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THE EQUIVALENCE BETWEEN DIGITALIZATION INDEXES

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Abstract

Digitalization is nowadays one of the fastest developing processes. The adoption of digital technologies can provide numerous opportunities for the organizations to evolve and gain competitive advantage by leveraging of technologies in order to respond to dynamic expectations and demands.

Information about the country digitalization level is essential to decision makers in both public and private organizations. It can present insights on which areas need the most investment, and furthermore to gain feedback on the outcomes of these investments. For companies, it can create a certain predictability on which products and services will be required the most.

To assess the evolution of this process in each country, various indexes were proposed and employed by different corporations. The information and methodology used by these indexes is diverse and there was the need to analyze the correlation between them.

The purpose of this research is to investigate the digitalization of public and private sector, identify the most used digitalization indexes and test their equivalences. The compared indexes are: Digital Economy and Society Index (DESI), Digitalization Index (DiGiX), ICT Development Index (IDI) and Cisco Digital Readiness Index. DESI and IDI are used by public organizations. DiGiX and CISCO are used by private companies. Comparing two sectors highlights the most common factors of digital evaluation.

Indexes are analyzed thoroughly by their structure, coverage, weights, methodology and ranking. Based on this information, a practical comparison between the indicators and sub-indicators of indexes is performed. The result of the practical work is the correlation table with equivalences between DESI, DiGiX, IDI and CISCO indexes, which shows the percentage of their alikeness. Additionally, a new digitalization index is proposed, based on the result of the previous comparison, which can be applied to analyze both public and private sector of the country's digitalization level.

Keywords: Business, Digitalization, Equivalence, ICT, Index, Society.

Resumo

A digitalização é hoje um dos processos em desenvolvimento mais rápido. A adoção de tecnologias digitais pode fornecer inúmeras oportunidades para as organizações evoluírem e ganharem vantagem competitiva ao alavancar tecnologias para responder às expectativas e demandas dinâmicas.

Informações sobre o nível de digitalização do país são essenciais para os tomadores de decisão em organizações públicas e privadas. Pode apresentar indicações sobre quais áreas precisam de mais investimento e, além disso, obter feedback sobre os resultados desses investimentos. Para as empresas, pode criar uma certa previsibilidade sobre que produtos e serviços serão mais necessários.

Para avaliar a evolução deste processo em cada país, diversos índices foram propostos e utilizados por diferentes empresas. As informações e a metodologia utilizadas por esses índices são diversas e houve a necessidade de analisar a correlação entre eles.

O objetivo desta pesquisa é investigar a digitalização do setor público e privado, identificar os índices de digitalização mais utilizados e testar suas equivalências. Os índices comparados são: Índice de Economia e Sociedade Digital (DESI), Índice de Digitalização (DiGiX), Índice de Desenvolvimento das TIC (IDI) e Índice de Preparação Digital da Cisco. O DESI e o IDI são usados pelas organizações públicas. O DiGiX e o CISCO são usados por empresas privadas. A comparação de dois setores destaca os fatores mais comuns da avaliação digital.

Os índices são analisados pela sua estrutura, extensão, pesos, metodologia e classificação. Com base nessas informações, é realizada uma comparação prática entre os indicadores e sub--indicadores dos índices. O resultado do trabalho é a tabela de correlação com equivalências entre os índices DESI, DiGiX, IDI e CISCO, que mostra o percentual da sua semelhança. Além disso, é proposto um novo índice de digitalização, baseado no resultado da comparação anterior, que pode ser aplicado para analisar o nível de digitalização do setor público e privado do país.

Palavras-chave: Negócios, Digitalização, Equivalência, TIC, Índice, Sociedade.

Contents

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III. Abbreviations

BBVA – Banco Bilbao Vizcaya Argentina

BM – Business Model

BMI – Business Model Innovation

COCOM – Coordinating Committee for Multilateral Export Controls

DESI – Digital Economy and Society Index

DiGiX – Digitalization Index

DSL – Digital Subscriber Line

GDP – Gross Domestic Product

HTTP – Hypertext Transfer Protocol

IDI – Information and computer technology Development Index

ICT – Information and Computer Technology

ITU – International Telecommunication Union

LPI – Logistics Performance Index

MISR – Measuring and Information Society Report

OEM – Original Equipment Manufacturers

RFID – Radio Frequency Identifier

SME – Small and medium sized enterprise

VHCN – Very High-Capacity Network

1. Introduction

"Change is the law of life and those who look only to the past or present are certain to miss the future."

— John F. Kennedy

The evaluation of the digitalization level regarding business processes and countries is the subject research of this thesis. Digitalization is becoming an inevitable part of growth of business, its virality and functional improvement (Bryukhovetskaya, 2019). The digitalization evaluation is still not used in all countries and it prevents them from leading in innovation, providing multi-channel services and advance in e-commerce and digital economy (Shin et al., 2020). As well, by Stremousova & Buchinskaia (2019), digital technologies don't have a recognized model for assessing the economic effects, growth and development, presented to public yet. And at the same time, the last few decades have seen plenty of studies in the subject of impact of digital transition on specific industries and processes in the economy (Tarasova et al., 2020). That is why this topic is very promising to be investigated.

The focus of the work is what is digitalization and which kind of evaluations of digitalization exist. To do this it is important to define the digitalization, compare the digitalization indexes and find the most optimal from the suggested variants (Kotarba, 2017). There are four digitalization indexes presented. Two of them are public, DESI from the European Union, and ICT Development index from International Telecommunication Union. The other two are from private sector: DiGiX from BBVA company and CISCO Digital Readiness index from CISCO company.

There is a big scope of geographical area investigated. Digital indexes vary geographically, and they are compared by the territory (Konovalova et al., 2020). The evaluation of digitalization in different regions can vary drastically due to political situation, ideology, culture and level of development (Petrenko et al., 2017).

As digitalization is a recent process (Lederer et al., 2017), the research is based on the most recent data and definitions. This work can apply to all demographic groups and communities.

The most specific aspect is to develop optimal digital evaluation of country, business and locality. This is achieved by the finding the equivalence between the most used digital indexes and concluding the most important aspects for this process (Kotarba, 2017).

This dissertation is aimed to analyse both theoretical and practical problems and propose a solution.

The research problem of this work is finding the connection between the digital economy and digitalization process, searching for opportunity of digitalization of industries, find a gap in adjusting the business into the online economy, and analysing the most used digitalization indexes (Sidorov et al., 2020).

The theoretical problem is to expand the knowledge of digitalization, understanding how to evaluate the economy and business, explore the contradiction of defining digitalization, compare the given information about the indexes and show how discrepancies in evaluation are still not well understood in the new digital modern world (Billon et al., 2010).

In the second chapter the term digitalization is explained, from the older definition to the newer one. Also, in the second chapter covers the explanation what it the digital economy, which areas the informational technology is embracing, and how the digitalization is connected to the digital economy. As well research is conducted on which industries can be digitalized, and how to change a business structure to adjust online economy.

In the third chapter it is observed the indicators of digital evaluation. It is chosen four indicators to compare: Digital Economy and Society Index (DESI), The Digitization Index (DiGiX), the ICT Development Index (IDI), and the Cisco Global Digital Readiness Index. These indicators can show the evaluation through the time, region, and they are used by the international organizations, and successful international informational companies. DESI index is chosen, as it is used by the European Union Commission. DiGiX index is chosen as it covers more than 100 countries' digital performance. IDI index was chosen as it is used by the International Telecommunication Union, and Cisco index is an example of index from the multinational technology company, which is one of top companies with highest revenues.

In the fourth chapter a practical research is made, how the digitalization indexes are equivalent to each other by the estimation of the digitalization, and how aligned they are. Also, each index has own rating of countries, and it is presented in thesis.

At this point the research question can be stated: how these digitalization indexes are equivalent to each other? The research aim is to answer this question compare all mentioned index's structure and thus, reach the objective of the paper. The objective is to establish the percentage equivalence of the data and based on this data add the new digital evaluation index.

2. Literature review

It is used a critical literature review method in the work as it is important to have the context and theoretical framework. From the approach perspective the work is done by inductive approach, what means planning to explore data and develop the context of the data.

Initial stage of review includes an in-depth analysis of definition digitalization, how the digitalization is connected with digital economy, which industry can be digitalized and how to change a business structure to adjust the online economy.

There are different sources of information in this research. Mostly the work consists on exploring the most recent and relevant papers about digitalization, but also books, company reports, and international organizations reports.

The thesis is combining an integrative, methodological and systematic types of review. Integrative, as it explores a new perspective of the topic, for example how to change a business structure to adjust economy and how to create a new index with data given. Methodological, as the data collection is necessary. For example, for each index the methodology, table of weights and ranking data is collected. And systematic, as it is critically appraising and analysing the literature, for example the digitalization term or best business structure change method.

2.1. Definition of digitalization

There are two generally confused concepts – digitization and digitalization.

By Dimitrova and Dimitrovski (2020) digitization is a digital representation of physical objects or in other words converting something non-digital into digital representation or artifact.

By Jensen (2016) digitization is the process of converting analogue data into digital set data and its framework for digitalization.

And by Jensen (2016), digitalization is a framework of exploitation of digital opportunities.

By Petrenko (2017) it is the transition from the analogue form of transferring information to digital form, with the assumption not just digitizing but also creating a new innovative product with new consumer and functionality properties.

By Dimitrova and Dimitrovski (2020) digitalization refers to enabling, improving or transforming business processes by leveraging digital technologies and digitalization data.

For a purpose of the thesis this definition of digitalization is chosen.

As well, this process leads to digital transformation that is defined as a process of restructuring economies, institutions, and society as a whole (Annarelli et al., 2021). Also this process is a change, not a product that can be bought (Schaebs, 2020).

Over the past few decades, global industries not only have faced technological changes that have led to opportunities such as greater flexibility, reactivity and product individualization, but also have presented diverse challenges such as rapid technological change, increased complexity and changing customer preferences and legal requirements (Sidorenko & Khisamova, 2020) . This has led to challenging situations in a corporate context: manifold new technological opportunities are perceived, but people are uncertain how to use and implement them simultaneously in terms of product and service offers (Lerch & Gotsch, 2015). The situation in the field of digitalization and business model innovation (BMI) is interesting because the influence of digitalization on the business model (BM) is fuzzy, and the exploitation of technological opportunities – also from a strategic viewpoint – is challenging (Loebbecke & Picot, 2015).

Digitization (that is the process of converting analogue data into digital data sets) is the framework for digitalization, which is defined as the exploitation of digital opportunities. Digital transformation is then defined as the process that is used to restructure economies, institutions and society on a system level (Jensen et al., 2016).

While the latter embraces changes on all societal levels, digitalization by means of combining different technologies (e.g. cloud technologies, sensors, big data, 3D printing) opens unforeseen possibilities and offers the potential to create radically new products, services and BM (Matzler et al., 2016).

Digitalization is used to describe any changes in the organization and the organization's business model due to their increasing use of digital technologies to improve both the performance and the scope of the business (MIT, 2011).

2.2. Is digitalization connected with digital economy?

With a rapid development of the informational technologies, we face the growth of Internet of things in everyday life. The informational progress has already touched almost every sphere, and now it is the time to adopt a new kind of economy – the digital economy (Barinova et al., 2020).

Digital transformation belongs to Industry 4.0 in the sphere of development of manufacturing and services, designed to create "smart manufacturing" and integrate it into all spheres of human life, customizing it for the tasks of each individual (Bataev & Aleksandrova, 2020).

The term "digital economy" is more and more heard by the politicians, entrepreneurs, journalists. First, it is about the process of digitalization, which is a knowledge stored in form of 0s and 1s. It is about the transformation from the physical exchange of information into the exchange with help of digital devices, which create a new way of communication and movement as well as processing the huge amount of information, which can be supplied from anywhere in the world (Bowman, 1996).

Digital economy describes an economic system where the usage of informational and communication technology is widely spread, embracing the:

- base infrastructure (high-speed Internet access, computing power, security services),
- e-business (business models with high utilization of ICT for front- and back-office functions),
- eCommerce (usage of the ICT in business-to business (B2B), business-to-consumer (B2C), and consumer-to-consumer (C2C) transactions) (Bowman, 1996) .

On the daily basis the issues regarding the digitalization of the economy are already discussed by the national governments, international organizations, big corporations, small and medium sized enterprises and the economic cooperation (UNCTAD, 2019). The digital economy is vastly growing (Lederer et al., 2017)."The size of digital economy is evaluated in the range of 4.5 to 15.5% of the World GDP" (UNCTAD, 2019). Investors are actively financing the technological companies. In the beginning of 2020, market capitalization of Apple, Microsoft, Alphabet, Amazon and Facebook for the first-time history exceeded 5 trillion dollars (Gronum et al., 2016)The leading role in this process is played by applying digitalization of production, implementation Industry 4.0 related technologies with big data analysis, using artificial intelligence and industrial internet of things (UNCTAD, 2019).

Expectations regarding economic efficiency of implementation these technologies are mostly optimistic (Gronum et al., 2016). According to the company's researchers Accenture investing in industrial Internet of Things for 20 countries (USA, Switzerland, Finland, Sweden, Norway, the Netherlands, Denmark, United Kingdom, Japan, Germany, Sword, Australia, Republic of Korea, Canada, China, France, Spain, Brazil, Italy, India, Russia) may provide additional GDP growth of 10.6 trillion dollars (Purdy & Davarzani, 2015).

According to the calculations of the World Economic Forum every US dollar directed to investment in digital technology, for the latter 30 years increased GDP by $20. And every dollar aimed at non-digital investment, increased GDP by only $3(Xu & Cooper, 2017). It is expected that by 2025 that 24.3% of world GDP will be provided digital technologies such as artificial intelligence and cloud computing (Kumar, 2019).

The characteristic feature of the digital economy is its connection with the economy on demand, which provides for not the sale of goods and services, but access to them now when it is needed. The advantages of the economy on demand are high speed of obtaining the necessary services or goods; reducing their cost for the end-user by reducing the number of intermediaries; simplifying the output of suppliers of goods and services to users (Borysiuk et al., 2020).

2.3. Which industries can be digitalized?

> *"We're only at the very, very beginning of this next generation of computing and I think that every industry leader will be the ones that transform first. I don't care what industry you're talking about."*
>
> *— Kim Stevenson, CIO, Intel*

Nowadays any company or organization can be digitalized, and no matter which business we are talking about. Moreover, any sphere has already mastered in e-commerce or leading the online business. According to Westermann and Bonnet there are two concepts for the companies which can be defined: the "What" and the "How". "The What" concept is about using technology to transform the model and structure of business, impression and experience of the users and operational process. And "The How" answer is in successful transformation from classical ways and sources of solving the problem into an implementation of innovative technologies (Technology, 2013).

For industry leaders it is required to provide information that they have digital literate supervisory and executive board. It should be multigenerational, diverse and with sufficient expertise to advise on fast-moving business and technology topics, such as cybersecurity. The digital transformation should be driven at the CEO and board level of organization. In a business perspective, the organization should assure that it is working with industry clusters, have a platform business model strategy, consistent with its role in industry and implementing the digitalization will be risk-rewarded and sufficiently ambitious to achieve top-quartile performance. In a talent and leadership perspective, the industry leaders should address both technical and creative digital skills in the talent strategy, recruit the best talents and skills, and have an action plan how to rate the effectiveness of employees (Laurens, 2019).

For governments and policy makers the tasks may wary. They must accomplish the government operations and mission. Government operations mean that the customer service model is user friendly, using open standards and easily accessible in line with industry digital best practices, Also, there should exist the platform for rapid multi-stakeholder interaction and corporate consultation; clarity on the implication of the global security, privacy and cross-border data flows in the industry, timeline to coordinate and resolve challenges with industry stakeholders (World Economic Forum, 2016).

Government mission is in understanding the implications for the industry when addressing the societal opportunities, implementing flexible policy frameworks to realize benefits in the short and medium term. Policy makers should consider for policies that are currently subject to legal challenge and increase the relevance of regulations and policy frameworks to foster innovation while protecting customer interests (World Economic Forum, 2016).

In this part of work automotive, consumer, electricity, logistics, media and healthcare industries which can profit from digitalization are observed.

For automotive industry, the biggest opportunities to create the value are initiatives such as channel migration to virtual purchases, value added subscriptions and next-generation servicing. There are, however, barriers to realize this value. First, regulatory constraints exist in some markets, preventing, for instance, Original Equipment Manufacturers (OEMs) from operating as direct-to-market dealers. Second, without democratizing the flow of profits from usage-based insurance, the telematics solutions that underpin this business model are unlikely to be installed as standard in most cars (World Economic Forum, 2016).

For consumer industry there is a huge open market for digital transformation. There are four digital transformation themes – consumer data flow and value capture, experience economy, omni-channel retail and digital operating model (Rachinger et al., 2019).

For electricity sector the following initiatives can be taken asset performance management, energy solution integration, energy storage integration and real-time network clouds. The largest impact of digitalization to the logistics industry is likely to come from crowdsourcing. It will allow newer entrants to grab a share of the market from existing players. At the same time, it will allow smaller trucking companies to improve their utilization levels by as much as 20%, which could provide an uplift to their bottom line (Rachinger et al., 2019).

Media and entertainment industries will need personalization and contextualization, content fragmentation. The media industry is already more digital than many other industries, having been transformed by several waves of innovation – desktop internet, mobile, social and the Internet of Things. Digitalization has unleashed an explosion of content that is fragmented across multiple channels and platforms. There are significant opportunities for media enterprises if they can successfully personalize their content and adverts to engage the user, create new services that bridge the physical and digital words, and industrialize their content production and monetization processes (Rachinger et al., 2019).

Healthcare provision model is becoming increasingly unsustainable. To deliver continued improvements to the world's health, healthcare will need to be transformed, with digital playing a central role. Four digital themes – smart care, care anywhere, empowered care and intelligent healthcare enterprise – that will be of crucial importance to the digital transformation of healthcare over the next decade (World Economic Forum, 2016).

2.4. How to change a business structure to adjust online economy?

Digital technologies, like cloud computing, artificial intelligence, are the opportunities for companies. Often, the goal of companies is to repeat the success after high-technology companies, such as Amazon, Apple, Google, Netflix and Facebook (Linde et al., 2020). When the businesses are going digital, in the beginning it faces a lot of challenges, for example, increased competitiveness, loss the control over the customer relationship, new way of communicating with partners, employees, suppliers and, again, customers (BCG, 2012).

Before making a transformation of a business to a new way, it should be taking a strategic decision for all company, not being focused just on functional technological implementations. Any organization can be a digital master, and the profitability will grow. Leaders and managers should make a perfect business model plan before commercialization and implementation to

avoid the digitalization traps (Linde et al., 2020). But which actions should the company take, and which requirements are needed to make changes better?

First, it should be a good understanding of the customer, touch points and top line growth. On operations level, it should be checked if a company can meet the digitalization process and enable the performance management well (Linde et al., 2020). The result of such evaluation is changing the structure slightly – from digitally-modified business into new branch of it, as an e-commerce (Vyshnevskyi Oleksandr, 2020). So, first step should be designing the experience of the customer. Then it is needed to increase the enlargement with smart digital investments, put the customer data and eventually rush the digital experience. The amount of time and knowledge of the customers are very important. By using the online operational performance, the business can break the traditional operational constrains, such as: time, distance, coordination or risk and gain the better productive empowerment cost, improve quality, create a better employee coordination through the online programs, and have a more organized decision-making process and responsibilities (BCG, 2012).

The companies should create models with end-to-end response. What does it mean? Firstly, the research of management department and the engagement with suppliers, investors, customers should be always continuous, and the leadership must be taken by the top managers and executives. If companies are going well to communicate with customers, the suppliers' intersection is usually remaining not well developed. But with employees' situation is different, as e-recruiting makes better option for company to find a target or desired fulfilment of requirements by the employees as well as for employees to find a more suitable job. By creating a new online segment, many of information technologies graduators can have a potential employment and this is a positive effect on job market and increase the communication capabilities (BCG, 2012).

Consumers want choice and the e-commerce provides it sufficiently. Its channels lower barriers for enterprises to entry and increase the process of globalization, which is good in term of trade, especially for enterprises. The cost competency becomes the major priority rather than differentiation. This is called a commoditization process. (Ernst & Young, 2011).

In the figure below you can see the pace of change of the new technologies to adjust the business model for digitalization:

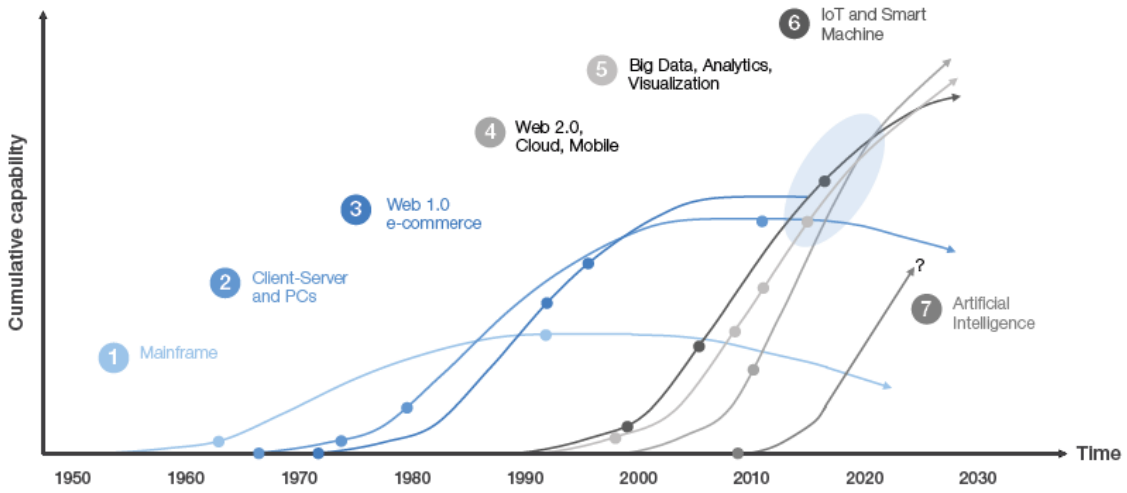


Figure 2.1 - New technologies accelerating pace in time. (adapted from World Economic Forum, 2016)

Also, it is important to mention the value chain process inside the business. There is a mapping out for the industry value chain to identify where digitalization is being or will be applied. First in value chain is the supplier. Digitalization might be applied to inventory and supply, such as inventory and optimization, lower cost provider and supply network optimization (Deevi, 2020).

Next in value chain is the manufacturer. In manufacturing process digitalization can be applied to manufacturing predictive maintenance, profitable bill of materials and defecting, detection and prevention. In logistic value chain step, it is important to mention sales and operation planning: pricing and quoting optimization order to promise, demand forecasting, stocking and next-generation CRM. After logistics goes the distribution. The following fields can be digitized: telematics, predictive maintenance and operation distribution. The last step in value chain is the customer. So, from value chain perspective, aftermarket insights and warranty optimization can be improved digitally (Deevi, 2020).

2.5. Similarities and differences between indexes and ID rating

The main indicators of measuring the level of digital economy are here analysed and the world countries' ranking leaders are defined. It is shown that each of the indexes has different methodological approaches to determining the level of digitalization and contains various factors. Highly developed countries have the highest level of digitization of their own economies, because they have high-quality access to the Internet, a high level of scientific and technological capacity development and wide information access (Kononova, 2015).

Index name	Full name of index	Originator	First publication	Number of covered countries	Number of partial indicators
DESI	Digital Economy and Society Index	European Union	2014	28	33
CISCO	Digital Readiness Index	CISCO company	2016	141	30
DiGiX	The Digitization Index	BBVA	2015	100	22
IDI	Information and computer technology Development Index	International Trade Union	2006	180	13

Table 2-A - Indexes of the digital development (adapted from Kononova, 2015).

3. Methodology and Data

From the previous chapter it is possible to state the research hypothesis. The hypothesis is that indexes are equivalent to each other at in some degree and weights of similarities are enough to build a new index, which combines the definition of all four indexes presented. And the new index can be applied to any country.

To study this is it is important to define the method of research. It is a quantitative study with inductive approach to theory development, as own emerging research is a richer perspective. In this case the perspective is a new digitalization index.

The methodology method strategy is archival and documentary research. The sources of information are predominantly organizational sources, such as conference materials, reports and strategy documents; government sources, like publications, national statistics and reports, as well as printed or online articles. This kind of study brought limitations to the thesis subject, because of lack of shared data regarding digital evaluations (Saunders, 2015) .

The purpose of research design is evaluative as the research question is supposed to be evaluated by certain criteria.

Methodological time horizon is longitudinal, as the found results can be continuously used. Thesis is regarding digitalization, which is a development process and development means longevity.

It is an ethics of conducted research design, such as using only open to public sources of data, respect to patent ad innovations and responsible using of companies' data (Saunders, 2015).

3.1. Digital Economy and Society Index (DESI)

The Digital Economy and Society Index is an index which reveals the progress of European countries in digitalization performance by different aspects. The parameters of it are the human capital, use of Internet, connectivity, integration or digital technology and digital public services. The most recent data is published in the official website of the European union (Stremousova & Buchinskaia, 2019).

The progress of the country is defined by the sum of all these parameters:

- **Connectivity** is the dimension, which revels the level of fixed broadband coverage, what is the percentage of households which use broadbands, DSL, cable, MiMAx and FTTP. Next is the mobile broadband, described in number of people who use mobile data per 100 people. Also, the internet connection is about speed, which is enough when it is more than 30 Mbps. The last sub-factor of connectivity is affordability, comparison of fixed price of broadband between 12 and 30 Mbps (European Commission, 2019a).
- **Human capital** is the degree to which citizens of the European union can use the Internet and other tools and services. Use of internet parameter indicates the productivity of people in the time of using the digital providers (European Commission, 2020c).
- **Digital public service** is a branch of so-called eGovernment. It is about the modernization of the public administration for better serving of citizens. Connectivity factor is about the broad infrastructure and the quality of it (European Commission, 2020e).
- **Use of Internet** value is the content, communication and transactions. People search different content in digital tools, like news, music, video, games. Lately the communication is getting the higher rank, and e-communication consists of social networking, mailing and video calls. The transactions online are shopping or banking. Digital skills can be basic, advanced or developing. Basic skills element in the table shows the amount of Internet users who access at least once a week and people who are using editing, mailing or installing. Advanced and developing skills already have higher level, and people who use Internet or tools already not only for personal use on everyday basis, but they make certain contribution into development of digitalization or use the means of it for educative purposes in other spheres of science. Such people are Information and Communication Technology specialists (ICT specialist hereinafter) like ICT professionals, technicians, service managers. Also, to the advance users are connected people with degree of science, technology, mathematics, engineering (European Commision, 2020b).
- **Integration of Digital Technology** value includes business digitalization and e-commerce. Electronic formation sharing is the first characteristic of the business digitalization. It is number of businesses who used software's for resource planning or sharing the information between the functional departments like accounting, production,

marketing and planning. Second characteristic is the Radio Frequency Identification (RFID) ratio which is the extend of technologies for delivery or identification of goods. Next goes the social media, when businesses use more than social media, for example networks, websites, blogs, and many others. The business should create own profile or account and fulfil the legislative requirements for advertisement. Invoices which are not made manually by the company, but digitally in standard forms and they are being automatically processed (European Commission, 2020b).

3.1.1. Methodology of the DESI index

Methodology of evaluation is clearly explained in the Methodological Manual written by the European Commission (2019). They use 3 level structure of evaluation, dimension, sub-dimension, and indicator, which are indicated in the table below.

Dimension	Sub-dimension	Indicator
Connectivity	Fixed broadband take-up	Overall fixed broadband take-up At least 1000 Mbps fixed broadband take-up
	Fixed broadband coverage	Fast broadband (NGA) coverage Fixed Very High-Capacity Network (VHCN) coverage
	Mobile broadband	4G coverage Mobile broadband take-up 5G readiness
	Broadband price index	Broadband price index
Human capital	Internet user skills	Basic digital skills At least basic software skills
	Advanced skills and development	ICT specialists and graduates Female ICT specialists
	Internet use	People who never used Internet Internet users

Use of Internet services	Activities online	News, music, videos and games Video calls Social networks Doing an online course
	Transactions	Banking Shopping Selling online
Integration of digital technology	Business digitalization	Electronic information sharing Social media Big data Cloud
	E-Commerce	SME's selling online e-Commerce turnover Selling online cross-border
Digital public services	E-Government	E-government users Pre-filled forms Online service completion Digital public services for businesses Open data

Table 3-A - The structure of DESI index (adapted from European Commission, 2015).

The table view of indicators with their description, breakdown, units of measurement and sources of information is presented below. Firstly, the connectivity dimension is presented.

Indicator	Description	Breakdown	Unit	Source
1a1 – Overall fixed broadband take-up	% of households subscribing to fixed broadband	All households	% of households	Eurostat - Community survey on ICT usage in

				Households and by Individuals
1a2 – At least 100 Mbps fixed broadband take-up	% of households subscribing to fixed broadband of at least 100 Mbps, calculated as overall fixed broadband take-up (source: Eurostat) multiplied with the percentage of fixed broadband lines of at least 100 Mbps (source: COCOM)	All fixed broadband subscriptions	% of households	European Commission, through the Communications Committee (COCOM) and Eurostat - Community survey on ICT usage in Households and by Individuals
1b1 – Fast broadband (NGA) coverage	% of households covered by fixed broadband of at least 30 Mbps download. The technologies considered are FTTH, FTTB, Cable Docsis 3.0 and VDSL	All households	% of households	Broadband coverage in Europe studies for the European Commission by IHS Markit, Omdia and Point Topic
1b2 – Fixed Very High-Capacity Network (VHCN) coverage	% of households covered by any fixed VHCN. The technologies considered are FTTH and FTTB for 2015-2018 and FTTH, FTTB and Cable Docsis 3.1 for 2019	All households	% households	Broadband coverage in Europe studies for the European Commission by IHS Markit, Omdia and Point Topic
1c1 – 4G coverage	% of populated areas with coverage by 4G - measured as the average coverage of telecom operators in each country	All households	% of households	Broadband coverage in Europe studies for the European Commission by IHS Markit, Omdia and Point Topic
1c2 – Mobile broadband take-up	Number of mobile data subscriptions per 100 people	All subscriptions	Subscribers per 100 people	European Commission services, through the Communications Committee (COCOM)
1c3 – 5G readiness	The amount of spectrum assigned and ready for 5G use by the end of 2020 within the so-called 5G pioneer bands. These bands are 700 MHz (703-733 MHz and 758- 788 MHz), 3.6 GHz (3400-3800 MHz) and 26 GHz (1000 MHz within 24250-27500	5G pioneer bands	% of harmonised spectrum	European Commission services, through the Communications Committee (COCOM)

	MHz). All three spectrum bands have an equal weight			
1d1 – Broadband price index	The broadband price index measures the prices of representative baskets of fixed, mobile and converged broadband offers	All fixed, mobile and converged broadband offers	Score (0-100)	Broadband retail prices study, annual studies for the European Commission realised by Empirica.

Table 3-B - DESI Connectivity dimension (adapted from European Commision, 2020).

Connectivity dimension analysis is taken with the help of such sources: Eurostat, COCOM, IHC Markit, Omdia, Point Topic and Empirica. The second table attached below, shows the data for the human capital dimension.

Indicator	Description	Breakdown	Unit	Source
2a1 – At least basic digital skills	Individuals with 'basic' or 'above basic' digital skills in each of the following four dimensions: information, communication, problem solving and software for content creation (as measured by the number of activities carried out during the previous 3 months).	All individuals (aged 16-74)	% of individuals	Eurostat - Community survey on ICT usage in Households and by Individuals
2a2 – Above basic digital skills	Individuals with 'above basic' digital skills in each of the following four dimensions: information, communication, problem solving and software for content creation (as measured by the number of activities carried out during the previous 3 months).	All individuals (aged 16-74)	% of individuals	Eurostat Community survey on ICT usage in Households and by Individuals
2a3 – At least basic software skills	Individuals who, in addition to having used basic software features such as word processing, have used advanced spreadsheet functions, created a presentation or document integrating text, pictures and tables or charts, or written code in a programming language.	All individuals (aged 16-74)	% of individuals	Eurostat - Community survey on ICT usage in Households and by Individuals
2b1 – ICT specialists	Employed ICT specialists. Broad definition based on the ISCO-08 classification and including jobs like ICT service managers, ICT professionals, ICT technicians, ICT installers and servicers.	Individuals in employment aged 15-74	% of individuals in employment aged 15-74	Eurostat - Labour force survey

2b2 – Female ICT specialists	Employed ICT specialists. Broad definition based on the ISCO-08 classification and including jobs like ICT service managers, ICT professionals, ICT technicians, ICT installers and servicers.	Females in employment aged 15-74	% of females in employment aged 15-74	Eurostat - Labour force survey
2b3 – ICT graduates	Individuals with a degree in ICT	Graduates	% of graduates	Eurostat (table educ_uoegrad03, using selection ISCED11=ED5)

Table 3-C - DESI Human capital dimension (adapted from European Commission, 2020d).

The main source for human capital dimension analysis is Eurostat statistical organization. The third table, which is shown below, has information of the next dimension of DESI index, called "the use of internet services" dimension.

Indicator	Description	Breakdown	Unit	Source
3a1 – People who never used the internet	Individuals who never used the internet	All individuals (aged 16-74)	% of individuals	Eurostat - Community survey on ICT usage in Households and by Individuals (I_IUX)
3a2 – Internet users	Individuals who used the internet at least once a week	All individuals (aged 16-74)	% of individuals	Eurostat - Community survey on ICT usage in Households and by Individuals (I_IUSE)
3b1 – News	Individuals who used the internet to read online news sites, newspapers or news magazines	All individuals (aged 16-74)	% of individuals who used internet in the last 3 months	Eurostat - Community survey on ICT usage in Households and by Individuals (I_IUNW1)
3b2 – Music, videos and games	Individuals who used the internet to play or download games, images, films or music	All individuals (aged 16-74)	% of individuals who used internet in the last 3 months	Eurostat - Community survey on ICT usage in Households and by Individuals
3b3 – Video on demand	Individuals who used the internet to use video on demand services	All individuals (aged 16-74)	% of individuals who used internet in the last 3 months	Eurostat - Community survey on ICT usage in Households and by Individuals
3b4 – Video calls	Individuals who used the internet to make	All individuals (aged 16-74)	% of individuals who used internet	Eurostat - Community survey on ICT usage in Households

	telephone or video calls (e.g. Skype)		in the last 3 months	and by Individuals (I_IUPH1)
3b5 – Social networks	Individuals who used the internet to participate in social networks (create user profile, post messages or other contributions)	All individuals (aged 16-74)	% of individuals who used internet in the last 3 months	Eurostat - Community survey on ICT usage in Households and by Individuals (I_IUSNET)
3b6 – Doing an online course	Individuals who used the internet to do an online course (on any subject)	All individuals (aged 16-74)	% of individuals who used internet in the last 3 months	Eurostat - Community survey on ICT usage in Households and by Individuals (I_IUOLC)
3c1 – Banking	Individuals who used the internet to use online banking	All individuals (aged 16-74)	% of individuals who used internet in the last 3 months	Eurostat - Community survey on ICT usage in Households and by Individuals (I_IUBK)
3c2 – Shopping	Individuals who ordered goods or services online	All individuals (aged 16-74)	% of internet users (last year)	Eurostat - Community survey on ICT usage in Households and by Individuals (I_BLT12)
3c3 – Selling online	Individuals who sold goods or services online	All individuals (aged 16-74)	% of individuals who used internet in the last 3months	Eurostat - Community survey on ICT usage in Households and by Individuals (I_IUSELL)

Table 3-D - DESI Use of Internet dimension (adapted from European Commission, 2020d).

Eurostat is as well the source for all indicators of the use of internet services dimension. Next table attached is the integration of digital technology dimension.

Indicator	Description	Breakdown	Unit	Source
4a1 – Electronic information sharing	Businesses who have in use an ERP (enterprise resource planning) software package to share information between different functional areas (e.g., accounting, planning, production, marketing)	All enterprises (no financial sector, 10+ employees)	% of enterprises	Eurostat - Community survey on ICT usage and eCommerce in Enterprises (E_ERP1)

4a2 – Social media	Businesses using two or more of the following social media: social networks, enterprise's blog or microblog, multimedia content sharing websites, wiki-based knowledge sharing tools. Using social media means that the enterprise has a user profile, an account or a user license depending on the requirements and the type of the social media.	All enterprises (no financial sector, 10+ employees)	% of enterprises	Eurostat - Community survey on ICT usage and eCommerce in Enterprises (E_SM1_GE2)
4a3 – Big data	Enterprises analysing big data from any data source	All enterprises (no financial sector, 10+ employees)	% of enterprises	Eurostat - Community survey on ICT usage and eCommerce in Enterprises (E_BD)
4a4 – Cloud	Businesses purchasing at least one of the following cloud computing services: hosting of the enterprise's database, accounting software applications, CRM software, computing power	All enterprises (no financial sector, 10+ employees)	% of enterprises	Eurostat - Community survey on ICT usage and eCommerce in Enterprises
4b1 – SMEs selling online	SMEs selling online (at least 1% of turnover)	SMEs (no financial sector, 10-249 employees)	% of SMEs	Eurostat - Community survey on ICT usage and eCommerce in Enterprises (E_ESELL)
4b2 – e-Commerce turnover	SMEs total turnover from e-commerce	SMEs (no financial sector, 10-249 employees)	% of turnover	Eurostat - Community survey on ICT usage and eCommerce in Enterprises (E_ETURN)
4b3 – Selling online cross-border	SMEs that carried out electronic sales to other EU countries	SMEs (no financial sector, 10-249 employees)	% of SMEs	Eurostat - Community survey on ICT usage and eCommerce in Enterprises (E_AESEU)

Table 3-E - DESI Integration of digital technology (adapted from European Commission, 2020d) .

Integration of digital technology dimension is as well based on Eurostat statistics. The last one dimension represented in a table form is the digital public services.

Indicator	Description	Breakdown	Unit	Source
5a1 – eGovernment users	Individuals who sent filled forms to public authorities over the internet in the previous 12 months	All individuals (aged 16-74)	% of internet users who, during the previous year, needed to send filled forms to the public administration.	Eurostat - Community survey on ICT usage in Households and by Individuals (IGOV12RT)
5a2 – Pre-filled forms	Amount of data that is pre-filled in public service online forms	Services assessed in the e- government benchmark	Score (0 to 100)	E-government benchmark
5a3 – Online service completion	The share of administrative steps that can be done online for major life events (birth of a child, new residence, etc.)	Services assessed in the e- government benchmark	Score (0 to 100)	E-government benchmark
5a4 – Digital public services for businesses	The indicator broadly reflects the share of public services needed for starting a business and conducting regular business operations that are available online for domestic as well as foreign users. Services provided through a portal receive a higher score, services which provide only information (but must be completed offline) receive a more limited score.	Services assessed in the e- government benchmark	Score (0 to 100)	E-government benchmark
5a5 – Open data	This composite indicator measures to what extent countries have an open data policy in place (including the transposition of the revised PSI Directive), the estimated political, social, and economic impact of open data and the characteristics	Aggregate score	% of maximum score	European data portal

	(functionalities, data availability and usage) of the national data portal.			

Table 3-F - DESI - Digital public services dimension (adapted from European Commission, 2020d).

The sources for digital public services dimension are: Eurostat, e-government benchmark, and European data portal.

3.1.2. DESI index table of weights

In every kind of evaluation, it is important to prioritize the information. That is why in each of indexes, there are the tables of weights, showing the percentage of each dimension, or indicators

The following table was produced to show each sub-indicator percentage, as this information will be needed for the subsequent practical part of thesis.

Below is presented the table of weights for DESI index.

Indicators	Sub-indicators	Weighting %	Total weighting %
Connectivity	Fixed broadband take-up	6.25	25
	Fixed broadband coverage	6.25	
	Mobile broadband	6.25	
	Broadband price index	6.25	
Human Capital	Internet user skills	12.5	25
	Advanced skills and development	12.5	
Use of Internet Services	Internet use	5	15
	Activities online	5	
	Transaction	5	
	Business digitalization	10	20

Integration of digital technology	E-Commerce	10	
Digital public services	E-Government	15	15

Table 3-G - Weighting of indicators DESI index (adapted from Stavytskyy, 2019).

3.1.3. DESI ranking

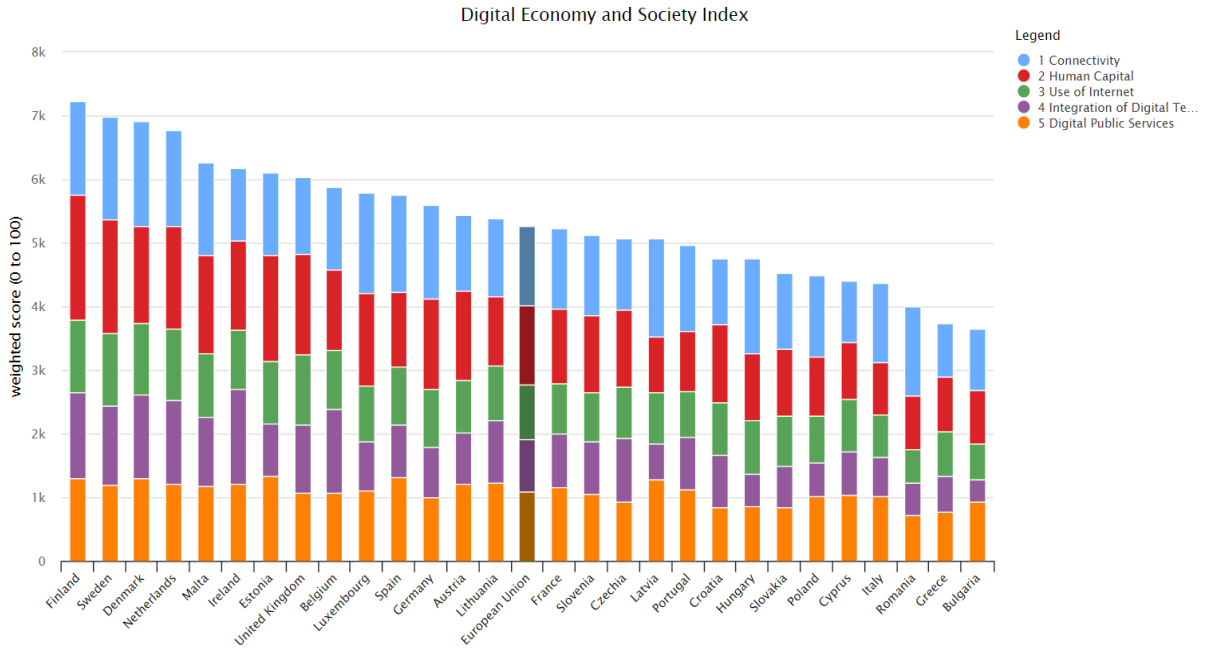


Figure 3.1 - Ranking of countries DESI index (adapted from European Commission, 2020).

From the chart above we can see that in top 5 are: Finland, Sweden, Denmark, Netherlands and Malta. Finland is the first because of highly developed integration of digital technology and human capital system (European Commission, 2019b).

The last in this ranking are the following countries: Cyprus, Italy, Romania, Greece and Bulgaria. The biggest difference for these countries is making the low integration of digital technology dimension, which includes in itself electronic info sharing, big data, cloud, SME selling, e-Commerce turnover internally and cross-border (European Commission, 2020a).

Portugal is on the 19th place of 28 EU Member States in 2020. Over the last years, the rating has grown closely with the EU-average rating (European Commision, 2020a).

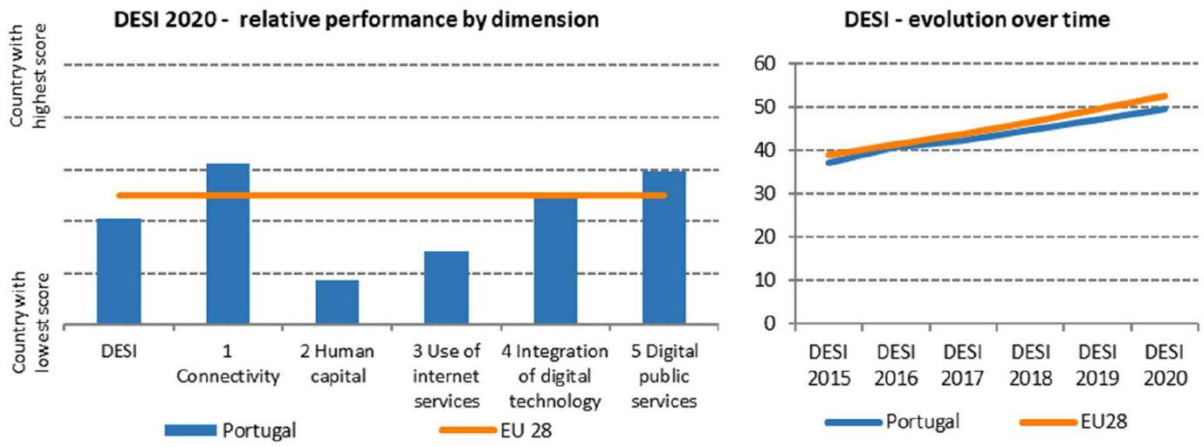


Figure 3.2 - Portugal ranking DESI index (adapted from European Commision, 2020).

By the table above, Portugal is highly developed in connectivity, digital public services and integration of digital technology dimensions. Although, Portugal is still below the EU countries average in overall DESI index. This is resulted from low results in human capital and use of internet services dimension.

On the right part of the table, we can see the continuous development in DESI in period of 2015 to 2020. This strongly positive evolution shows the interest of authorities in digital improvement of Portugal.

3.2. Digitalization Index (DiGiX)

The DiGiX Digitalization index is created by BBVA company (Banco Bilbao Vizcaya Argentina). BBVA is a multinational financial services company situated in Spain, Bilbao. It is considered as one of the largest financial institutions of the world (BBVA, 2020).

Citing the quote from the BBVA main web page*: "As our purpose says, we work to bring the age of opportunity to everyone. And today, many of these opportunities lay in the digital world. Here's where we navigate, to share with you the best stories of our trip."*

DiGiX index was chosen from this company as it *"evaluates the behaviour of institutions and agents and factors that help the community to use the information and communication technology to increase the competitiveness"* (Cámara & Tuesta, 2017).

Also, it is a complex index which analyse 100 countries. Six main components of the DiGiX index are adoption of households and enterprises, costs, regulations, infrastructure and maintenance (Kravchenko et al., 2019).

Figure 3.3 summarizes the structure of the DiGiX index.

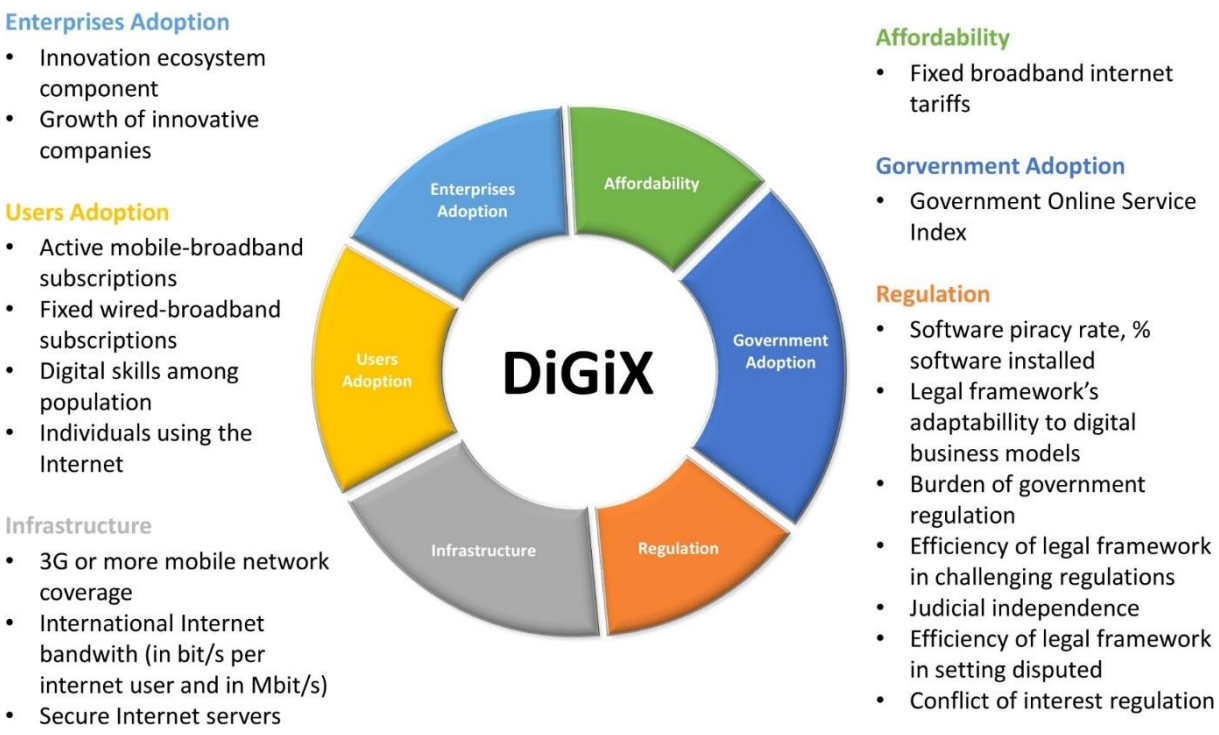


Figure 3.3 - DIGIX index components (adapted from Cámara & Tuesta, 2017)

Following is presented the list of DiGiX indicators:

Affordability

- Fixed broadband internet tariffs
- Internet and telephony competition (Kuzina et al., 2020)

Government Adoption

- Government Online Service Index

Regulation

- Effectiveness of law-making bodies
- Judicial independence
- Efficiency of legal system in settling disputes
- Efficiency of legal system in challenging regulations
- Laws regarding to ICT´s
- Software privacy rate and percentage of software installed (Kuzina et al., 2020)

Infrastructure

- 3G or more mobile network coverage
- International internet bandwidth

- Secure Internet servers

Enterprises Adoption

- Business-to-Business Internet Use
- Business-to-Consumer Internet Use
- Firm-level technology adaptation

Users Adoption

- Active mobile broadband subscriptions
- Fixed (wired) broadband subscriptions
- Use of virtual social networks
- Households with Internet
- Individuals using the Internet (BBVA, 2020)

3.2.1. Methodology of the DiGiX index

For evaluation of DiGiX index there exists the latent variable: parameters and relevant variables. It is applied the two-staged components methodology to have the indexing strategy correct. Dataset is composed by the causal variables. The estimation is going by the evaluation the sub-indexes as for methodological purposes, sub-indexes have inter-correlated indicators, it is estimated the sub-indices first, rather than estimating the overall index directly by picking all the indicators at the same time (BBVA, 2020).

The table shows the variance by each indicator from dimension:

Explained Variance	Percentage
Infrastructure	47%
Costs	58%
Regulation	80%
User's adoption	90%
Enterprises' adoption	100%
BBVA-DIGIX	64%

Table 3-H - DiGiX variance by indicator (adapted from Cámara & Tuesta, 2017)

The latent variable is calculated by the formula:

$$DiGiX_i = \beta_1 * I_i + \beta_2 * UA_i + \beta_3 * EA_i + \beta_4 * C_i + \beta_5 * R_i + \beta_6 * Co_i + \varepsilon_i$$

- *i* denotes the country
- error (ε_i)
- The importance of each dimension is: $\beta_j = \frac{\sum_{j=1} \lambda_j \phi_{jk}}{\sum_{j=1} \lambda_j}$
- λ_j represents the variance
- *j* principal component (weights)
- *k* the number of variables

3.2.2. DiGiX table of the weights

As it is very to interpret the importance of each sub-indicators, the table of weights for DiGiX index is shown below. This table shows the total weighting in percentage of the indicators as well as each weight of the sub-indicators of DiGiX index.

Indicators	Sub-indicators	Weight %	Total weight %
Infrastructure	3G or more mobile network coverage	6	18
	International internet bandwidth	6	
	Secure Internet servers	6	
Government Adoption	Government Online Service Index	17	17
Affordability	Fixed broadband internet tariffs	4.5	9
	Internet and telephony competition	4.5	
Regulation	Effectiveness of law-making bodies	3	18
	Judicial independence	3	
	Efficiency of legal system in settling disputes	3	
	Efficiency of legal system in challenging regulations	3	
	Laws regarding to ICT´s	3	
	Software privacy rate and percentage of software installed	3	

Enterprises Adoption	Business-to-Business Internet Use	6.33	19
	Business-to-Consumer Internet Use	6.33	
	Firm-level technology adaptation	6.34	
Users Adoption	Active mobile broadband subscriptions	3.8	19
	Fixed (wired) broadband subscriptions	3.8	
	Use of virtual social networks	3.8	
	Households with Internet	3.8	
	Individuals using the Internet	3.8	

Table 3-I - DiGiX table of the weights (adapted from Cámara & Tuesta, 2017).

3.2.3. DiGiX ranking

Below it is placed the DiGiX ranking map. This map is taken from the official BBVA Internet page (Cabirta, 2019).

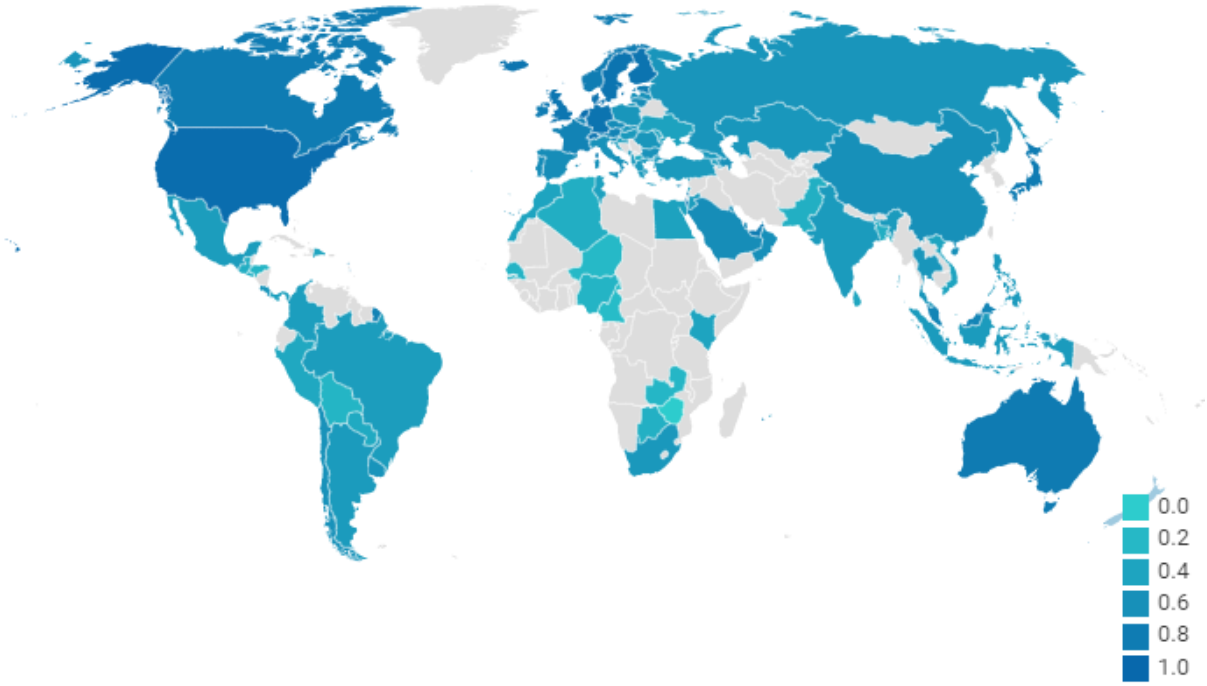


Figure 3.4 - DIGIX ranking map (adapted from Cabirta, 2019).

The coloured areas show which countries of the world the DiGiX is applied. In the top five of DiGiX results are Luxembourg, USA, Netherlands, Singapore and Hong Kong. The

following countries have the lowest result of digitalization score: Zimbabwe, Cameroon, Niger, Zambia, Bolivia. Portugal is taking the 30th place, with score 0.64 from 0 to 1.

Figure 3.5 - Portugal ranking in DIGIX index (Cabirta, 2019).

3.3. ICT Development Index (IDI)

The ICT Development Index (IDI) is a composite index that has been reported, since 2009, by the International Telecommunication Union (ITU) in its "Measuring the Information Society Report" (MISR). The index is intended to measure the progress of each country towards the information society, respectively it is as a tool able to describe the current state of development of the ICT sector. IDI framework includes 3 dimensions which represent the combination of factors needed for each country in the process of transforming into / becoming an information or knowledge-based society: the availability of ICT structure and access, the level of ICT usage, and the capability to use ICTs effectively. Thus, IDI has 3 sub-indexes and 11 indicators. The "ICT access" sub-index includes 5 infrastructure and access indicators, the "ICT use" sub-index comprises 3 intensity and usage indicators, and the "ICT skills" sub-index includes 3 proxy indicators showing relevant skills for ICTs. Each IDI sub-index is calculated as a simple average of its indicators (ITU, 2017).

The list and description of the ICT indicators is as follows:

ICT access

- International Internet bandwidth (bit/s) per internet user

  It is the total used Internet bandwidth capacity, calculated in megabits, taking to consideration average of incoming and outgoing internet traffic (Preda et al., 2019).

- Percentage of household with computer

  Computers are desktop, tablet, laptops and other similar. Telephone devices as smartphones and mobile phones, smart TVs are not included. Computer of the

household is not necessary belongs to the owner but is considered as an asset of the household.

- Percentage of households with Internet access

  This index includes in itself the availability of Internet for all members of the households at any time.

  1. Population covered by at least 3G mobile networks
  2. Fixed-broadband subscriptions by speed tiers, equal to or above 10 Mbit/s (Preda et al., 2019)

ICT use

- Percentage of individuals using the Internet

  Individuals who used Internet in the last three months by any device. This is still not very developed indicator, as data is taken from the national statistic offices and some developing countries do not conduct this statistic.

- Active mobile-broadband subscriptions per 100 inhabitants

  It is a sum of dedicated (USB modems or dongles) and standard (with access to Internet via HTTP) mobile subscriptions, used on computer or handset devices.

  1. Mobile-broadband Internet traffic (per mobile-broadband subscription)
  2. Fixed-broadband Internet traffic (per fixed-broadband subscription)
  3. Mobile phone ownership (Preda et al., 2019)

ICT skills

- Mean years of schooling
- Secondary gross enrolment ratio

  This ratio is explaining the enrolment to certain education level, regardless of the age. It is calculated as a percentage of school-age population to the actual level of education.

- Tertiary gross enrolment (Preda et al., 2019)

3.3.1. Methodology of the ICT Development index

There are five steps in methodology of ICT index calculation: imputation of missing data, normalization of data, weighting and aggregation, calculating the IDI and sensitivity analysis.

There are various techniques to calculate the missing data. Mostly it is used the hot-deck imputation to impute the missing data. The similar characteristics for the hot-deck imputation are Gross National Income per capita and the geographic location. For example, if there is a

sub-index of fixed Internet missing for country A and there is a data for country B, and their Gross National Income is similar, we can suppose that fixed Internet value of country A will be similar to country B (ITU, 2019).

Normalization of data is needed because the unit of measurement should be the same for all sub-indexes, otherwise it will not be possible to align the data. Normalization procedure can allow to check the countered progress over the time. The distance to the reference measure is a chosen method of normalization (ITU, 2019). Reference measure is a goalpost, or the perfect measure. It is value of 100 except the following indicators:

- International Internet bandwidth per Internet user: data is converted into the logarithmic scale and the goal point is a cut-off value, calculated as the mean of values with two standard deviations.
- Fixed broadband subscriptions per 100 inhabitants: the perfect value is between sixty and one hundred inhabitants.
- Mobile-cellular subscriptions per 100 inhabitants: the ideal score is 120.
- Fixed-broadband subscriptions per 100 inhabitants: 60 to 100 is a perfect value.
- Mean years of schooling: 15.

When the normalization process is finished, then the sub-indexes are rescaled from 1 to 10 (ITU, 2019).

3.3.2. ICT Development index table of weights

To set up the correct evaluation, it is necessary to have the table of weights of indicators.

The table below shows the weights of each of indicators and sub-indicators of ICT Development index.

Indicators	Sub-indicators	Weighting %	Total weighting %
ICT access	International Internet bandwidth per internet user	8	40
	Percentage of household with computer	8	
	Percentage of households with Internet access	8	
	Population covered by at least 3G mobile networks	8	
	Fixed-broadband subscriptions by speed tiers	8	
ICT use	Percentage of individuals using the Internet	8	40
	Active mobile-broadband subscriptions per 100 inhabitants	8	
	Mobile-broadband Internet traffic	8	
	Fixed-broadband Internet traffic	8	
	Mobile phone ownership	8	
ICT skills	Mean years of schooling	6.7	20
	Secondary gross enrolment ratio	6.7	
	Tertiary gross enrolment	6.7	

Table 3-J - ICT Development Index. Table of Weights (adapted from ITU, 2011).

The last part of evaluation is the sensitivity analysis. It is made for eliminating the uncertainty of variables.

3.3.3. ICT Development index ranking

The IDI index was last time mentioned in the Measuring the Information Society Report 2017 (ITU, 2017). On 14th of September 2020 International Telecommunication Union introduced the new proposal for ICT Development index to improve the measurement methods. Since the proposal was done recently, the results of ranking are still not available (ITU, 2020).

In the table below you can see the ranking of countries for ICT development index for 2017.

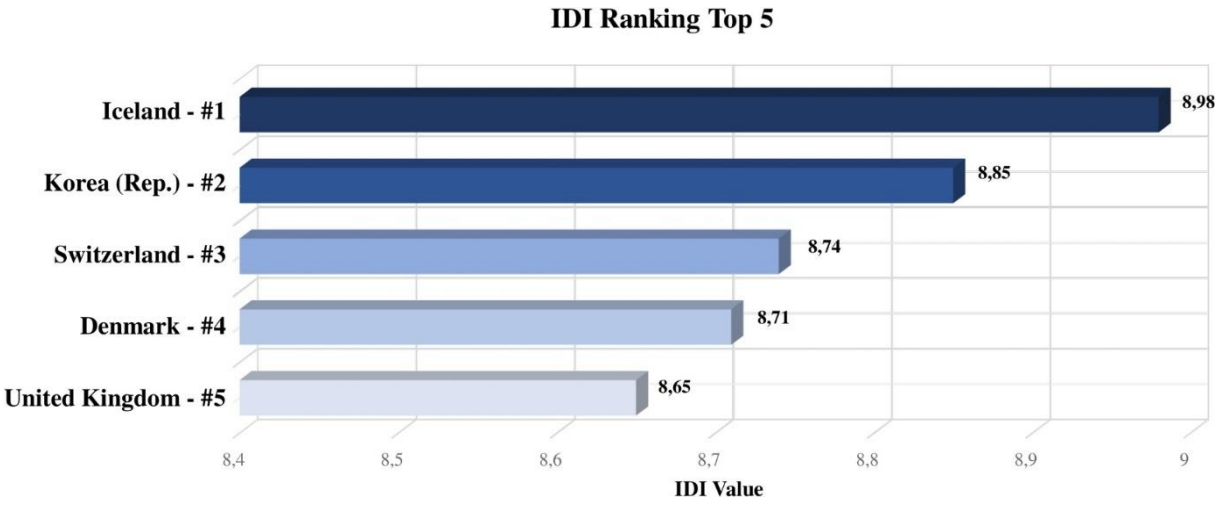


Figure 3.6 - Top 5 of ICT development index (adapted from ITU, 2017).

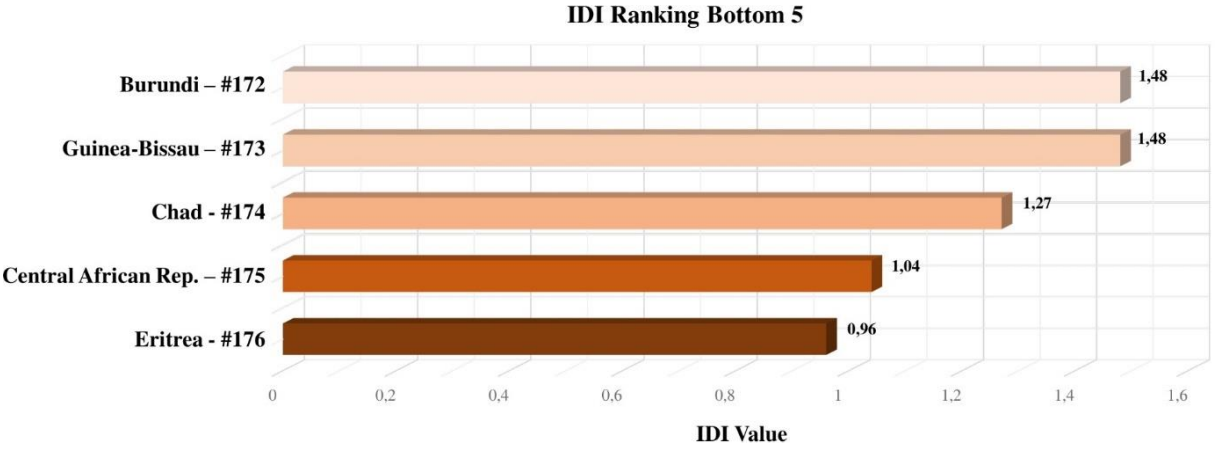


Figure 3.7 - 5 Last positions in ICT development ranking (adapted from ITU, 2017).

By the tables above, we can conclude that ICT Development is very high in Europe and Asia and very low in African region. Iceland is 89% more digital developed than Eritrea.

Portugal is taking the 44th place in ICT development ranking with IDI Value score 7.13 (ITU, 2017).

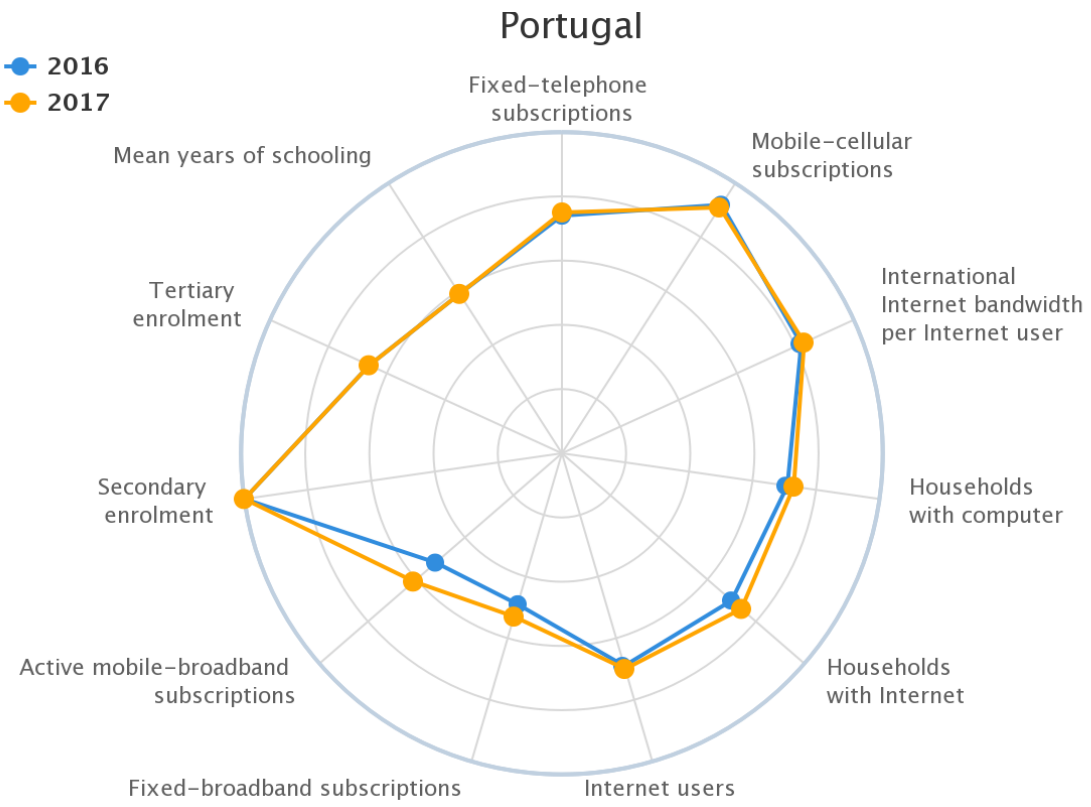


Figure 3.8 – Characterization of Portugal by IDI (adapted from ITU, 2017).

Figure 3.8 shows the proportion of the indicators.

As was mentioned above, the latest data available for now is dated year 2017. From this image, Portugal is having the highest level of the secondary enrolment from the all indicators. Blue line is the year 2016 and orange line is year 2017. As well, on good high level are: mobile-cellular subscriptions, international Internet bandwidth per Internet user, households with internet and computer, internet users and fixed-telephone subscriptions. The indicators to improve are: mean years of schooling, tertiary enrolment, active mobile and fixed broadband subscriptions (ITU, 2017).

By the dynamics of these two years, it can be concluded that Portugal increased the digitalization by the level of active mobile-broadband subscriptions, level of fixed broadband subscriptions, households with computer and internet. Other indicators in these years stayed the same.

3.4. Cisco Digital Readiness Index

This index is chosen for consideration as it is made by the multinational technology conglomerate, Cisco. This company provides recent reports and profound studies of digitalization as the main profit for this company is consulting and cybersecurity, as well as selling the hardware.

The information is taken from the Cisco Global Digital Readiness Index 2019 Report. The Global Digital Readiness Index consists of:

- **Basic Needs**

  The true value of technology and infrastructure is delivered through a population's ability to take advantage of it. Without a population's basic needs met, communities are not able to reap the benefits of technology. To measure a population's basic needs, the assessed data are relating to life expectancy, the mortality rate of children under five years of age, and access to basic services such as electricity and safe drinking water (Yoo et al., 2018).

- **Human Capital**

  The ability to utilize and create advanced digital services is determined in part by the digital skills level within the workforce. There are examined four factors to determine the presence of an appropriately skilled labour force that is available to support digital innovation: the total labour force participation rate, adult literacy rate, and the country's education quality and average years of schooling.

- **Ease of Doing Business**

  Human capital skills can only contribute to the economy if people are gainfully employed, so having a thriving business ecosystem is another key determinant of a country's digital readiness. This was measured by examining the ease of doing business within each country, including factors such as: local rule of law, the Ease of Doing Business Index, the Logistics Performance Index (LPI) infrastructure rating, and the time it takes businesses to obtain access to electricity.

- **Business and Government Investment**

  Building digital infrastructure and capabilities requires significant investment on behalf of both government and business. To measure these investments, should be different sources of private and public investment, including foreign direct investment, research and development spending, and investment freedom.

- **Start-Up Environment**

  Start-ups create new innovations that can benefit entire markets and communities. They also demonstrate high levels of agility in terms of their ability to adapt to new market conditions and are often the leading creators of new wealth from digital technologies, and a crucial source of job creation. To assess a country's start-up environment, should be examined factors such as its venture capital availability and investment, new business density, and patent and trademark registrations.(Yoo et al., 2018)

- **Technology Adoption**

  In the technology adoption indicator, it is evaluated the demand for digital products and services. The sub-indicators are: mobile device penetration, internet usage and cloud services, such as cloud service spent and IT forecast data.

- **Technology Infrastructure**

  Technology infrastructure means the infrastructure available to enable the digital activities and conceited consumers. It is measured by the level of mobile and fixed broadband subscriptions, secure internet servers and networking services (Yoo et al., 2018).

3.4.1. Methodology of Cisco Digital Readiness Index

In the methodology of the CISCO company report it is mentioned that they use the company use the holistic method using the sub-indicators, apply to the 141 countries, and have a rating scale of 0 to 25. The datapoints for the Cisco Digital Readiness Index are reputable sources, such as United Nations, World Economic Forum, World Bank, Heritage Foundation, International Monetary Fund, Centre for American Entrepreneurship, International Labour Organization, World Health Organization and World Justice Project (Cisco Systems GmbH, 2018).

The table below (2-L) shows the metrics and sources for evaluating each component of the CISCO index.

Digital readiness components	Definition	Metric	Source
Basic Needs	Basic human needs for a population to thrive	Life Expectancy	UN
		Mortality Rate (Under Age 5)	UNIGME
		Access to basic services	World Health Organization and UNICEF
Business and Government Investment	Private and public investment in innovation and technology	Foreign Direct Investment	IMF
		Research and Development Expenditure	UNESCO
		Investment Freedom	Heritage Foundation
Ease of Doing Business	Basic infrastructure / policies needed to support business continuity	Ease of Doing Business Index	World Bank
		Rule of Law	World Justice Project
		Logistics Performance Index	Transparency International
		(LPI) – Infrastructure Rating	
Human Capital	Skilled labour force available to support digital innovation (build and maintain)	Labour Force Participation Rate	World Bank
		Adult Literacy Rate	UNESCO
		Education Index (Years of School)	UN Development Program
		Harmonized Test Score	World Bank
Start-up Environment	Environment which fosters innovation within a community	New Business Density	World Bank
		Patents Granted and Trademarks Registered	World Intellectual Property Organization
		Venture Capital Investment and Availability	Center for American Entrepreneurship (2017) WEF
Technology Adoption	Demand for digital products / services	Mobile Cellular Penetration	ITU
		Internet Usage	ITU
		Cloud Services (Spend, IT Forecast Data)	Gartner
Technology Infrastructure	The infrastructure available to enable digital activities and connected consumers (IoT, Cloud)	Mobile Broadband Subscriptions	ITU
		Fixed Broadband Subscriptions	ITU
		Secure Internet Servers	Netcraft
		Household Internet Access	ITU

Table 3-K - Metrics and sources of CISCO index (adapted from Cisco Systems GmbH, 2018).

3.4.2. Cisco Digital Readiness table of weights

This table of weights shows the sub-indicators and indicators percentages of Cisco Digital Readiness Index. This information is going to be used to find out the equivalences of indexes in the following chapter.

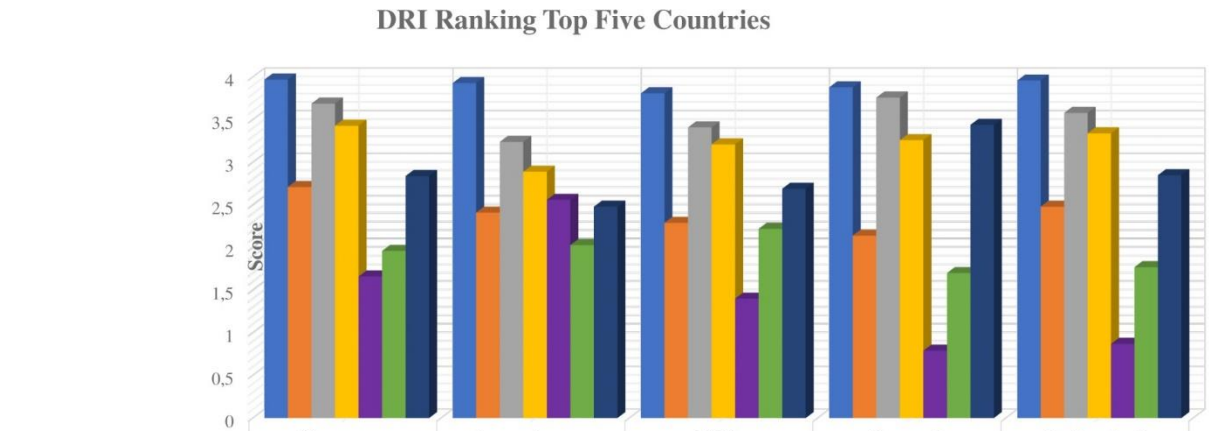
Indicator	Sub-indicators	Sub-indicators value %	Total value %
Basic Needs	Life expectancy	**5.33**	**16**
	Mortality rate under age of 5	**5.33**	
	Access to basic services	**5.34**	
Business and Government investment	Foreign Direct Investment	**4**	**12**
	Research and development expenditure	**4**	
	Investment freedom	**4**	
Ease of doing business	Ease of doing business index	**4**	**16**
	Rule of law	**4**	
	Logistics performance	**4**	
	Infrastructure	**4**	
Human Capital	Labour force participation rate	**5.33**	**16**
	Adult literacy rate	**5.33**	
	Education quality	**5.34**	
Start-Up environment	New business density	**4**	**12**
	Patents and trademark registered	**4**	
	Venture Capital and availability	**4**	
	Mobile cellular penetration	**4**	**12**

Technology adoption	Internet Usage	**4**	
	Cloud services	**4**	
Technology Infrastructure	Mobile broadband subscriptions	**4**	**16**
	Fixed broadband subscriptions	**4**	
	Secure internet servers	**4**	
	Household internet access	**4**	

Table 3-L - Table of weights of CISCO index (adapted from Yoo et al., 2018).

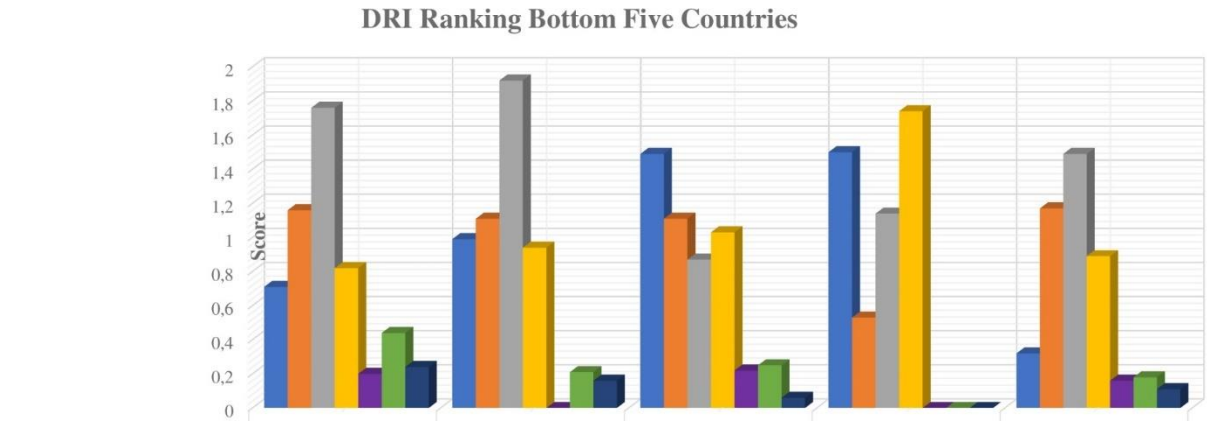
3.4.3. Cisco Digital Readiness ranking

Below is introduced the top five and bottom five results of Cisco Digital Readiness index.



	Singapore	Luxembourg	USA	Denmark	Switzerland
Basic Needs	3,97	3,93	3,81	3,88	3,96
Busin. & Gov. Investment	2,71	2,41	2,29	2,14	2,48
Ease of Doing Business	3,69	3,24	3,41	3,76	3,58
Human Capital	3,43	2,89	3,21	3,26	3,34
Start-Up Environment	1,66	2,56	1,4	0,79	0,87
Technology Adoption	1,96	2,03	2,22	1,7	1,77
Technology Infrastructure	2,84	2,48	2,69	3,44	2,85
Overall DRI Score	**20,26**	**19,54**	**19,03**	**18,98**	**18,86**
Ranking Position	#1	#2	#3	#4	#5

Figure 3.9 - Top 5 of Cisco Digital Readiness Index (adapted from CISCO, 2019).



	Sierra Leone	Niger	Liberia	Eritrea	Chad
Basic Needs	0,71	0,99	1,49	1,5	0,32
Busin. & Gov. Investment	1,16	1,11	1,11	0,53	1,17
Ease of Doing Business	1,76	1,92	0,87	1,14	1,49
Human Capital	0,82	0,94	1,03	1,74	0,89
Start-Up Environment	0,2	0	0,22	0	0,16
Technology Adoption	0,44	0,21	0,25	0	0,18
Technology Infrastructure	0,24	0,16	0,06	0	0,11
Overall DRI Score	**5,33**	**5,31**	**5,03**	**4,91**	**4,32**
Ranking Position	#138	#139	#140	#141	#142

Figure 3.10 - Negative 5 of Cisco Digital Readiness Index (adapted from CISCO, 2019).

Singapore is known as the country with the highest quality of life and in the CISCO analysis, it is taking the first place by the level of basic needs, ease of doing business and human capital. Slightly below Singapore, Luxembourg. USA, Denmark and Switzerland show with the win formula of high results in ease of doing business, basic needs, human capital and technology infrastructure.

The bottom five in Cisco Readiness Index are: Sierra Leone, Niger, Liberia, Eritrea and Chad. Sierra Leone has a poor development of start-up environment and technology adoption and infrastructure. Niger shows as no opportunity for start-up environment. Liberia has very badly resulted in infrastructure. Eritrea seems like completely closed country with no technology adoption and infrastructure. Chad is taking the last place due to the lowest result of all indicators sum.

Portugal is taking the 32nd place in the ranking and the speed of level increase is high.

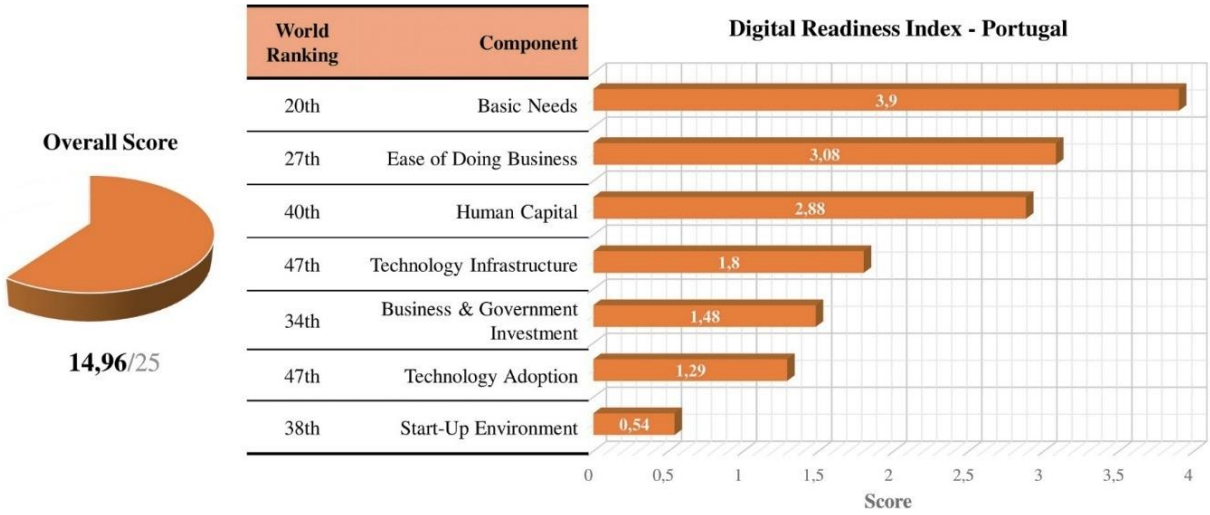


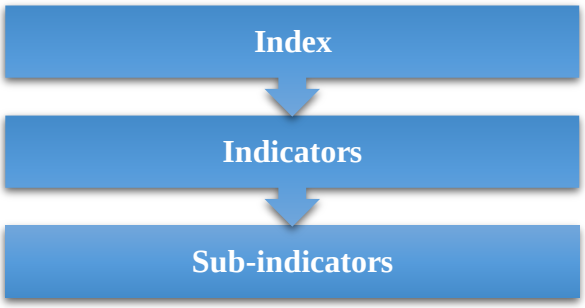
Figure 3.11 - Portugal ranking of CISCO index (adapted from CISCO, 2019).

In the table above, taking from the Cisco official web-site, we can analyse in which indicators Portugal is having success and which ones are still to improve. By the CISCO company study, Portugal is having a high-profile in basic needs achievement, ease of doing business and human capital. Medium results are achieved for the business and government investment and technology infrastructure. Lower results in digitalization are in technology adoption field and start-up environment.

4. Analysis of Results and Conclusions

This chapter presents the research about how the indexes are equivalent to each other and identifies the most common indicators.

Each index consists of indicators, and contained on each indicator there is one or more sub-indicators, as depicted in the model below.



To make the comparison as accurate as possible, the sub-indicators of the proposed four indexes were compared and taken into account each ones' percentage weights. This information was taken from the previous chapter, in the methodology description, from the tables of weights. These values are needed not only to understand more precisely the equivalence between indexes, but also for defining key sub-indicators, which have higher value to consider.

4.1. Sub-indicators equivalence

Sub-indicator	DESI	%	DIGIX	%	ICT	%	CISCO	%
A	Broadband price	6.25	Fixed broadband tariffs	4.5				
B	Mobile broadband	6.25	3G or more mobile network coverage	6	Population covered by at least 3G mobile networks	8		

C	Internet use	5	Individuals using the Internet	3.8	Percentage of individuals using the Internet	8	Internet usage	4
D	Internet user skills	12.5			Mean years of schooling	6.7	Average years of schooling	5.33
					Secondary gross enrolment ratio	6.7		
					Tertiary gross enrolment	6.6	The education quality	5.34
E	Advanced skills and development (ICT graduate specialists)	12.5						
F	Activities online	5	Use of virtual social networks	3.8				
G	Transaction (banking, shopping)	5	Business to Consumer use	6.33				
H	Business digitalization (electronic info sharing, big data, cloud)	10	Firm level technology adaptation	6.33			Networking services. The Ease of Doing Business index Logistics performance Cloud services New business density	20
I	E-Commerce	10	Business to Business Consumer use	6.33			Investment freedom	4
							Venture capital availability	4
J	E-Government	15	Government online service Index	20			Research and development spending	4

			Effectiveness of law-making bodies				Private and public investment	4
K	Fixed broadband take-up	6.25	Fixed(wired) broadband subscription	3.8	Fixed broadband subscriptions by speed	8	Level of fixed broadband subscriptions	4
L			Internet and telephony competition	4.5	Mobile phone ownership	8	Mobile device penetration	4
M			Households with Internet	3.8	Percentage of households with Internet	8	Household internet access	4
N			Judicial independence	3				
O			Efficiency of legal system in settling the disputes and regulations	6				
P			Laws regarding ICT	3			Local rule of law	4
Q			International Internet bandwidth	6	International Internet bandwidth	8		
R			Software privacy rate and percentage of software installed	3			Patent and trademark registrations	4
S			Secure Internet servers	6			Secure Internet servers	4
T	Mobile broadband	6.25	Active mobile broadband subscriptions	3.8	Active mobile-broadband subscriptions per 100 inhabitants	8	Level of mobile subscriptions	4
U					Mobile and fixed internet traffic	16		
V					Percentage of household with computer	8		

W							Life expectancy	5.33
X							Mortality rate	5.33
Y							Access to basic services	5.34
Z							The total labour participation rate	5.33

Table 4-A - Equivalence of indicators.

As we can see about some of indexes have a lot of matching sub-indicators by their content. By the comparison above we can define that the most common evaluators, such as: mobile broadband coverage with at least 3G connection, fixed and mobile broadband subscriptions, internet user skills, level of business digitalization in the technology adoption, cloud database, and logistics, e-commerce availability, e-government and research and development spending.

Then the sub-indicators differ. Firstly, the difference is between the organizations who has created the index. Public organizations indexes, such as DESI and ICT development differ in evaluating society advanced skills, online banking, mobile and fixed internet traffic. Private companies' indexes, such as DiGiX and CISCO, differ in evaluating the indicators, like use of social networks, judicial independence, efficiency of legal system in settling disputes and challenging regulations, patents and trademark registrations and secure Internet servers.

After making the comparison of the sub-indicators by their content, next important step to find out the equivalence should be taken - to define the weights.

In the table above, there are the corresponding letters to each sub-indicator which match. It is added this column to compress the information and have better visibility in the following tables. Although, the sub-indicators match by their content, they have different weights for the own index.

Let us see the example of matching sub-indicators in the row A.

	DESI	%	DIGIX	%	ICT development	%	CISCO	%
A	Broadband price	6.25	Fixed broadband tariffs	4.5				

Table 4-B - Matching sub-indicators example.

For DESI index, broadband price index value 6.25% of the total weight, and for DIGIX index fixed broadband tariffs value 4.5%. The weight of DESI is designated as W1 and the weight of DIGIX as W2. To normalize the equivalence answer we take the average value of these two sub-indicators: $(W1 + W2) / 2$

The average value was chosen as we are not giving the priority to any of indexes and, from my perspective, average is be the best way to show the relation of one index to another.

So, a dual comparison between two indexes and their all-matching sub-indicators was developed. The total sum of the average weights is the equivalence between two indexes.

Below are presented six tables which represent all the dual comparison of the selected indexes and their equivalence value.

4.2. DESI to DiGiX equivalence

Matching Sub-indicator	Weight DESI % W1	Weight DIGIX % W2	Average weight % (Wa) = (W1+W2)/2
A	6.25	4.5	5.38
B	6.25	6	6.13
C	5	3.8	4.40
F	5	3.8	4.40
G	5	6.33	5.67
H	10	6.33	8.17
I	10	6.33	8.17
J	15	20	17.50
K	6.25	3.8	5.03
T	6.25	3.8	5.03
		Total Sum	**69.85**

Table 4-C - Equivalence DESI to DiGiX.

The first comparison had shown that DESI index is equivalent to the DiGiX to the 69.85 percent. The highest equivalence weight was brought by the equivalences of sub-indicators J, H and I. J stands for the E-Government and Government online service index equivalence. H stands for business digitalization in DESI and firm technology adoption in DiGiX.

4.3.DESI to ICT equivalence

Matching Sub-indicator	Weight DESI % W1	Weight ICT % W3	Average weight % (Wa) = (W1+W3)/2
B	6.25	8	7.13
C	5	8	6.50
D	12.5	20	16.25
K	6.25	8	7.13
T	6.25	8	7.13
		Total Sum	**44.13 %**

Table 4-D - Equivalence DESI to ICT.

DESI is equivalent to ICT by 44.13 percent. The highest weight of this comparison belongs to line D, with 16.25 percent internet user skills in DESI are equivalent to the mean years of schooling, tertiary and secondary gross enrolment ratio in ICT.

4.4. DESI to CISCO equivalence

Matching Sub-indicator	Weight DESI W1	Weight CISCO W4	Average weight % (Wa) = (W1+W3)/2
C	5	4	4.5
D	12.5	10.67	11.59
H	10	20	15
I	10	8	9

J	15	8	11.5
K	6.25	4	5.13
T	6.25	4	5.13
		Total Sum	**61.85 %**

Table 4-E - Equivalence DESI to CISCO

CISCO is equivalent to DESI index by 61.85 percent. Lines H and D have the highest weight: networking services, cloud, logistics performance and the ease of doing business in CISCO to the electronic info sharing, cloud and big data in DESI; and average years of schooling and education quality in CISCO to the internet user skills in DESI.

4.5. DiGiX to ICT equivalence

Matching Sub-indicator	Weight DIGIX W2	Weight ICT W3	Average weight % (Wa) = (W1+W3)/2
B	6	8	7
C	3.8	8	5.9
K	3.8	8	5.9
L	4.5	8	6.25
M	3.8	8	5.9
Q	6	8	7
T	3.8	8	5.9
		Total Sum	**43.85 %**

Table 4-F - Equivalence DIGIX to ICT.

DiGiX is equivalent to ICT index by 43.85 percent. Most weighted are sub-indicators B and L: 3G coverage in both DiGiX and ICT and telephony competition in DiGiX to the mobile phone ownership in ICT.

4.6. DiGiX to CISCO equivalence

Matching Sub-indicator	Weight DIGIX W2	Weight CISCO W4	Average weight (Wa) = (W1+W3)/2
C	3.8	4	3.9
H	6.33	20	13.17
I	6.33	8	7.16
J	20	8	14
K	3.8	4	3.9
L	4.5	4	4.25
M	3.8	4	3.9
P	3	4	3.5
R	3	4	3.5
S	6	4	5
T	3.8	4	3.9
		Total Sum	**66.19 %**

Table 4-G - Equivalence DIGIX to CISCO.

DiGiX is equivalent to CISCO by 66.19 percent. Sub-indicator H has brought the biggest value in comparison: firm level technology adaptation in DiGiX to the ease of doing business, new business density, cloud and networking services in CISCO. Its weight is 13.17 percent from 66.19 percent.

4.7. ICT to CISCO equivalence

Matching Sub-indicator	Weight ICT W3	Weight CISCO W4	Average weight % (Wa) = (W1+W3)/2
C	8	4	6
D	13.3	10.67	11.99
K	8	4	6

L	8	4	6
M	8	4	6
T	8	4	6
		Total Sum	**41.99 %**

Table 4-H - Equivalence ICT to CISCO.

ICT is equivalent to CISCO to the 41.99 percent. Matching sub-indicator D weights 11.99 percent from 41.99 percent total. It means that the highest value gave a match of education quality, average year of schooling and enrolment ratios in both ICT and CISCO indexes.

4.8. Overall index equivalence

These are the result table of all the equivalences between indexes.

	DESI	**DIGIX**	**ICT**
DIGIX	69.85%		
ICT	44.13%	43.85%	
CISCO	61.85%	66.19%	41.99%

Table 4-I - Results of overall index equivalence.

The highest equivalence is between the DESI and DIGIX index, 69.85%, which means that the indicators of these indexes not only are very similar by the context and data, but also by their weights.

High equivalence is also between DIGIX and CISCO indexes, 66.19%. It might be the reason that indexes are more equivalent, because they are created by the private companies, BBVA and CISCO. With a little difference, DESI is equivalent to CISCO, by the 61.85%.

ICT index shows the least equivalence by the matching indicators to all other indexes. It is equivalent to DESI by the 44.13%, to DIGIX by the 43.85% and to CISCO by the 41.99% (Kravchenko et al., 2019).

4.9. New Index

After analysing the equivalences between the most used digitalization evaluation indexes, it can be concluded which factors have been the most valuable in the index calculation. Another index which combines the data from the public, like DESI and ICT, and private, like CISCO and DIGIX indexes is here introduced.

The indicators and sub-indicators weights are based on the average weight of similar matching indicators from the compared indexes.

The proposed index has the following indicators:

- **Connection** - this indicator is displaying network coverage, broadband, and speeds.
- **Government regulation** – includes the government online and privacy and ICT goals.
- **Business integration** – e-commerce and possibility to conduct the business easily.
- **Users analysis** – price per broadband, content of use, fixed price per broadband and content of use.

The table with index structure, its sub-indicators and indicators is shown below.

Indicator	Sub-indicator	Weight (%)
Connection	3G or more mobile network coverage	**7**
	Fixed broadband	**6**
	Active mobile broadband subscriptions	**6**
	Maximum speed coverage	**7**
Government regulation	Government online	**15**
	Laws regarding ICT	**3**
	Privacy rate	**3**
Business integration	E-commerce	**10**
	Ease of doing business	**15**
Users analysis	Internet usage	**5**

	Content of use	**10**
	Fixed price per broadband	**5**
	Cloud service availability	**8**

Table 4-J – Proposed Index sub-indicators and weights.

Firstly, the reason of chosen sub-indicators is that they are the equivalent in the compared above four indicators.

The weight of sub-indicators is calculated as the average from the equivalent indexes and by settling priorities.

Let us see the example of users' analysis indicator, sub-indicator Internet usage:

Sub-indicator	DESI	%	DIGIX	%	ICT	%	CISCO	%
C	Internet use	5	Individuals using the Internet	3.8	Percentage of individuals using the Internet	8	Internet usage	4

The average of the internet usage of four indexes is *(5+3.8+8+4)/4=5.2*. By rounding up, internet usage in the new index is weighted as 5%.

That was an example of weighting by the average. But, of course, to have accurate results, it would not be possible to assume average, as not all indicators can be equivalent, and the new index does not contain some of old sub-indicators.

In the new index, it was chosen the following sub-indicators:

- **3G or more mobile network coverage**

  This sub-indicator is important, and equivalent in compared above indexes, as this is the speed, with which the digitalization can be measured. It can be measured by the average data from the country's telecom.

- **Maximum speed coverage**

  This is a new added sub-indicator. Maximum speed analysis can show how much the country is ready for conducting the operations and business which requires high processed information is a very short time, like autonomous vehicles, remote surgeries control, IoT management of traffic, industrial automation, drones' control and virtual reality.

- **Active mobile broadband subscriptions**

  This data shows how many active mobile users the country has.
- **Fixed broadband**

  In fixed broadband it is calculated the overall take-up of fixed broadband.
- **Government online**

  Government online is an extremely important factor in the digitalization development. It allows people to fill forms for government authorities online, provide liquidity of tax information, use Internet as a tool of government communication, prevent from important government information losses.
- **Laws regarding ICT's**

  ICT Laws analysis should be as a fast government response to any cybercrimes. The quantity of government regulation and laws can show how much each country's users are protected online.
- **Privacy rate**

  As digitalization emerged, privacy became vulnerable. This rate can show many trademarks are registered and patents are granted.
- **E-Commerce**

  In the current pandemic times, e-commerce was an only way for businesses to survive. E-commerce takes huge advantage from the digitalization, and this sub-indicator should necessary be present in new index.
- **Ease of doing business**

  This sub-indicator is one of key factor for thriving of business. This data can open a lot of opportunities for people starting and conducting any business activity. It combines the local laws and logistics performance of business.
- **Internet usage**

  Internet usage data can clearly describe the demand of adoption of technology and digital products and services.
- **Content of use**

  Data is getting the most precious item to sell. Content of use can not only show the level of digitalization but also much more important statistics in a global scale.
- **Fixed price per broadband**

  Countries with the most affordable access to fixed broadband are a step further in the digitalization ranking.

- **Cloud service availability**

  To make a well digital functioning of a country it is necessary to have a protected storage of data. Cloud availability level is showing the limits and opportunities for digitalization.

4.10. Conclusions

Digitalization process is the biggest informational evolution we are facing nowadays. It has touched almost every sphere of the life. Since the humanity started to implement the tasks by use of machines as sources of communication, predominantly Internet, the world has changed. There is a new path for development for exchanging goods and services and soon we can face a so-called Fourth Industrial Revolution (Stremousova & Buchinskaia, 2019).

Digitalization is a process of converting analogue data into digital data sets, knowledge stored in 0's and 1's which drives for changes in corporate world, establish new technologies and restructure economies and society at a system level.

Digitalization is directly connected to the digital economy. Digital economy is an economic system where ICT is widely spread by base infrastructure, e-business and e-commerce. Digitalization makes the transformation of information storage, sharing and processing from anywhere in the world. By the UNSTAD statistics, the size of digital economy is in the range of 4.5 to 15.5% of the world Gross Domestic Product (Jensen et al., 2016). It is expected that 24 percent of world GDP will be provided from AI and cloud computing.

Any organization or company can be digitalized. The prognosis for the digital evolution is optimistic. By the Westermann and Bonnet companies should define the "What" and the "How". "What" concept is to create a new model of business, where digitalization can be applied and "How" is to implement this process using sources. To make a new business model, industry leaders, executive and supervisory board should be sufficient expertise to advise on technology topics and cybersecurity and recruit best talents with digital skills (Westerman et al., 2014).

Business structure should be adjusted for going digital. Many challenges can appear, such as losing control over the customer, increased competitiveness, new ways of communication with customers, suppliers, employees. The business should have models with end-to-end response. Firstly, supply should be under network optimization. Second, manufacturer should apply digitalization to predictive maintenance. After, the logistics department can demand

forecasting and make operation planning. Next, distribution can use telematics. In the end of every business is the customer. From customers point of view company might use digitalization to for aftermarket insights and warranty optimization.

To measure the country digitalization level, it is useful to have an index of evaluation. Nowadays, there is no standardized methods to make this analysis, so the most acknowledged indexes of digital evaluation have been here investigated: DESI, DIGIX, ICT Development Index and CISCO Networking Index.

DESI index was created in 2014 by the European Union and it covers 28 EU Members. The indicators of the index are: connectivity, human capital, digital public service, use of internet, integration of digital technology and digital public services. Connectivity consists of fixed broadband take-up and coverage mobile broadband and broadband price index. Human capital includes internet user skills and development. Use of internet dimension is level of internet use, activities online and transactions. Integration of digital technology is business digitalization and e-commerce. Digital public service is the e-government (European Commission, 2020b).

DIGIX index was created in 2015 by BBVA company. This index covers 100 countries. The components of DIGIX are: affordability, government adoption, regulation, infrastructure, enterprises adoption and user's adoption. Affordability is broadband tariffs and internet and telephony competition. Government adoption is the online government service index. Regulation is the judicial independence, effectiveness of law-making bodies, efficiency of legal system, privacy rate. Infrastructure is internet bandwidth, 3G mobile coverage and secure servers. Enterprise's adoption is firm technology adaptation and B2B and B2C internet use. Users Adoption is the number of households with internet, use of social networks and internet subscriptions (BBVA, 2020b).

ICT Development Index was created in 2009 by the International Telecommunication Union and analyses 180 countries. It consists of three indicators: ICT access, ICT use and ICT skills. ICT access is internet bandwidth, percentage of households with Internet access and computer, fixed-broadband subscriptions and population covered by at least 3G mobile networks. ICT use is number of individuals using the Internet, mobile and fixed traffic and mobile phone ownership. ICT skills is mean years of schooling, tertiary enrolment and secondary gross enrolment ratio (ITU, 2011).

Cisco Digital Readiness Index emerged in 2016 by the CISCO company. It covers 141 countries. The components of CISCO digital index are: basic needs, business and government investment, human capital, ease of doing business, technology adoption, start-up environment, technology infrastructure. Basic needs cover up life expectancy level, access to basic services

and mortality rate. Business and Government investment combines investment freedom, research and development expenditure and foreign direct investment. Human capital is a skilled labour force available to support, build and maintain the digital innovation. Start-up environment is venture capital investment and availability, new business density, and patents and trademarks registrations. Technology adoption is a level of internet usage, cloud services and mobile phones ownership. Infrastructure includes fixed and mobile broadband subscriptions, internet access and secure internet servers (Cisco Systems GmbH, 2018).

By the results of indexes comparison, it is concluded the following equivalences: DESI to DiGiX is equivalent by 69.85%; DESI to ICT by 44.15%: DESI to CISCO by the 61.85%; DiGiX to ICT 43.85%, DiGiX to CISCO by 66.19 %, ICT to CISCO by 41.99%. The equivalences are not very strong and these discrepancies in evaluation might be caused by different approaches from public and private companies.

Based on the mentioned figure 4-I it is introduced the new index. The new index has four indicators in it: connection, government regulation, business integration and user analysis. Connection indicator includes 3G or more mobile network coverage, fixed broadband, mobile broadband and maximum speed sub indicators. Government regulation contains such sub-indicators: government online, laws regarding ICTs, and privacy rate. Business integration is e-commerce and ease of doing business. User analysis indicator has in its internet usage, content of use, fixed price per broadband, and cloud service availability.

5. Contributions, Limitations and Future Research

5.1. Contributions

Starting with a literature review, this thesis presents a pragmatic analysis of the four most acknowledged indexes: DESI, DiGiX, IDI and Cisco Index. Their structure and methodology is investigated in order to make a detailed comparison.

In was also proposed an effective approach for measurement of digitalization, which relies on measurable data and can be applied to perform the digital evaluation of any country. By using the proposed index, we can analyse, explain and predict the level of digitalization and gaps to be improved.

The principal contributions of thesis are:

- Development of summary tables and figures regarding the structure and methodology of the selected indexes.
- Proposal of an index evaluation and comparison method, using their evaluation components and respective weights.
- Evaluation of the indexes' equivalences, resulting in the production of a comparison matrix of the selected digital evaluation indexes.
- Proposal of a new index using the most significant evaluation dimensions.

5.2. Limitations

An important limitation was regarding the available literature to develop this thesis. The main source of research papers was the B-On platform (www.b-on.pt). This website allows to find most recent and relevant articles with the advanced search use options. Although the number of articles about digitalization are quite significant, the number of papers regarding DESI, DIGIX, CISCO and ICT index was very limited.

Additional sources needed to be consulted, specifically the international organization sources, like the website of the European Commission (ec.europa.eu) and the International

Telecommunication Union (www.itu.int). There was also the need to consult private companies' websites, such as CISCO company website (www.cisco.com) and BBVA company website (www.bbva.com), were open reports, conference papers and presentations were publicly available.

As well, the thesis is predominantly done in COVID pandemic time, when the libraries are not open to public, and literature search is done by only digitalized literature, which one more time points the importance of being up-to-date to the digitalization topic and this study in particular.

5.3. Future Research

After making this research, it comes up the conclusion how much it is important to standardize the information. New index is a proposed standardized answer, as compared indexes have different geopolitical area research, methodology and structure.

As by the example of DESI, ICT, CISCO and DiGiX indexes, new index should be well structured. First of all, it is important to find the most reliable sources of information for each indicator. Next should be introduced the index measurement formula and units of measurement.

After the data should be normalized using the statistical tools. After that, each of new index indicator and sub-indicator much have the table of weights to prioritize the information.

After all these steps are done, it will be possible to introduce the scope of index coverage and countries ranking. With the ranking done, new index can be introduced to the public.

The idea of new index might be introduced in a specific European Union web-page developed for the discussion of innovative ideas regarding EU policies (futurium.ec.europa.eu).

Future work is also to test the new index with some real data. For example, choosing Portugal as a first country to test, it is necessary to access the following data: 3G or more mobile network and fixed broadband coverage; amount of active mobile subscriptions; maximum speed coverage; government online assess, local laws regarding informational and communication technology, level of privacy rate; e-commerce and ease of doing business factor; level of internet usage and main content of use. After getting the data for Portugal, the next global ranking can be done and proportionally the new ranking can be done.

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