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The Role of 5G Technology in Sustainable Development of Smart Cities

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ABSTRACT

The main goal of this scientific research is to examine the role of new information and communication technologies (ICTs) in the sustainable development of smart cities. Thus, we have used descriptive analysis and critical comparative analysis in order to highlight the impact of the new generation of 5G technologies on the smart development of the main areas that form the structure of a city. The main results of this scientific article have shown that the benefits of integrating 5G technology are decisive for the smart, inclusive and long-term development of a city as a whole, but in order to sustainably benefit from these, it is imperative that cities / states create an efficient implementation framework in terms of technological infrastructure, human capital, innovation, internal regulations and users.

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1. Introduction

Smart and sustainable development is the main goal of major cities globally. This desideratum has become imperative in recent decades due to the fact that increasing urban agglomerations have led to overexploitation of resources, increasing pollution and the need for public services to meet the current social realities.

The optimal solution to respond to the new challenges is the continuous integration of Information and Communication Technologies (ICTs) into the development of public services, so that they can sustain a high quality of life for citizens.

Thus, the main objective of this scientific article is to analyze how the ICTs contribute to the sustainable and long-term development of smart cities.

To accomplish this goal, we will undertake an empirical analysis in which we will try to determine the role of the next generation of 5G technologies in supporting this development and the requirements to be met by each city so that these new technologies produce the expected benefits.

The methodology that we apply is based on descriptive analysis and critical comparative analysis.

In order to be able to develop and organize smart cities and also to manage more efficient the community resources, the policymakers use open data. Most of the data and informations are collected, based on ICT, from different sources (for instance: devices, citizens, assets, and databases)..

Smart cities are centered around people, so understanding the way people interact with the community and infrastructure means better planning and response to critical situations.
Meijer and Rodriguez-Bolivar (2015) said that the main aim of smart city development is sustainability, and ICT is the main instrument to help achieve this goal.

On the other hand, more and more researchers who have analyzed the smart cities development (Bulu, 2014; Vanolo, 2014; Luque-Ayala & Marvin, 2015; Kirwan, 2015; Huston et al, 2015 etc.) highlights the extremely important role of the citizen participation in the processes of creating and implementing smart public services and the need to involve them in social activities, aimed to improve the living standards of their community.

According to Hollands (2014) and Willis & Aurigi (2018), citizens participation can be facilitated by bringing together a range of innovative technologies, infrastructure and methods for data management.

To successfully accomplish the goal of sustainable and smart growth of the cities, it is necessary that strategies and projects undertaken by each city to be in accordance with their own characteristics, in other words, the best practices needs to be adapted and customized according to the local specificity.

For example, Urry (2016) believes that lack of knowledge and awareness of historical developments is, in most cases, the reason why urban and technological development policies and strategies fail.

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Considering these aspects, in the next section we will try to emphasize the role of the latest ICT's for the smart growth of the cities.

2. The importance of 5G technologies for the development of smart cities

5G is the latest generation of mobile Internet that, according to the studies and tests conducted so far, will provide ultra-fast data and will allow a high level of accesibility. Among the most important features of 5G technologies that can contribute decisively to the sustainable development of smart cities are:

- Higher speed and bandwidth, which will allow simultaneous connection of a large number of devices;
- Reduced latency, providing quick response for time-critical applications;
- 5G Infrastructure - 5G aerials will be placed in a large number of locations in order to support the network-connections of all devices;
- Network Grid Enabling - the 5G network can be devided into subnetworks that can be adjusted to support unique apps such as: autonomous vehicles (AV), intelligent metering, public Wi-Fi, the appropriate allocation of utility resources and so on.

Starting in 2018, major telecom companies have begun to deploy 5G communications networks to test how they respond to the increasingly complex requirements and new challenges that arise in the economic and social environment.

Thus, the new 5G technologies are expected to integrate a variety of devices, infrastructure, buildings, products and services and in this way, to provide optimal and sustainable solutions to address urban issues such as: high energy consumption, high CO2 emissions, traffic, health system and so on.

As it can support the analysis of a large amount of data, 5G technologies can support complex strategies and projects through which urban settlements can turn into smart cities, that ensure the development of living standards for urban citizens.

Among the solutions that 5G technologies ca, we mention: public parking system and smart transport, reducing energy consumption and associated costs by using smart public lighting concepts, proper water and waste management, advanced mobile applications through which the devices, autohevicule and autonomous drones can be connected, the development of new software and industrial technologies, and so on.

Also, 5G technologies will provide the opportunity to develop new public services that currently can not be adequately delivered (eg telehealth), and will have a high resilience in critical times (eg, natural disasters).

Table 1 lists some of the most important benefits of using 5G technology to develop the core areas of a city.

Table 1. The main benefits of using 5G technologies in the sustainable development of smart cities

Domain	BENEFITS OF USING 5G TECHNOLOGIES
Energy	- Establishing fast connections between devices to manage energy consumption efficiently, and thereby reduce associated costs; - When a voltage drop occurs, there will be a real-time diagnosis of the causes and immediate solutions will be applied, such as changing the load in another device; - Reduce energy consumption in public space and associated costs by diminishing light intensity when there is no traffic.
Health	- General medical examinations via mobile devices; - Reducing hospitalization rates by remotely monitoring the evolution of patients' health status; - Wider adoption of digital devices for health monitoring.
Transport	- Reducing time spent in traffic; - Easily identify free parking spaces; - Reducing urban agglomeration levels; - Rapid communication between vehicles to report traffic problems.
Retail	- Reducing time and cost associated with shoppings, by purchasing all products and services online; - Retailers will better manage stockpiles of products and establish price strategies by collecting market demand data at a time.
Security	- Through a high-bandwidth, fast and reliable communication can be implemented so that offenses will be avoided or resolved in a timely way; - Ultra HD video remarks will allow authorities to use facial recognition to

Domain	BENEFITS OF USING 5G TECHNOLOGIES
	detect offenders; - Warning systems developed based on 5G sensors will provide real-time information to people about triggering a natural disaster such as fires or floods.
Environment	- Accuracy monitoring the level of air and water pollution by installing high precision sensors at key points of the city; - Increasing the selective recycling rate; - Adopting sustainable strategies against climate change.

Source: author's table

As we have seen in this section, new ICTs have a great capacity to deliver the most advanced and diversified solutions for the sustainable development of smart cities, but in order for them to produce the expected effects it is necessary that each city that implements it to accomplish essential characteristics, both in the period preceding their adoption and afterwards.

Thus, we will continue in the next section to try to identify these characteristics by which we can determine the degree of state preparedness for the sustainable adoption of 5G technologies, with long-term positive effects on the development of smart cities.

3. 5G technology adoption in the European Union

In this part of the article, we will try to determine the degree of European Union (EU) countries preparedness to adopt the new 5G technologies, the factors that contribute to achieving this goal and the causes of disparities between these countries.

InCITIES Consulting S.A.R.L has performed the "Europe 5G Readiness Index" report, through which comparisons can be made regarding the degree of European countries readiness for the implementation of 5G technologies nationwide.

The index consists of 6 criteria: *infrastructure and technology, regulation and policy, innovation, human capital, country profile and demand.*

Table 2 shows the ranking of EU countries according to the index calculated by InCITIES Consulting S.A.R.L.

Table 2. The 5G adoption training index

Rank*	Country**	Infrastructure and technology	Regulation and policy	Innovation	Human capital	Country profile	Demand	TOTAL SCORE
		SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	
1	Finland	63.4	71.7	72.2	78.5	83.4	61.3	71.8
2	Sweden	66.7	69.0	73.2	61.1	83.0	65.7	69.8
4	Netherlands	55.7	73.1	65.7	70.9	83.1	60.5	68.2
5	Denmark	59.3	64.8	65.9	66.8	78.6	71.8	67.8
7	Germany	65.6	67.8	69.1	66.6	81.8	50.3	66.9
8	UK	60.4	72.6	64.2	60.3	81.5	62.0	66.8
10	Luxembourg	56.1	70.1	63.1	49.1	88.3	59.5	64.3
11	France	64.8	59.8	59.0	61.5	80.2	50.9	62.7
12	Ireland	46.5	65.0	59.3	66.9	82.4	55.0	62.5
13	Estonia	51.7	65.4	52.0	62.4	81.7	58.9	62.0
14	Austria	50.3	53.2	62.4	63.9	78.9	60.8	61.6
15	Belgium	43.4	58.4	64.4	66.5	79.3	55.2	61.2
16	Portugal	61.3	48.8	52.7	57.4	80.8	51.8	58.8
17	Spain	65.2	47.2	46.9	57.5	75.9	52.6	57.6
18	Lithuania	52.7	49.9	48.5	55.6	76.1	57.3	56.7
19	Slovenia	47.8	44.5	51.6	59.6	73.0	46.8	53.9
20	Latvia	55.9	44.2	39.7	49.5	67.6	63.0	53.3

Rank*	Country**	Infrastructure and technology	Regulation and policy	Innovation	Human capital	Country profile	Demand	TOTAL SCORE
21	Czech Republic	53.2	43.4	49.3	55.5	71.3	45.5	53.0
23	Italy	61.8	34.9	42.9	55.7	70.3	44.7	51.7
25	Poland	44.8	34.0	41.2	54.7	71.0	53.8	49.9
26	Slovakia	44.3	37.5	46.7	45.1	71.2	48.0	48.8
27	Hungary	42.4	42.7	44.6	43.2	70.3	47.0	48.4
28	Cyprus	41.4	52.2	35.5	53.6	67.9	39.3	48.3
29	Greece	42.5	33.8	36.2	65.4	64.3	42.5	47.4
30	Romania	49.7	39.0	33.8	48.9	69.7	42.7	47.3
31	Croatia	43.4	33.7	33.4	53.5	70.1	43.8	46.3
32	Bulgaria	38.2	35.7	41.7	46.4	68.4	43.2	45.6

** The other countries that complete this ranking are not part of the EU*
*** Malta is not part in this ranking due to data unavailability*
Source: Table made by authors based on the data published by InCITIES Consulting S.A.R.L.

As we can see in Table 2, among the countries that currently part of the European Union, Finland is, in average, the best performer and meets the key conditions for the sustainable adoption of 5G technology in the near future. The following in this ranking are Sweden, Netherlands and Denmark, while at the opposite is Romania, Croatia and Bulgaria, the last three states that have joined the European Union.

By dividing into two performance clusters according to each criterion, we obtain the following results:

Table 3. Hierarchy of the EU states according to performance clusters

	Infrastructure and technology	Regulation and policy	Innovation	Human capital	Country profile	Demand
Cluster 1*	Sweden	Netherlands	Sweden	Finland	Luxembourg	Denmark
	Germany	UK	Finland	Netherlands	Finland	Sweden
	Spain	Finland	Germany	Ireland	Netherlands	Latvia
	France	Luxembourg	Denmark	Denmark	Sweden	UK
	Finland	Sweden	Netherlands	Germany	Ireland	Finland
Cluster 2**	Belgium	Bulgaria	Latvia	Luxembourg	Romania	Croatia
	Greece	Italy	Greece	Romania	Bulgaria	Bulgaria
	Hungary	Poland	Cyprus	Bulgaria	Cyprus	Romania
	Cyprus	Greece	Romania	Slovakia	Latvia	Greece
	Bulgaria	Croatia	Croatia	Hungary	Greece	Cyprus

** Cluster 1 is made up of the top five EU states in terms of readiness for the 5G implementation*
*** Cluster 2 is formed by the five lowest-performing EU states in terms of readiness for the 5G implementation*
Source: Table made by authors based on the data published by InCITIES Consulting S.A.R.L.

From Table 3 we can see that Finland is the only country that is found in Cluster 1 according to each hierarchy criterion. The next ranked is Sweden, which is in Cluster 1 according to 5 hierarchy criteria, followed by the Netherlands (4/6) and Germany (3/6).

On the other hand, Bulgaria and Greece are in Cluster 2 according to most classification criteria (5/6). The ranking is continued by Cyprus (4/6), Romania and Croatia (3/6).

From this cluster analysis, we can see that the states that are most prepared to adopt the new 5G technologies are those in Northern and Western Europe, and at the opposite end are the states of Southeastern Europe. This demonstrates, in particular, that economically developed countries will be able to

adopt in a sustainable and efficient manner the new 5G technologies, in order to achieve the smart development goals of cities.

On the other hand, developing countries will need to initially adopt strategies and implement concrete measures to improve the current situation of the analyzed criteria, so that the adoption of 5G technologies will not lead to higher costs compared to the created benefits.

Sustainable development of smart cities within these countries can only be achieved gradually based on sound economic fundamentals, such as those found in Cluster 1.

Considering these aspects, we will continue to highlight through a comparative analysis how the 6 criteria presented in Table 2 have evolved over time in the case of the best performing Cluster 1 states and the least performing Cluster 2 states.

Using this analysis we can explain the reasons of the identified discrepancies and then we will try to formulate concrete opinions to reduce these gaps.

This analysis is essential in the context in which, according to the Digital Agenda for Europe, at least one of the major cities in each European Union Member State needs to implement a 5G business network by 2020.

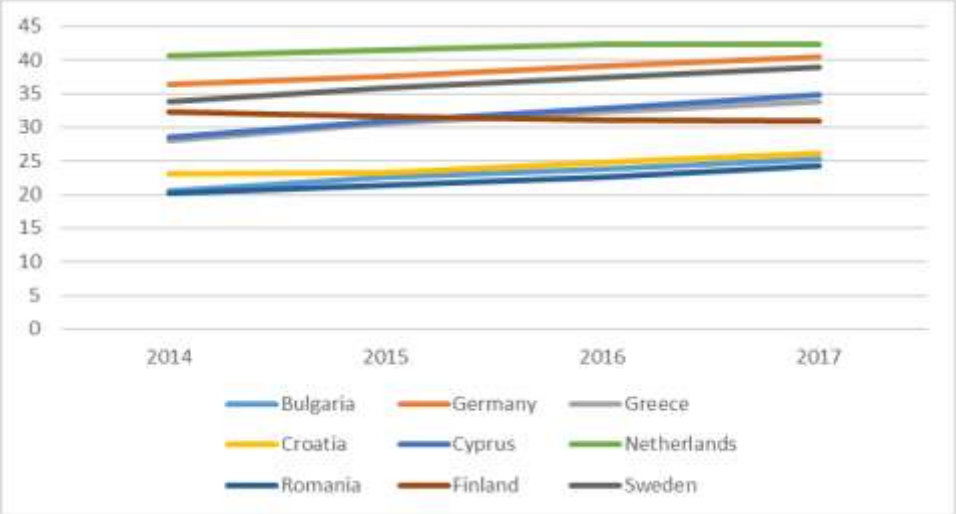
For this empirical analysis we will select one statistically relevant indicator for each of the 6 criteria, as follows:

- *Infrastructure and technology*: fixed broadband subscription (per 100 people)
- *Regulation and policy*: laws related to ICT sector (index ranging from 1-7)
- *Innovation*: R & D expenditure (% GDP)
- *Human capital*: % of the population with tertiary education
- *Country profile*: the importance of ICT in the Government's view (index ranging from 1-7)
- *Demand*: Internet users (% of the population aged 15-64)

The reference period is between 2014 and 2018, depending on the data availability for each statistical indicator.

Figure 1 shows the evolution in 2014-2017 of fixed broadband subscriptions in the top performing countries of Cluster 1 and the less developed countries of Cluster 2.

Figure 1. Fixed Broadband Subscription (per 100 people)



Source: Author's chart based on World Bank data

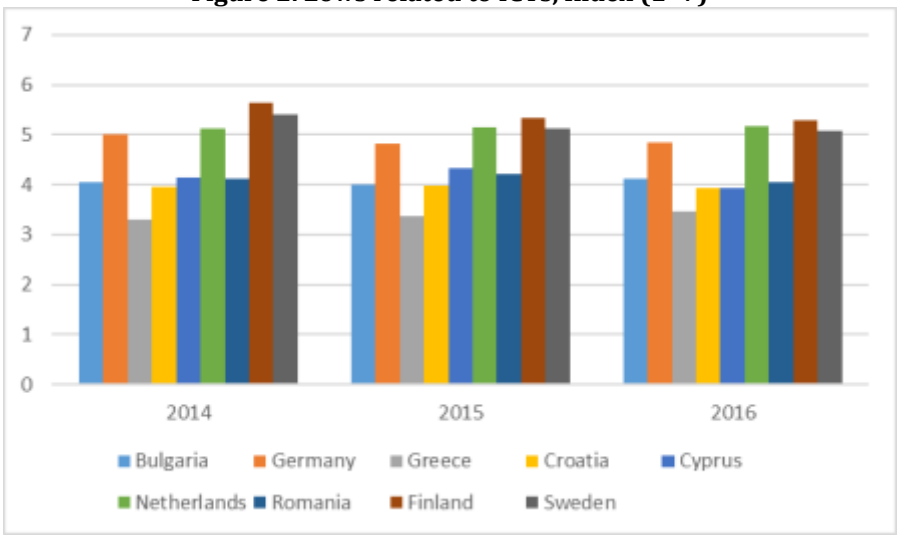
As can be seen from this figure, the Netherlands, Germany and Sweden are the countries that record the most fixed broadband subscriptions in the analyzed period, and at the opposite is Romania, Bulgaria and Croatia, which have approximately half of the fixed broadband subscriptions of the most performing states.

Even though there is a considerable difference regarding the number of broadband connections, it is important to note that less performing countries are following an upward trend over the period under review, converging with that recorded in the performing states.

Another important aspect of Figure 1 is that Cyprus and Greece are making the fastest progress among all the countries under review and if this rhythm is maintained in the future they will be able to reach the performance level of the Cluster 1 states in the coming years.

Regarding the internal regulations and policies of each state included in the analysis, Figure 2 shows the state of ICT laws adopted in 2014-2016.

Figure 2. Lows related to ICTs, Index (1- 7)



Source: Author's chart based on World Bank data

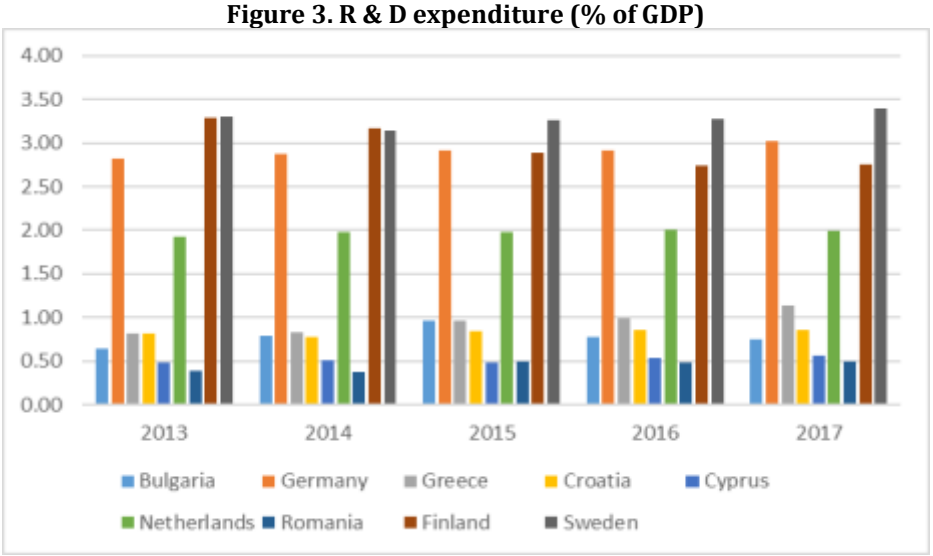
Figure 2 shows that the countries where the ICT sector is well regulated are Finland, Sweden and the Netherlands. Also, in this case, at the opposite side are the Cluster 2 states: Greece, Croatia, Bulgaria and Romania.

If we saw an upward trend regarding the number of broadband connections in these countries, we noticed a steady level of government regulation over the entire analyzed period, resulting in political decision-makers in these countries not adopt new policies and measures for the development of this sector.

This phenomenon can also be noticed in case of each state in Cluster 2 expenditure on research and development (R & D).

In Figure 3, it is noted that there is a considerable difference between Cluster 1 and Cluster 2 states in terms of share of GDP allocated to the R & D sector.

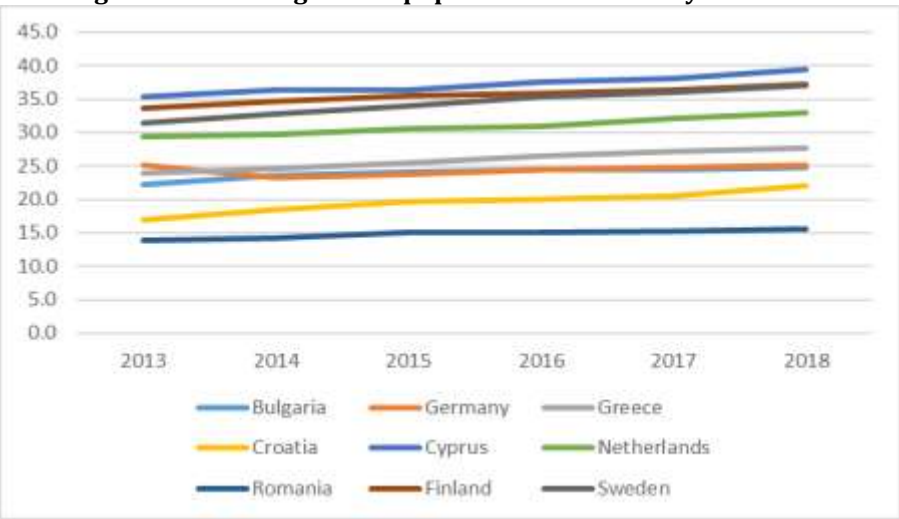
Figure 3. R & D expenditure (% of GDP)



Source: Author's chart based on Eurostat data

Thus, while countries like Sweden, Finland or Germany allocate around 3% of GDP for R & D, Romania, Cyprus, Bulgaria or Croatia only allocate between 0.5% and 1% of GDP for this sector, which results in much higher competitive advantages for the national and regional economy of developed countries. This has repercussions on human capital, the percentage of population following tertiary education being much lower in the case of almost all countries in Cluster 2 (Figure 4).

Figure 4. Percentage of the population with tertiary education

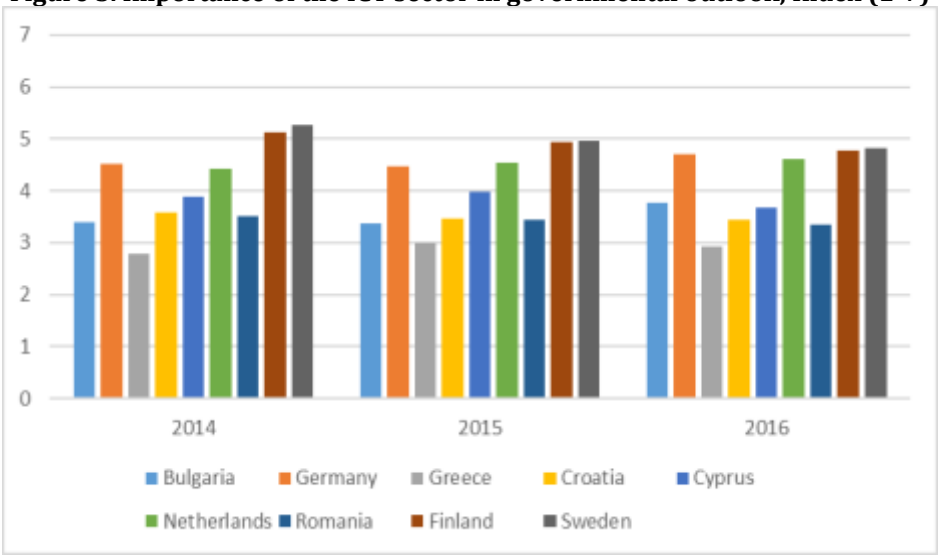


Source: Author's chart based on Eurostat data

Romania and Croatia are well below the level recorded in the other analyzed countries from the point of view of their affiliation to tertiary education, while Cyprus, a state classified in Cluster 2, ranks first. Thus, although Cyprus is one of the European Union smallest countries, most of the population (about 40%) have long-term university studies. This human capital statistic shows that in countries where this asset is well developed, there are high expectations for the successful development of 5G networks and applications that incorporate the benefits of these performing networks.

Regarding the profile of each country in terms of vision on the ICT sector, in Figure 5 we can see the states that provide the greatest importance to this sector are Sweden and Finland, while Greece and Romania ranks last two places.

Figure 5. Importance of the ICT sector in governmental outlook, Index (1-7)

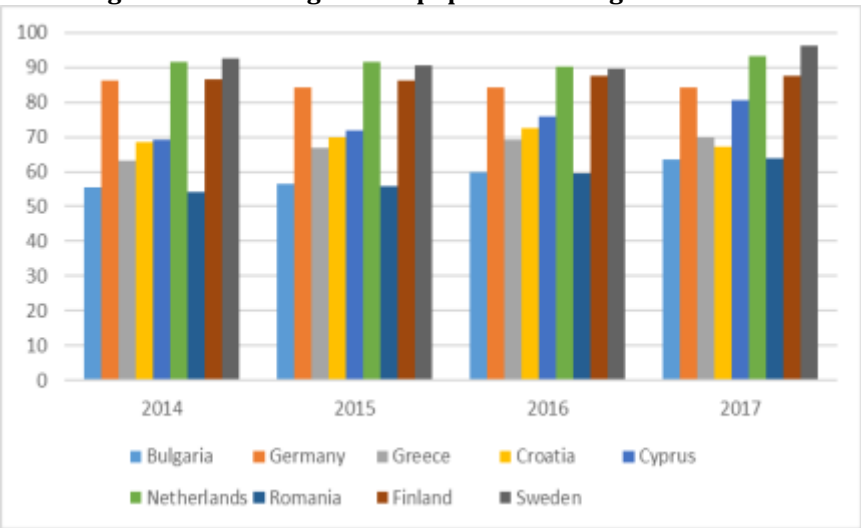


Source: Author's chart based on World Bank data

The results presented in Figure 5 are particularly relevant, as they demonstrate the affinity of states for high-performance technologies and also the chances for investment in this sector to be very high in case of Cluster 1 countries. Government perception regarding the importance of the ICT sector is closely correlated with the percentage of the population that frequently uses the Internet.

Figure 6 presents the latest official statistics related to the percentage of Internet users in the states included in the analysis.

Figure 6. Percentage of the population using the Internet



Source: Author's chart based on World Bank data

Like the other analyzed indicators, countries that recorded the best performance are those in Cluster 1, the percentage of Internet usage in these countries is much higher compared to that of countries that form Cluster 2, especially Romania.

This demonstrates that the telecom operators present in these countries will face difficulties with the 5G technology implementation's sustainability.

3. Conclusions

In this research we have empirically analyzed the importance of the new ICTs (5G) in the sustainable development of smart cities.

The results of the first part of the research have shown that the integration of 5G technologies can generate extremely important benefits that support the smart and sustainable development of the most important areas of the cities: energy, transport, environment, retail, health and safety.

At the same time, the results have shown that it is essential that cities have a number of features in order to benefit in a sustainable way by the powerful and diversified solutions provided by 5G technologies for smart development.

Thus, in the second part of the research we have demonstrated that before the adoption of the 5G technologies, cities have to meet certain fundamental requirements, such as: adequate infrastructure, government regulations in favor of the ICT sector development, sustaining the permanent development of the highly qualified human capital and the degree of innovation, high level of information technologies usage in all activity areas.

Depending on these fundamental prerequisites for the implementation of 5G technologies, we have shown that among the current European Union countries, the most prepared to integrate in a sustainable way the new information technologies are Finland, Sweden and Denmark, while at the opposite side is Romania, Croatia and Bulgaria.

Through a more in-depth analysis, we have come to the conclusion that Romania, Croatia and Bulgaria are on the last place in terms of most analyzed criteria, registering significant differences compared to the states in the top ranking.

This demonstrates that the current adoption of 5G technologies can not generate the expected benefits for the smart cities development in these countries.

Romania, like the other countries in Cluster 2, must adopt a series of important measures to develop, in particular, the 6 analyzed criteria before the 5G technologies be widely adopted, so that these performant technologies support the medium and long-term sustainable development of smart cities.

Among the most important such measures, we consider to be opportune the following: strategies and programs for growing highly qualified human capital, high investment in R & D to increase the degree of innovation and competitiveness, the creation of a good legal framework defined to sustain the development of ICT sector and to facilitate the people's access to information technologies in all aspects of everyday life.

Policymakers also need to facilitate the involvement of the private sector in the process of achieving this extremely important objective, so that the implemented measures be as effective as possible in the short term, given that, according to the Digital Agenda for Europe, at least one of the major cities in each Member State of the European Union must implement a 5G business network by 2020.

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