indicates an increase in the production of cutting-edge and sustainable semiconductors in Europe to 20% of global production. In addition, the strategy envisages having the first quantum computer on the European market (European Commission, 2021, p. 17).

Monitoring of the strategy's implementation will be carried out using multi-annual strategic road maps of digital transformation, which have been prepared for each EU country.

Given the above, the level and potential of digitization of the large enterprise sector in the EU zone should be considered in terms of the implementation of modern technologies, transformation, and achieving digital independence, and the differences between Member States should be determined.

3. Materials and Methods

The problems of this article focus on determining the level of digitization associated with the use of technological resources, which shaped the digital potential of large enterprises from 27 EU countries in the period 2014-2022, according to the EDD strategy. Due to the exit of the UK from the structures on February 1, 2020, the research carried out in this study concerned the 27 countries of the European Community. While diagnosing this issue, indicators from Eurostat databases in the section on ICT usage in enterprises were used.

The data were collected in June 2023. The research was carried out at the turn of July and August 2023 based on the desk research technique. Large enterprises employing over 250 people located in the following countries were analyzed: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. In the absence of data for a given year, data from the preceding or following year were used. All indicators with percentage values were reduced to real numbers.

3.1. Principal component analysis

PCA was used to interpret the collected data. This type of method is based on the orthogonal transformation of an *n*-dimensional set of variables describing the properties of the studied phenomenon into a new uncorrelated set of variables, the so-called principal components (PC). They have a dimension smaller than *n* and occur as a linear combination of primary variables (Tanaka-Yamawaki, Ikura, 2023, p. 23). The transformation consists of the fact that the variances of successive variables reflect an increasingly smaller structure, and the total variance of all analyzed data creates an equivalent sum of variances of the main components (Bloem, 2023, p. 31). Thus, PCA intends to decompose the variability of the data set into a set of components, in which the first component (PC1) interprets the maximum part of the variability, while the second (PC2) justifies the largest part of the remaining variability (Marquez, 2022, pp. 57-58). The method used to carry out the research is based on the presentation of the input data set by orthogonal transformation of the input matrix into a linear set of new unobservable factors in accordance with the equation:

$$Z_j = b_{j1}S_1 + b_{j2}S_2 + b_{j3}S_3 + \cdots + b_{jn}S_n \quad (1)$$

where:

Z_j - the *j*-th variable (j = 1, 2, …, n),

$S_1 \dots S_n$ - main components,

$b_{j1} \dots b_{jn}$ - main components coefficients.

Reducing the space dimension of the analyzed data and their juxtaposition into subsets makes it possible to graphically explain the relationships between the examined features and define their significance. The diagram generated during the analysis presents the relationship between the objects for the PC data. Factor loading values, on the other hand, act as correlation/covariance coefficients that run between the original data and PC (Jollffe, 2016). For the purposes of the analysis of the collected data, the normalized rotation varimax (maximum of the variance) was used, which allows for the maximum differentiation of loads within the factor. In relation to individual factors, variables grouping the highest values of factor loading about the relative factor were determined (according to the assumed value ≥ 0.7).

In this study, 43 indicators have been compiled that shape the technological resources of large enterprises operating in EU countries (see Tab. 1 in appendix). The calculation of the collected indicators was performed using the Statistica 13.1 statistical package.

3.2. VIKOR multi-criteria decision optimization method

In the second stage of the research, one of the methods of multi-criteria decision support VIKOR (Serbian Visekrzterijumska Optimizacija i Kompromisno Resenje) was used to analyze and evaluate the use of modern ICT technologies by large enterprises located in 27 EU countries. It is designed to solve decision-making problems in the event of conflicting circumstances and the impossibility of a common set of criteria.

The process of shaping the ranking and the selection of a compromise solution from many alternatives takes into account mutually exclusive decision criteria (Kobryń, 2014, p. 184). Thus, the VIKOR method uses a multi-criteria ranking coefficient, the so-called ranking index, which is based on the distance of a specific solution from the ideal result.

The generated model provides the best alternative from the perspective of obtaining the result closest to the ideal (Opricovic, 1998). Therefore, in the VIKOR analysis, the average and maximum weighted distance from the ideal point is calculated for each decision variant. In the decision-making process, the so-called comprehensive Q_i indicator allows a balance to be maintained between the average and maximum distance.

The VIKOR ranking is created in accordance with an algorithm in which the spread coefficient of the criterion function d_{ij} is determined in order to normalize the criteria for the evaluation of variants in accordance with the formula (Kim and Ahn, 2019, p. 127):

$$d_{ij} = \frac{f_i^* - f_{ij}}{f_i^* - f_i^-} \quad (2)$$

where:

d_{ij} - spread coefficient of the criterion function [-];

f_{ij} - the value of the i-th criterion function for the *j*-th alternative solution [-];

f_i^* - maximum f_{ij} value when the *i*-th criterion function shows advantage, minimum f_{ij} value when the *i*-th criterion function shows a disadvantage [-];

f_i^- - maximum f_{ij} value when the *i*-th criterion function shows an advantage, minimum f_{ij} value when the *i*-th criterion function shows disadvantage [-].

Then, the best (f_i^*) and worst (f_i^-) values are determined from all alternatives (j = 1, 2, 3, …, m) and for all criteria functions (i = 1, 2, 3, …, n), where it is a benefit criterion that is maximized or minimized by the equation (Zeng et al., 2019, p. 78):

$$f_i^+ = max_j f_{ij,} f_i^- = min_j f_{ij} \quad (3)$$

In the next step, weights related to various criteria are assigned. For the purposes of this study, to ensure the comparability of results, weights were determined based on the Shannon entropy *H(p)* of the probability distribution *p*, based on the formula (Vale Cunha et al., 2020):

$$H(p) = -\sum_{i=1}^{N} pi \ln(pi) \text{ where it is accepted that } 0 \ln(0) \equiv 0 \quad (4)$$

where:

n – the number of equivalent variants of the eventp (in the case of the conducted research n = 43), subsequent *pi* (for *i* = 1, 2, 3, …, *n*) are the probabilities of subsequent versions,

pi – the probability of the *i*-th realization of a discrete random variable,

xi – the *i*-th implementation of the random variable *p* essentially affects the character of the basis for measuring spatial homogeneity and differentiation.

After determining the weights, the compromise ranking indices S_i and R_i are calculated for each of the alternatives, based on the relationship (Siregar et al., 2018, p. 2):

$$S_i = \sum_{j=1}^{n} \left[w_i \left(\frac{f_i^* - f_{ij}}{f_i^* - f_i^-} \right) \right] R_i = max_j \left[w_i \left(\frac{f_i^* - f_{ij}}{f_i^* - f_i^-} \right) \right] \quad (5)$$

where:

S_i, R_i – compromise ranking index,

w_i – relative weight of the criterion.

In the penultimate stage of the VIKOR method, the indicators are used to estimate the normalized ranking index Q_i (Akram et al., 2022, pp. 7212-7214):

$$Q_i = \sum_{j=1}^{n} \left[v \left(\frac{S_i - S^*}{S^- - S^*} \right) + (1 - v) \left(\frac{R_i - R^*}{R^- - R^*} \right) \right] \quad (6)$$

where: $S^* = min_i S_i, S^-$; $S^- = max_i S_i$; $R^* = min_i R_i$; $R^- = max_i R_i$; $v \in [0,1]$ weight measure reflecting the strategy value of most criteria, for the purposes of this article v = 0.5 (corresponds to the preferred consensus); the difference 1-v is the weight that determines the power of the veto.

The final step is to sort the alternatives S_i, R_i, Q_i in ascending order, resulting in three ranking lists. Next, a compromise solution is proposed according to the variant a' corresponding to the minimum Q_i provided that the assumptions are met (Akram et al., 2021, p. 20):

Condition 1. Acceptable advantage

$$Q(a'') - Q(a') \geq DQ \quad (7)$$

where: a'' is the second variant on the list according toQ and $DQ = \frac{1}{n-1}$

Condition 2. Acceptable stability in decision subtraction

Alternative a' should reflect the best variant according to the S or/and R criteria.

For the purposes of this article, the Q_i index was also the basis for the classification and grouping of linearly ordered objects using the standard deviation method. The assumption of the process of hierarchizing objects is the intervals of values of the synthetic variable Q_i created in accordance with the arithmetic mean $\bar{x}$ and standard deviation σ (Xu , Da, 2010). The created collection of objects is systematized into four groups, which concern clusters with the value of the synthetic variable contained in the following separate ranges (Maldonado-Moscoso et al., 2020):

- group I: $Q_i \geq \bar{x} + \sigma$; very high level,
- group II: $\bar{x} + \sigma > Q_i \geq \bar{x}$; high level,
- group III: $\bar{x} > Q_i \geq \bar{x} - \sigma$; medium level,
- group IV: $Q_i < \bar{x} - \sigma$; low level.

For this study, 43 indicators, included in Table 1 in appendix, were compiled. The collected data were statistically analyzed using the MATLAB&Simulink program.

3.3. ICT diffusion rate

For the purpose of this study, in the last stage of the research, to assess the varied rate and scope of MT diffusion implemented on the basis of the EDD strategy in large EU enterprises, a measure of the dissemination of modern technologies was formulated. The proposed indicator makes it possible to determine the direction and degree of changes in the considered variables in relation to the initial stage. The purpose of this type of analysis is to determine the trend towards the dissemination of ICT and the strength of the relationship between the level of DT and the use of technological resources by large entities operating in the territory of the 27 EU countries.

The initial step in creating the ICT diffusion index was to determine the diffusion coefficient (DF_i). This was calculated based on the difference between the level of the analyzed phenomenon at the analyzed moment in comparison with the previous period ($Q_{i\,(t-1)}$) and the final period ($Q_{i\,(n-1)}$). According to the following formula:

$$\Delta DFX_{t/(t-1)} = Q_{i\,(t)} - Q_{i\,(t-1)};\ \Delta DFY_{t/n-1} = Q_{i\,(t)} - Q_{i\,(n-1)}\ ;\ (t = 2,3, \dots n) \quad (8)$$

where:

$\Delta DFX_{t/t-1}$; $\Delta DFY_{t/n-1}$ – fixed-base diffusion coefficient,

$Q_{i\,(t)}$ – VIKOR index, technological resources of enterprises in the analyzed period,

$Q_{i\,(t-1)}$ – VIKOR index, the use of modern technologies in the period preceding the analyzed period,

$Q_{i\,(n-1)}$ – VIKOR index, the use of modern technologies in the final period,

n – the final examined period.

Then, the interdependence of the studied variables was determined by determining the technology dissemination index ICT (CH_i). Its task is to define the degree of convergence of the diffusion coefficient values according to the equation:

$$CH_i = \frac{DFY}{DFX} \quad (9)$$

if:

$CH_i = 0$ lack of interdependence between the degree of digital transformation and the use of technological resources in large enterprises - symmetrical level of digital potential,

$CH_i = 1$ strong interdependence between the degree of digital transformation and the use of technological resources in the surveyed entities - high level of digital potential,

$CH_i < 1$ average correlation between the degree of digital transformation and the use of technological resources in large organizations - negligible level of digital potential resulting from limitations in the implementation of technological solutions,

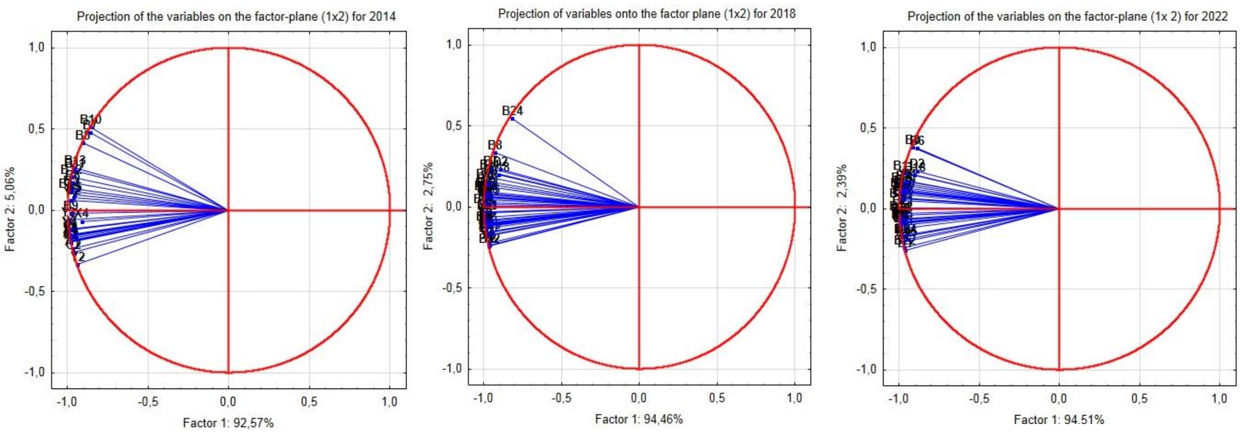
$CH_i > 1$ increased interdependence between the degree of digital transformation and the use of technological resources in large enterprises - an increase in the level of digital potential resulting from the intensive use and implementation of technological solutions.

In order to carry out this research, 43 indices collected in Table 1 in appendix and the calculated VIKOR index from Table 4 were used, which were analyzed using the MS Excel package.

4. Results

4.1. Technological resources of large enterprises in the European Union

Based on the collected data, which concerned the years 2014-2022, in the initial phase of the research carried out using PCA, the set of technologies available to large enterprises operating in the EU was determined. The study made it possible to identify the factors (technologies used) that contribute to the correlation between the analyzed variables (technological potential). The procedure of graphical projection of PCA data made it possible to distinguish interdependencies and discrepancies between the examined technological solutions used by large enterprises in the comparison of the first two PCs (see Fig. 2).



a) 2014 b) 2018 c) 2022

Figure 2. Configuration of the charge vectors concerning the first two principal components for the set of technologies of large EU enterprises: a) scatter of factor charges for 2014; b) distribution of factor loading values for 2018; c) distribution of factor loading values for 2022.

Source: Own elaboration using the Statistica 13.3 package.

Based on PCA for 2014, the dependent variables were transformed into orthogonal components, which together explain 98.32% of the total variance, i.e., the total multivariate variability of the MT application parameters. Thus, the study showed that the digital potential of large enterprises in the EU was diversified due to the resources and technological solutions related to the first three components: PC1 - 92.27%, PC2 - 5.06%, PC3 - 0.69%. The projection plot of the PC1 and PC2 standardized coefficients shows linear combinations of variables. They are responsible for the type of applied technological solutions affecting a circle with a unit radius centered at the origin of the coordinate system illustrating the correlated groups of technological resources determining the digital potential (see Fig. 2a). Both components justify 97.63% of the data variability.

PC2 classifies the analyzed variables into two groups with opposite signs of the coefficients. In the first of them, CC solutions for the purchase of office software (B10) and access to e-mail (B7) have the greatest digital potential. However, the second group, is shaped by tools related to providing content via the Internet, i.e., enterprises that provided descriptions of goods, services, and price lists on their website (Y2) and provided training to employees to improve their ICT competencies (C2). Based on defined factor weightings, a strong positive correlation was also noted for technological resources related to BDA, which are processed in CC. Among the technological solutions of this type is the purchase of CC services, which are delivered from servers made available by service providers (B13), and equipping enterprises with CC-based CRM software for customer relationship management (B11); analytics of big data from smart devices or sensors (B3) - purchase of CC services used over the Internet (B14); and analysis of large data sets that are generated from social media (B5) - analysis of large data sets from the geolocation of mobile devices (B2).

Moreover, PC1 is distinguished by a strong positive correlation, which is related to Internet accessibility, technological infrastructure and cybersecurity. Thus, the digital potential of enterprises was created by technological solutions in the field of using websites to share multimedia content (Y8) and placing online orders, reservations or using the shopping cart (Y4); Internet access (X1) – use of social media (Y6); and employment of ICT/IT specialists in enterprises (C1) – use of computers by employees (X2). In 2014, the digital potential of large enterprises operating in the EU did not show a strong negative correlation.

The conducted PCA also made it possible to identify technological solutions that do not have correlations. This group included large enterprises that purchased office software processed in CC (B10) and had websites with descriptions of goods, services, and price lists (Y2); and purchased database hosting as a CC service (B8) - used customer relationship management programs (A1).

In 2018, PC explained a total of 97.21% of data variability (see Fig. 2b). PC2 highlights a significant number of large enterprises analyzing internal big data using machine learning (B24) and corresponding to a small group of organizations using 3D printing (B22). Based on the obtained PCA results, it should be assumed that factor loads characterized by a positive correlation determine the digital potential of large enterprises operating in the EU. In particular, they should be assigned technological resources that enable the collection, storage, management, and analysis of large data sets. With the use of this type of technology, entities shape the digital potential in the purchase of customer relationship management (CRM) software (B11) and the use of AI technology to manage enterprises (B18); purchase of office software (B10) - use of a company blog or microblogs (Y7); procurement of CC services provided from shared servers of service providers (B13) - application of AI technologies performing text mining (B20); and purchase of a file storage service (B12) and computing power to support software in the enterprise (B9). Enterprise resources are also configured by AI technologies that automate tasks and support the decision-making process (B16) - enabling the use of IoT (B15).

Moreover, PC1 is strongly positively correlated with the technologies that enterprises acquire over the Internet to process services using cloud computing (B14). In addition, organizations used SMAC technology solutions to improve communication because the used websites shared multimedia content (Y8) and enabled the exchange of information through a chat service where a chatbot or virtual agent answered customers' questions (B21); and provided employees with a mobile Internet connection for business use to access the company's e-mail system (X3) - had Internet access (X1). In 2018, organizations used systems that ensure control over resources and products and improve business operations. Therefore, they used CRM (A1) customer relationship management systems - they provided employees with training to improve digital competences in the field of ICT technology (C2).

However, a lack of correlation between the analyzed technologies was observed in the case of the purchase of hosting for the company's database (B8) and the use of websites that provided descriptions of goods or services and price lists (Y2); occurrence of incidents related to ICT security, as a result of which data were damaged as a result of infection (D2) - the use of computers by employees (X2); purchase and use of e-mail in the cloud (B7) - use of 3D printers for prototyping or printing models for internal use of the company (B1); purchase of a CRM system as a cloud service (B11) - the use of AI technology to ensure ICT security (B17); and the use of AI technology for business management (B18) - analysis of large data sets using algorithms for processing and generating natural language or speech recognition (B25). In the analyzed year, large enterprises did not have technological resources that were distinguished by a strong negative correlation.

Based on the Hotelling method, which uses the Lagrange multiplier test related to the maximization of functions of many variables, in 2022, PCs accounted for 96.9% of the variability of the technologies used, which accounted for the digitization potential of large EU enterprises (see Fig. 2c). PC2 presents organizations that purchase financial or accounting applications processed in CC (B6) balanced by the use of 3D printing for their own needs to build prototypes or models (B1).

According to the identified factor weightings, resources based on the purchase of financial or accounting applications processed in the cloud (B6) and the purchase of hosting for the enterprise database implemented as a cloud service (B8) were characterized by a positive correlation; the use of AI technology to manage enterprises (B18) - equipping with CRM systems processed in the cloud (B11); the use of service robots (B4) - running a company blog or microblogs (Y7); and purchase of cloud solutions for file storage (B12) - application of AI technology to conduct written language analysis (text mining) (B20).

However, PC1 is distinguished by a strong positive correlation in the use of chat services, in which a chatbot or virtual agent communicates with the company's customers (B21). This type of dependence was also characteristic of technologies that concerned the use of industrial robots (B23) and the analysis of large data sets from the geolocation of mobile devices (B2). Strong positive links were also based on resources enabling the company's presence on the Internet through the use of social networks (Y6) and websites for sharing multimedia content (Y8); having a website (Y1) - using the IoT (B15); making references to the company's social media profile on the website (Y5) - using different types of CRM software (A1); and posting a description of goods, services and price lists on the website (Y2) - the use of Al technology to ensure ICT security (B17).

Just as in previous years, in the analyzed year, no resources with a negative correlation were identified. Moreover, independent technologies were observed, which concerned the purchase of cloud hosting for the company's database (B8) and the use of 3D printing (B22); the occurrence of incidents related to ICT security, which resulted in the destruction or damage of data (D2) - the use of computers by employees (X2); the use of AI technology for enterprise management (B18) - big data analysis, for which enterprises use natural language processing and generation or speech recognition (B25); and purchase of CRM software in the cloud (B11) - analysis of large data sets using machine learning tools (B24).

Based on the research conducted using the PCA method, it should be stated that the digital potential of large enterprises operating in the EU depends on the technological resources they have. The surveyed entities use a diverse set of technological solutions that they implement in connection with the ongoing digital transformation. In the surveyed years 2014-2022, organizations based on founding technologies (computer - X2, Internet – X1), classified as Web 1.0 tools of the information network, created their digital potential.

Starting in 2014, they implemented solutions in the field of mobile Web 2.0 technologies developed in the social network by the following solutions: Y4, Y6, Y8, B7, and B11. In addition, large enterprises also collected Web 3.0 technological tools based on the semantic web, which include digital technologies B13, B3, B14, B5, B2, and B10.

In turn, in 2018, organizations continued to implement Web 1.0, Web 2.0, and Web 3.0 solutions. They also used the founding X1 and mobile X3, Y8, and A1 technologies to run their business. Their digitization consisted mainly of using resources in the field of cloud computing B9, B10, B11, B12, B13, B14, and the Internet of Things B15. The next stage of digital transformation of large enterprises was based on the use of automation technologies B1, B18, B20, and B22 based on the mobile and flexible network Web 4.0.

In 2022, organizations based on the Web 1.0 information network (Y1) and the Web 2.0 social network (Y5, Y6, Y7, Y8) used DT characteristics of the Web 3.0 semantic network, i.e., cloud computing tools (B6, B8, B11, B12), big data analytics (B2), and the Internet of Things (B15). In the next phase of digital transformation, the entities used automation solutions that resulted from the use of the mobile-flexible Web 4.0 network consisting in printing three-dimensional 3D objects (B22). In addition, the digital potential of large enterprises consisted of technological resources, in the structure of which hyper-automation technologies based on the Web 5.0 sensory network became dominant. As part of this type of technology, organizations used tools in the field of artificial intelligence (B17, B18, B20, B21), robotics (B4, B23), and machine learning (B24). The essence of these technological solutions is interaction between devices and people.

Based on the conducted research, it can be concluded that large enterprises carried out digital transformation in stages, as a result of which they gathered technological resources necessary to shape the digital potential.

4.2. Application of modern technological solutions in large enterprises

To present the diversity of large enterprises operating in individual EU countries regarding the degree of using ICT solutions, the VIKOR method of multi-criteria decision support was used to balance the diffusion processes of modern technologies (see Tab. 2).

Table 1.
Ranking of indicators of ICT use by large enterprises in EU countries according to the VIKOR method

Years / UE country	2014				2018				2022			
	Qi	**V**	**SKE**	**VIKOR ranking**	**Qi**	**V**	**SKE**	**VIKOR ranking**	**Qi**	**V**	**SKE**	**VIKOR ranking**
AT	0.735	24%	-3.254	19	0.807	13%	-3.621	20	0.791	12%	-3.207	18
BE	0.767	27%	-3.453	18	0.863	15%	-6.447	16	0.725	15%	-3.631	20
BG	0.868	27%	-2.864	12	0.962	14%	-5.312	10	0.951	12%	-3.377	9
HR	0.913	25%	-3.357	8	0.966	16%	-3.917	8	0.961	16%	-2.948	8
CY	1.000	28%	-3.134	1	1.000	15%	6.245	1	1.000	15%	-3.669	1
CZ	0.710	28%	-3.507	21	0.829	15%	-6.541	18	0.746	15%	-3.674	19
DK	0.819	26%	-3.422	16	0.827	14%	-6.020	19	0.824	14%	-3.522	15
EE	0.970	27%	-3.491	4	0.987	15%	-6.456	5	0.988	15%	-3.621	3
FI	0.826	19%	-1.486	13	0.863	28%	-2.062	17	0.813	24%	-1.649	17
FR	0.275	29%	-0.055	26	0.299	18%	-0.625	27	0.511	26%	-0.241	24
DE	0.436	27%	-3.509	23	0.440	15%	-6.512	26	0.500	15%	-3.638	25
GR	0.909	46%	-0.632	9	0.964	18%	-0.688	9	0.936	24%	-1.676	10
HU	0.824	28%	-3.519	15	0.925	16%	-6.556	13	0.879	15%	-3.684	13
IE	0.885	28%	-3.518	10	0.925	15%	-6.544	14	0.887	15%	-3.671	12
IT	0.251	27%	-3.515	27	0.476	15%	-6.501	25	0.414	15%	-3.643	26
LV	0.965	28%	-3.518	5	0.991	15%	-6.537	4	0.975	15%	-3.663	5
LT	0.932	27%	-3.501	7	0.972	14%	-6.131	7	0.968	14%	-3.500	7
LU	0.976	28%	-3.519	3	0.994	16%	-6.550	3	0.979	15%	-3.681	4
MT	0.998	23%	-1.890	2	0.999	14%	-1.014	2	0.999	12%	-2.696	2
NL	0.566	25%	-3.478	22	0.735	15%	-5.647	21	0.592	14%	-3.494	23
PL	0.387	20%	-2.755	25	0.641	14%	-1.105	23	0.617	14%	-2.167	21
PT	0.815	26%	-3.454	17	0.889	14%	-5.691	15	0.815	14%	-3.527	16
RO	0.825	26%	-3.190	14	0.955	15%	-5.527	11	0.866	14%	-3.457	14
SK	0.881	28%	-3.514	11	0.953	15%	-6.522	12	0.925	15%	-3.663	11
SI	0.955	27%	-3.443	6	0.986	15%	-6.439	6	0.974	15%	-3.622	6
ES	0.420	26%	-3.179	24	0.481	15%	-5.023	24	0.317	14%	-3.419	27
SE	0.716	24%	-2.877	20	0.724	14%	-2.290	22	0.602	12%	-2.957	22
Total EU countries												
$\bar{x}$		0.764				0.832				0.798		
σ		0.225				0.199				0.198		
V		29%				24%				25%		
SKE		-1.140				-1.421				-0.979		

where: $\bar{x}$ – average value, σ – standard deviation V – coefficient of variation, SKE – skewness factor;
AT – Austria, BE – Belgium, BG – Bulgaria, HR – Croatia, CY – Cyprus, CZ – Czechia, DK – Denmark, EE – Estonia, FI – Finland, FR – France, DE – Germany, GR – Greece, HU – Hungary, IE – Ireland, IT – Italy, LV – Latvia, LT – Lithuania, LU –Luxembourg, MT – Malta, NL – Netherlands, PL – Poland, PT – Portugal, RO – Romania, SK – Slovakia, SI – Slovenia, ES – Spain, SE – Sweden.

Source: Own elaboration using the Matlab program.

The ranking of countries prepared based on the VIKOR multi-criteria decision optimization method and grouping objects using the standard deviation method presents inequalities resulting from the level of use of modern technologies by large enterprises operating in the EU. In 2014, the range for the analyzed variables between the maximum value for CY of 1.000 and the minimum value for IT of 0.251 was 0.749. After four consecutive years, the difference between the highest level for CY of 1.000 and the lowest level represented by France of 0.299 was equal to 0.701. However, in the same period and the last surveyed year 2022, the diversity occurring within the highest limits for CY of 1.000 and minimum limits for SE of 0.317 reached the lowest value so far of 0.683.

Based on the research carried out using the VIKOR method, a similarity can be observed in the ranking positions occupied by individual EU countries in terms of the use of MT in large enterprises.

In the years 2014-2022, according to the analysis, the leading place was taken by CY, which stood out from other EU countries with significant values of diagnostic features. Large entities operating in this country used the most modern technologies in the field of X1 in 2014-2022 - 100%, Y1 in 2014 - 98%; 2018 – 95.7%; 2022 – 96.9%, Y2 in 2014 - 96.1%; 2018 – 95.7%; 2022 – 96.9%. Additionally, in 2018, 93.2% of them used Y6 solutions and 88.4% implemented C1 technologies. In 2022, 95.4% used X3 tools and 84.5% used B14 solutions.

In 2014, limited resources were available to large enterprises in the field of Y3 technology, which was implemented by 3.4% of entities, B8 - 7.4%, and B9 - 7.4%. They used the fewest technological solutions in the case of B1 in 2018 - 1.4%; 2022 – 1.5%, D2 in 2018 - 1.9%; 2022 - 1.9%, and B16 in 2018 - 2.6%. In addition, in the last surveyed year, 2022, organizations did not use B25 technology - 0%. In second place was MT in 2014-2022, where most large enterprises were equipped with X1 tools in 2014 - 93.5%; 2018 – 98.1%, Y1 in 2014 - 93.5%, 2018 – 97.6% and X3 in 2014 - 89.3%; 2018 – 98.8%. In addition, 92.1% of organizations of this type in 2018 used Y6 tools. However, in 2014 they used the B6 - 2.0%, B9 - 6.1%, and B10 - 6.1% technologies to a limited extent, and in 2018 they used the B25 - 1.2%, B20 - 1.3%, and D2 - 2.6% technologies. The third place in the ranking in 2014-2018 was taken by large enterprises operating in LU, all of which had access to X1 technology (100%). In addition, they also had Y1 solutions in 2014, with 95.5% of entities using them, in 2018 - 96.8%; and X3 in 2014 - 91%; 2018 – 91.1%; and 2022 - 96%.

In addition, the surveyed entities used the C2 technology in 2014 - 65.5%, and 2018 - 72.6%. They were also distinguished in 2014 by scarce technological resources of B6 - 5.5%, B9 – 5.0%, and B11 - 6.5%. In turn, in 2018, they implemented minor technological solutions, B25 - 2.1%, D2 - 4.8%, and B21 - 5.5%. In 2022, third place was taken by large enterprises located in EE. 99.9% of them implemented X1 technologies, 97.8% used X3 solutions and 96.7% used Y1 tools. In addition, 93.1% of entities used Y2 tools. However, they used technologies from the D2 category - 0.7%, B18 - 2.1%, and B17 – 4.8%, to a minimal extent.

In 2014, one of the lowest places in the ranking - 25th - was taken by PL, where 99.6% of large enterprises had X1 technology, 95.3% used X3 tools and 90.9% used Y1 solutions. However, the smallest interest was observed among technological solutions such as B6 - 4.0%, B9 - 4.0%, and B11 - 4.1%. In 2018, IT took the same place with 99.7% of entities using X1 technology, 94.7% of organizations using X3 solutions, and 89.5% of enterprises using Y1 solutions. At a minimum level, the technologies D2 - 2.8%, B25 - 3.3%, B19 - 4.5% and B18 - 5.5% were used. In 2022, this position was taken by DE, where X1 and X2 technologies were owned by all large entities (100%), X3 solutions were used by 99.6%, and Y1 were used by 95.7% of them. The smallest interest in modern technologies concerned D2 tools - 2.6%, B18 - 3.8%, and B19 - 5.1%.

One of the smallest values of the analyzed variables was adopted by the countries classified in 26th place. Among them, FR dominated in 2014 with X1 technologies used in 100%, X3 tools used by 95.8% of organizations, and Y1, used by 90.8% of entities. On the other hand, the use of technological resources was negligible for solutions in B9 - 6.6%, B6 - 6.7%, and B5 - 9.1%. In 2018, this position was taken by DE, where all large enterprises had X2 solutions (100%), X1 technology was used by 99.9%, and Y1 by as many as 96.7% of such entities. The least often used solutions were B18 - 3.8%, B24 - 4.2%, and B19 - 5.1%. However, in 2022, 26th place was taken by IT, in the area in which large entities used the technologies X1 - 99.7%, X3 - 95.9%, and Y1 - 91.8%. They minimally used solutions in the range of B25 - 3.3%, B19 - 4.5%, and B18 - 5.5%.

The classification in the ranking is closed by organizations ranked 27th. In 2014 it was IT with entities using X1 - 100%, Y1 – 88.9%, and A2 - 78.8%. Nevertheless, they used B5 - 7.2%, B9 - 7.4%, and B2 - 9.8% technologies to a minimal extent. From 2018, this place was occupied by FR, dominated by X1 - 99.9%, X3 – 96.2%, and Y1 - 94.7%. In turn, D2 - 3.7%, B25 - 4.2%, and B18 - 4.9% were used to a small extent. In the last year of 2022, 27th position belonged to large companies operating in ES. They were distinguished by the use of X1 technology - 99.7%, Y1 - 96%, and X3 - 89.5%. However, to a small extent, they used modern solutions, such as B21 - 5.5%, B25 - 6.4%, and B18 - 7.9%.

Based on the calculated coefficient of variation (V), the diversity in the use of modern technologies among all large enterprises operating in the EU countries should be considered average. In 2014, this parameter reached the highest value of 29%. However, in the following years, it was at the level of 24% in 2018 and 25% in 2022.

Nevertheless, depending on the location of large entities in the countries of the European Community, stratification resulting from the use of modern technological solutions can be observed. In 2014, it concerned low differences in SE (19%) and PL (20%), large disproportions in IT (46%), and average disharmony for the remaining countries NL (23%), BG, SE (24%), AT, DK (25%), IE, PT, RO, FI (26%), BG, CZ, GR, HR, LT, HU, SK (27%), EE, DE, CY, LV, LU, MT, SI (28%) %), and FR (29%). On the other hand, in 2018, medium variation was identified in ES (28%) and small discrepancies among the 26 other countries BE, GE (13%), CZ, IE, HU, NL, PL, PT, SE (14%), BG, EE, GR, HR, LV, LT, LU, AT, RO, SI, SK, DE, FI (15%), DK, CY, MT (16%), FR, and IT (18%). In turn, during the last surveyed year of 2022, disproportions in the use of technology at an average level were distinguished by ES, IT (24%), FR (26%), and a small range of differentiation was characterized by BE, CZ, NL, SE (12%), IE, HU, AT, PL, PT, RO, FI (14%), BG, DE, EE, GR, HR, CY, LV, LT, LU, MT, SK, SI (15%), and DK (16%).

Moreover, the skewness coefficient (SKE) was used to determine the direction of differentiation of variable values. Its task was to determine the years in which large enterprises operating in the EU made a significant and minimal amount in the implementation and use of MT. According to this type of criterion, in the analyzed period, the formation of left-sided skewness with a moderate asymmetry of distribution was observed for all large enterprises operating in 2014 (SKE takes the value of -1.140) and 2022 (SKE is -0.979) and in 2018 (SKE was -1.421) with a strong asymmetry of distribution.

In 2014, the method of applying the analyzed modern technological solutions in large enterprises was distinguished by an asymmetric distribution with very weak negative skewness for FR. A negatively skewed distribution with weak asymmetry characterized IT. The strong left asymmetry was represented by large enterprises located in ES. However, the surveyed entities operating in PL, NL, CZ, SE, FI, DK, RO, BE, SK, IE, PT, BG, HU, GR, AT, HR, EE, SI, LT, LU, LV, DE, CY, and MT had a very strong distribution symmetry.

Over the next four years, i.e., until 2018, large enterprises located in FR and IT were characterized by left-sided skewness with a weak asymmetry of the distribution of the analyzed variables. Moderate asymmetry concerned the surveyed entities located in NL and PL. On the other hand, a very strong asymmetry in the use of modern technological solutions occurred in SE, ES, BE, DK, BK, FI, AT, GR, CZ, RO, PT, IE, HU, SK, HR, LT, EE, CY, LV, LU, MT, DE, and SI.

However, during the next four years until 2022, the surveyed enterprises were also distinguished by a negative left-skew distribution with weak asymmetry in the case of FR (-0.241) and very strong for the remaining 26 EU countries.

According to the designated measures, after a linear ordering of the countries, taking into account the value of the aggregate variable, typological classes were determined. They present the division of EU countries from the perspective of the intensity of implementation and the use of technological resources while creating the digital potential of large enterprises. The results of the analysis are presented in Table 3 and Figure 3.

Table 2.
Typological classification of EU countries according to the intensity of the use of modern technologies by large enterprises in 2014-2022

Typological class	**Synthetic measure Qi**		**Number of states**	**Countries (value of a synthetic measure)**
	limit values	**level**		
year 2014				
I	≥0.989	very high	2	CY (1.0), MT (0.998)
II	<0.764-0.989)	high	16	BE (0.767), BG (0.868), HR (0.913), DK (0.819), EE (0.970), FI (0.826), GR (0.909), HU (0.824), IE (0.885), LV (0.965), LT (0.932), LU (0.976), PT (0.815), RO (0.825), SK (0.881), SI (0.955)
III	<0.539-0.764)	medium	4	AT (0.735), CZ (0.710), NL (0.566), SE (0.716)
IV	<0.539	low	5	FR (0.275), DE (0.436), PL (0.387), ES (0.420), IT (0.251)

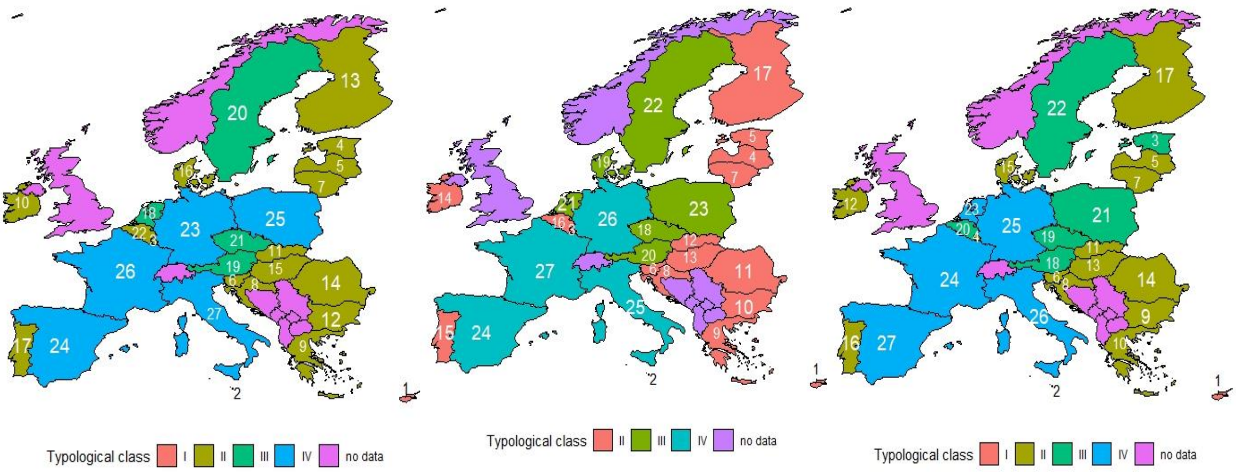
Cont. table 3.

year 2018				
I	≥1.030	very high	0	-
II	<0.832-1.030)	high	17	BE (0.863), BG (0.962), HR (0.966), CY (1.00), EE (0.987), FI (0.863), GR (0.964), HU (0.925), IE (0.925), LV (0.991), LT (0.972), LU (0.994), MT (0.999), PT (0.889), RO (0.955), SK (0.953), SI (0.986)
III	<0.633-0.832)	medium	6	AT (0.807), CZ (0.829), DK (0.827), NL (0.735), PL (0.641), SE (0.724)
IV	<0.633	low	4	FR (0.299), DE (0.440), IT (0.476), ES (0.481)
year 2022				
I	≥0.996	very high	2	CY (1.0), MT (0.999)
II	<0.798-0.996)	high	15	BG (0.951), HR (0.961), DK (0.824), EE (0.988), FI (0.813), GR (0.936), HU (0.879), IE (0.887), LV (0.975), LT (0.968), LU (0.979), PT (0.815), RO (0.866), SK (0.925), SI (0.974)
III	<0.60-0.798	medium	5	AT (0.791), BE (0.725), CZ (0.746), PL (0.617), SE (0.602)
IV	<0.60	low	5	FR (0.511), DE (0.500), IT (0.414), NL (0.592), ES (0.317)

where: data identical to those described in table 1.

Source: Own study.

Based on the conducted research, it should be stated that, as a result of the ongoing DX processes, which result from the established policy of shaping the digital future of Europe, large enterprises implement and use modern technological solutions to a different extent and pace (see Fig. 3).



a) 2014 b) 2018 c) 2022

Figure 3. Diversity of large enterprises in the EU in terms of the use of modern technologies: a) in 2014; b) 2018; c) in 2022.

Source: Own elaboration using the RStudio program.

In 2014 and 2022, entities operating in CY and MT formed the 1st typological class and, at the same time, were distinguished by a very high intensity of the use of modern technological solutions (synthetic measure at the level of ≥ 0.989 in 2014 and 0.996 in 2022). The indicated group of countries is distinguished by the highest percentage of large enterprises in which the scope of application of cloud computing technologies B7, B10, B12, and B14, increasing the level of digitization, has increased. It should be noted that in 2018 large enterprises in the surveyed countries did not form the first typological class. Such a situation may mean that they did not implement modern technological solutions.

The high intensity of technology use was characteristic of 16 (in 2014), 17 (in 2018) and 15 (in 2022) EU countries concentrated in the dominant typological class II. Large entities operating in their area were characterized by a high level of the analyzed variables, due to the value of the synthetic measure, which in the analyzed period reached a value of 0.989-0.764 (2014), 1.030-0.832 (2018), and 0.996-0.798 (2022). Class II organizations were distinguished by a high degree of increase in the use of big data technology B2, B5, cloud computing B6, B7, B8, B9, B10, B12, B14, Internet of Things B15, and social media Y5, Y6, Y8.

Class III with an average intensity of MT use in large enterprises was created by 4 (AT, CZ, NL, and SE in 2014), 6 (AT, CZ, DK, NL, PL, and SE in 2018), and 5 (AT, BE, CZ, PL, and SE in 2020) countries. According to the value of the synthetic measure, which ranged from 0.764-0.539 (2014), 0.832-0.633 (2018), and 0.798-0.60 (2022), the surveyed entities were characterized by an average intensity of implementation and use of technological solutions in the field of cloud computing B7, B8, B9, B10, B12, B14 and availability of social media Y5, Y6, Y8.

The last and 4th typological class was formed by countries (5 in 2014, 4 - 2018, 5 - 2022), which showed the lowest intensity of using modern technologies (the value of the synthetic measure <0.539 in 2014, <0.633 - 2015, <0.60 - 2022). Large enterprises operating in the countries that qualified for this group, due to the analyzed variables, achieve the poorest results. This type of situation is due to the low percentage of technology used in big data B4, B5, artificial intelligence B17, B18, B19, B21, and cybersecurity D2.

The conducted research shows that the scope and intensity of the use of modern ICT technologies in large enterprises operating in individual EU countries are shaped in a variable manner. This situation is a consequence of economic, technological, social, cultural, legal, and international differences. The continuous process of investing in new technologies is the reaction of large enterprises to growing market competition. In turn, the increasing requirements of buyers and the volatility of the environment contribute to the implementation of advanced solutions in the field of mobile, analytical, social, cloud computing, Internet of Things, and automation tools, which consequently affect the BM change. Nevertheless, the use of technological resources in large enterprises depends on the EDD strategy, which is intended to achieve digital sovereignty. Its main goal is to shape the technological potential and digitization processes by the adopted development concept of the surveyed organizations. The conducted research revealed a significant digital differentiation between large entities from EU countries, the so-called leaders (first typological class), which include two countries located in the Mediterranean region (CY and MT), in comparison with the lowest ranked (fourth group) countries of the so-called "old EU" (FR, DE, ES, and IT).

According to the conducted research, it can be concluded that large enterprises are gradually implementing modern technological solutions. They contribute to the achievement of competitive advantage and digital sovereignty and the continuous building of the digital potential necessary to conduct business in a changing environment. These circumstances result from the implementation of the EDD strategy.

4.3. Modeling the digital transformation process of large enterprises

The last stage of the research involved determining the level of dissemination of modern technologies among large entities operating in 27 EU countries. To assess the countries of the European Community from the perspective of the scope of implementing technological solutions in large enterprises, the ICT technology diffusion index was used. It was determined based on the value of the compromise index (Q_i) of the VIKOR method for all analyzed variables in 2018 and 2022 compared to 2014 and 2018, respectively (see Tab. 4). The use of such a concept made it possible to observe the changes that took place in large enterprises in the analyzed years. In addition, it allowed for the differentiation of the countries of operation of the entities due to the ongoing transformations.

Table 3.
The rate of dissemination of modern ICT technologies of large enterprises

UE country	Qi 2014	Qi 2018	Qi 2022	DFX 2018	DFY 2022	CHi
AT	0.735	0.807	0.791	0.072	-0.017	-0.231
BE	0.767	0.863	0.725	0.096	-0.138	-1.440
BG	0.868	0.962	0.951	0.094	-0.011	-0.115
HR	0.913	0.966	0.961	0.052	-0.005	-0.090
CY	1.000	1.000	1.000	0.000	0.000	0.000
CZ	0.710	0.829	0.746	0.119	-0.083	-0.693
DK	0.819	0.827	0.824	0.008	-0.004	-0.458
EE	0.970	0.987	0.988	0.017	0.001	0.035
FI	0.826	0.863	0.813	0.037	-0.050	-1.363
FR	0.275	0.299	0.511	0.024	0.212	8.870
DE	0.436	0.440	0.500	0.004	0.060	14.310
GR	0.909	0.964	0.936	0.055	-0.028	-0.501
HU	0.824	0.925	0.879	0.101	-0.047	-0.462
IE	0.885	0.925	0.887	0.039	-0.037	-0.944
IT	0.251	0.476	0.414	0.225	-0.062	-0.276
LV	0.965	0.991	0.975	0.026	-0.016	-0.624
LT	0.932	0.972	0.968	0.040	-0.004	-0.088
LU	0.976	0.994	0.979	0.018	-0.014	-0.802
MT	0.998	0.999	0.999	0.001	0.000	-0.100
NL	0.566	0.735	0.592	0.169	-0.143	-0.845
PL	0.387	0.641	0.617	0.254	-0.024	-0.094
PT	0.815	0.889	0.815	0.074	-0.074	-1.003
RO	0.825	0.955	0.866	0.130	-0.089	-0.686
SK	0.881	0.953	0.925	0.072	-0.028	-0.392
SI	0.955	0.986	0.974	0.032	-0.012	-0.374
ES	0.420	0.481	0.317	0.062	-0.165	-2.669
SE	0.716	0.724	0.602	0.008	-0.122	-15.250

where: data identical to those described in table 1.

Source: Own elaboration based on data from Eurostat.

Analyzing the years 2018 and 2014 as well as 2022 and 2018, significant differences can be noticed in the degree of disseminating technological resources in the territory of the 27 EU countries. The research shows that in large enterprises located in DE, FR, and EE in the years 2014-2022, the level of implementation of modern technological solutions increased. It should be concluded that the surveyed organizations are distinguished by significant capital involvement while creating digital potential and adapting to the requirements of the digital single market from the perspective of implementing the EDD strategy. In addition, such a situation also results from the intention to meet competition located in other EU Member States. So far, according to the results of the VIKOR ranking and the typological classification (subchapter 4.2), the surveyed entities occupied places in the top five - EE (3rd-5th place, class II), or were classified outside the top twenty - DE, FR (23-27th place, class IV).

In contrast, in the case of CY, the high-technology differentiation index remained unchanged. Therefore, it should be concluded that the dynamics of implementing technological solutions and investment outlays in the analyzed years were not influenced by EU legal regulations resulting from the implementation of the EDD strategy. In addition, in the VIKOR ranking, large enterprises from the analyzed country reached 1st place, and in the typological classification, they belonged to the first group.

In the situation of the remaining 23 EU countries surveyed, where large entities operate, the indicator of diversification in the use of modern technological solutions was characterized by a deficit. Thus, the dynamics of ICT implementation were at a negative level. Therefore, it should be assumed that organizations did not invest capital in technological resources, because having their digital potential enabled them to maintain a competitive position and build digital sovereignty by the assumptions of the EDD strategy.

Based on the conducted research, it should be assumed that the DX of large enterprises takes place gradually with a different level of MT absorption. The process of shaping it is distinguished by significant differences in the surveyed entities located in the territory of the 27 EU countries. Thus, the degree of digitization and the digital potential of large enterprises from the perspective of the EDD strategy among large enterprises in 2014-2022 is at an average level (23 countries with a negative intensity in technology implementation). Nevertheless, the development of the digital infrastructure of large entities in countries where the level of diffusion of access to MT is lower than the EU average is a significant problem. According to the EU digital policy agenda, within the DC 2030 strategic goals, 75% of enterprises (three out of four) in the EU should use CC, BDA, and AI.

According to the conducted research, it can be confirmed that large enterprises carry out digital transformation in stages, characterized by a diverse pace and scope of diffusion of modern technologies, which they adapt through the adopted policy of the EU digital single market, in the field of gaining digital sovereignty, seeing in them a strategic opportunity to achieve a market advantage and the ability to function in a changing, dynamic and uncertain environment.

5. Conclusions

Nowadays, all enterprises are subject to the process of digital maturation, which should be interpreted as an adaptation to rational functioning in a digital environment. The studies of large enterprises operating in 27 EU countries presented in this article allowed for the identification of changes in the use of technological resources, as well as the pace and scope of the dissemination of modern technologies in a changing environment, under the influence of the conditions of the digital single market policy.

It should be concluded that the individual components of digital potential play a fundamental role not only in the process of creating the competitiveness of large enterprises, but also affect the success of their market survival in an uncertain environment. The conducted PCA shows that technological resources shaping the digital potential are used in various areas of the functioning of the surveyed entities. The main technological solutions that are implemented in connection with the progressing digital transformation include tools based on Web 1.0 (skillful use of the Internet, having a computer and a website), and mobile technologies based on Web 2.0 (using social networks, sharing content multimedia, and making purchases and placing orders online). Moreover, to a varying degree, large enterprises digitize their activities as part of the following technologies: digital Web 3.0 (cloud computing, Internet of Things, big data), automating Web 4.0 (3D printing, process automation), and hyper-automating Web 5.0 (using artificial intelligence and machine learning, use of service and industrial robots).

In addition, the results of the conducted research indicate that, among the analyzed entities, there are significant inequalities in the level of digitization and intensity of technology use observed between the Member States of the European Community. The use of the VIKOR method and the grouping of linearly ordered objects using the standard deviation method made it possible to classify 27 EU countries with about 43 diagnostic variables characterizing the digital potential of large enterprises regarding the use and intensity of technological resources. Most large enterprises using modern ICT solutions are located in CY, MT, LU, and EE (countries classified from 1st to 3rd place in the VIKOR ranking for various years). However, entities located in PL, IT, FR, DE, and ES stand out with the lowest intensity of using such solutions (according to the VIKOR ranking, they are ranked 25th-27th).

Based on the determined technology dissemination index, the diversity of the studied phenomenon was assessed and countries where dynamic changes in the implementation of ICT are taking place were identified. A positive indicator of differentiation is characteristic of large enterprises operating in DE, FR, and EE. CY stands out with a constant level of the digital diversity index. However, in other EU countries, negative dynamics of the analyzed phenomenon appear.

The results of the conducted research indicate that large EU enterprises have not yet achieved the strategic goals of the "Road to the Digital Decade", DC2030, and the EDD strategy in the field of digital transformation and increasing the use of new technologies. According to their assumptions, they should have a digital potential of 75% in the use of CC, AI, and BDA. In 2014, the highest degree of digitization was achieved by large entities operating in DK (41.8%), FI (41.6%), and NL (21.5%). The lowest level of use of these technologies was in GR (0%), BG (3.6%), and RO (4.0%). According to the measure of the use of digital technologies, the maximum value was achieved by organizations located in FI (45.5% - 2018; 50.2% - 2022), DK (38.3% - 2018; 58.4% - 2022), and SE (36.0% - 2018; 54.9% - 2022). In turn, the use of such solutions was negligible in large entities in ES (2.5% - 2018), BG (2.4% - 2018; 8.3% - 2022), CY (1.4% - 2018), GR (8.8 % - 2022), and RO (7.4% - 2022).

The issues related to ICT technological resources presented in the article do not comprehensively exhaust those related to the application and implementation of technological solutions that create the digital potential of large enterprises. The components that make up the digital potential, under the influence of the development of new-generation telecommunications technologies (including 6G), strategic EU digitization programs, and environmental conditions, are constantly subject to diversification. For this reason, further directions of research should focus on the analysis of the use of modern Web 3.0, 4.0, 5.0 and subsequent technological solutions for sustainable development, delays in the implementation of ICT technologies, the use of quantum technologies and the levels of achieving digital sovereignty of entities operating in EU countries.

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Appendix

Table 4.
Diagnostic features included in own research

Id. characte-ristics	Indicator name	V for 2014	V for 2018	V for 2022
Computer software				
A1	Enterprises using software solutions like Customer Relationship Management (CRM)	1.77	1.65	1.53
A2	Enterprises who have ERP software package to share information between different functional areas	1.62	1.51	1.45
Data analysis and processing				
B1	Use 3D printing for prototypes or models for internal use	2.88	1.73	1.88
B2	Analyze big data from the geolocation of portable devices	1.18	1.45	1.41
B3	Analyze big data from smart devices or sensors	1.24	1.28	1.30
B4	Use service robots	4.63	1.70	1.32
B5	Analyze big data generated from social media	1.23	1.59	1.59
B6	Buy finance or accounting software applications (as a CC service)	1.54	1.24	1.19
B7	Buy e-mail (as a CC service)	1.34	1.13	1.26
B8	Buy hosting for the enterprise's database (as a CC service)	1.40	1.23	1.21
B9	Buy computing power to run the enterprise's own software (as a CC service)	1.42	1.28	1.32
B10	Buy office software (e.g., word processors, spreadsheets, etc.) (as a CC service)	1.26	1.18	1.31
B11	Buy Customer Relationship Management (CRM) software (as a CC service)	1.44	1.29	1.29
B12	Buy storage of files (as a CC service)	1.44	1.31	1.29
B13	Buy CC services delivered from shared servers of service providers	1.40	1.22	1.22
B14	Buy cloud computing services used over the internet	1.48	1.37	1.43
B15	Enterprises use IoT	2.88	1.28	1.45
B16	Enterprises use AI technologies automating different workflows or assisting in decision making (AI based software robotic process automation)	3.81	1.36	1.35
B17	Enterprises use AI technologies for ICT security	5.20	1.91	1.84
B18	Enterprises use AI technologies for management of enterprises	5.20	1.29	1.28
B19	Enterprises use AI technologies generating written or spoken language (natural language generation)	3.66	1.55	1.53
B20	Enterprises use AI technologies performing analysis of written language (text mining)	5.20	1.37	1.36
B21	Enterprises with a chat service where a chatbot or a virtual agent replies to customers	5.20	1.39	1.35
B22	Use 3D printing	2.88	1.91	1.81
B23	Use industrial robots	3.81	1.50	1.38
B24	Analyze big data internally using machine learning	3.63	1.12	1.84
B25	Analyze big data internally using natural language processing, natural language generation, or speech recognition	3.74	1.77	1.64
Digital skills				
C1	Enterprise employed ICT/IT specialists	1.61	1.48	1.45
C2	Enterprise provided training to their personnel to develop their ICT skills	1.76	1.60	1.48
Digital security				
D1	Enterprises experienced ICT security related incidents leading to: unavailability of ICT services due to hardware or software failures	3.60	1.58	1.56
D2	Enterprises experienced ICT security related incidents leading to: destruction or corruption of data due to infection of malicious software or unauthorised intrusion	4.25	1.47	1.48
Technological infrastructure				
X1	Enterprises with internet access	1.55	1.47	1.44
X2	Persons employed using computers	1.72	1.89	1.83
X3	Mobile connection to the Internet for business use to access the enterprise's email system	1.58	1.48	1.47
X4	Persons employed were provided a portable device that allows Internet connection via mobile telephone networks, for business purposes	1.20	1.33	1.31
Online technologies				
Y1	Enterprises with a website	1.58	1.50	1.46
Y2	Enterprises where the website provided description of goods or services, price lists	1.84	1.68	1.54
Y3	Enterprises where the website provided order tracking available online	1.50	1.32	1.34
Y4	Enterprises where the website provided online ordering or reservation or booking, e.g., shopping cart	1.39	1.24	1.42
Y5	Enterprises where the website had links or references to the enterprise's social media profiles	1.60	1.43	1.50
Y6	Use social networks (e.g., Facebook, LinkedIn, Xing, Viadeo, Yammer, etc.)	1.55	1.44	1.46
Y7	Use enterprise's blog or microblogs (e.g., Twitter, Present.ly, etc.)	1.49	1.41	1.41
Y8	Use multimedia content sharing websites (e.g., YouTube, Flickr, Picasa, SlideShare, etc.)	1.61	1.47	1.53

where: V- Coefficient of variation.

Source: Own elaboration based on data from Eurostat.