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TRABAJO FIN DE GRADO EN ECONOMÍA

PROGRAMA INTERNACIONAL DEL DOBLE GRADO EN ADMINISTRACIÓN Y
DIRECCIÓN DE EMPRESAS Y ECONOMÍA

SMART ECONOMY IN SMART CITIES

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EXECUTIVE SUMMARY

The term ¨smart city¨ is becoming increasingly popular in the urban development agenda. The purpose of this final degree project is to provide, from a theoretical approach, an analysis of what smart cities really are, while showing real life examples of initiatives being implemented by cities in order to become smarter.

Digitalization and the use of ICTs are affecting the way authorities tackle urban challenges such as climate change, employment, housing supply and affordability, energy efficiency or urban population growth. Many of the designed new policies intend to make the city smarter and more efficient, and they also improve citizens' quality of life.

This final degree project aims to serve as a guide to better understand the smart city concept and the importance of an innovative economy, including a comparison of actual smart cities around the world.

KEY WORDS: Smart cities, economy, technology, sustainability, innovation

RESUMEN EJECUTIVO

El término ¨ciudad inteligente¨ se está volviendo cada vez más popular en la agenda de desarrollo urbano. El propósito de este trabajo de fin de grado es proporcionar, desde un punto de vista teórico, un análisis explicando que son realmente las ciudades inteligentes, incluyendo ejemplos de iniciativas que las ciudades están llevando a cabo para volverse más inteligentes.

La digitalización y el uso de las TIC están afectando la forma en que las autoridades abordan desafíos urbanos como el cambio climático, el empleo, la oferta de la vivienda y su asequibilidad, la eficiencia energética o el crecimiento de la población urbana. Muchas de las nuevas políticas diseñadas tienen el propósito de hacer la ciudad más inteligente y eficiente, a la vez que se mejora la calidad de vida de los ciudadanos.

Este trabajo de fin de grado tiene como objetivo servir como guía para entender mejor el concepto de ciudad inteligente y la importancia de una economía innovadora, proporcionando una comparación de ciudades inteligentes existentes hoy en día.

PALABRAS CLAVE: Ciudades inteligentes, economía, tecnología, sostenibilidad, innovación

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1. INTRODUCTION

The urban population all around the world has increased from 751 million in 1950 to 4.2 billion in 2018 according to the World Urbanization Prospects 2018 (United Nations, 2018). According to the World Bank, it is expected that in the year 2050 almost 70% of the world will live in urban areas. Only in Europe (EU-28), the urbanization rate in 2015 was 72% (European Commission, 2018).

Urbanization growth brings challenges concerning housing, public transportation, employment and environment, among other factors. In fact, cities consume over 75% of natural resources, as stated by the United Nations Environment Programme. A report by Frontiers in Sustainable Cities showed that 23 Chinese cities, Tokyo and Moscow accounted for 52% of the total of greenhouse gas emissions (Wey et al., 2021). Such environmentally unfriendly emissions threaten the quality of life of future generations. Cities need solutions to make urbanization more sustainable while keeping up being attractive and modern. There is a need for a more environmentally friendly utilization of resources, a faster and more sustainable transport network which facilitates commuting and a more efficient energy consumption. Consequently, it is expected that city governments will invest an estimated amount of $41 trillion by the year 2037 to improve and upgrade their infrastructure and change the quality life of citizens (Smart America, n.d.). In fact, according to the Market Research Report of the platform MarketsandMarkets, the Smart Cities Market is expected to reach a value of $873.7 billion by the year 2026. Governments in developed and developing countries are implementing more regulations in order to reduce carbon emissions and control their carbon footprint. Although these new smart systems are more efficient and reduce operating costs in the long run, they are costly to implement (MarketsandMarkets, 2021).

The aim of this final degree project is to explain the smart cities model. The first part of the project is based on literature research to explain what smart cities are, their 6 dimensions, how smart cities can be implemented following a smart economy and how they can be financed.

The second part looks into 3 current cities among the top 10 smartest in the world according to the IMD-SUTD Smart City Index (SCI) 2021, and following the United Nations Sustainable Development Goals (SDGs) and through the use of public available

data, an analysis is carried out with the aim to understand the implementation and development of smart cities.

The chosen smart cities to be analyzed are Oslo (Norway, Europe), Copenhagen (Denmark, Europe) and Singapore (Singapore, Asia). 4 out of the 17 SDGs have been chosen in order to compare how these 3 cities have become smart. The 4 goals this project puts the emphasis on are those which have more to do with the main topic, smart cities. These 4 goals are, in order of importance:

- Goal 11. ¨Sustainable cities and communities¨
- Goal 7. ¨Affordable and clean energy¨
- Goal 13. ¨Climate action¨
- Goal 8. ¨Decent work and economic growth¨

I found inspiration in writing about smart cities because I really think it is the future (and in some aspects, the present) of city life and I wanted to study its effects in labor, mobility, social aspects, learning, government, digitalization and sustainability. We are transitioning to a new urban way of living, and I want to show how smart cities aim to solve the challenges cities are currently facing.

Achieving a more sustainable urban development is a challenge. As a result, more and more governments worldwide are considering transforming their cities into "smart cities", "intelligent cities" or "green cities", to improve efficiency in the accessibility of goods, services and resources. The definitions and differences among these three concepts are explained in the next section of the introduction.

1.1 ¨Smart cities¨, ¨intelligent cities¨ and ¨green cities¨
The available literature gives many definitions of a smart city, but the concept can be summarized as a city that explores and interacts with technologies and digital solutions to make its community better. As a result, it improves its governance and administration, services, opportunities, and social equity. It also enhances sustainability and produces less emissions by the use of smarter urban transport, smarter facilities, smarter construction and smarter public spaces (European Commission, 2022c). The term smart city is closely linked to ICT (Information and Communications Technology), in the sense that its use improves citizens' quality of life. But, what is more important, is citizen's active

participation, involvement and even change of behavior. The term does not only have to be limited just to ICT but also to people and community needs (Albino et al., 2015). Another way to see it is through the sense of ¨community¨ among citizens, which means that the community of a smart city needs to participate together to foster growth (Nam and Pardo, 2011). It can then be said that a smart city refers to the capacity of smart people to create smart solutions to urban challenges. Consequently, smart governments have to be able to communicate with citizens and make them understand and participate in the process.

The concept of an intelligent city emphasizes more on the ability to use IT to transform life and work. As a result, intelligent cities have digital components, but digital cities are not necessarily intelligent. However, the main difference is that the importance of the ¨people¨ component is not taken into account in an intelligent city as it is in a smart city (Woods, 2013). For a city to be smart, citizens have to participate and be involved in the *IT-based urban ecosystem*. A smart city is an intelligent city, although an intelligent city is not necessarily a smart city (Letaifa, 2015). An intelligent city will then become smart when there is a compromise and involvement among the inhabitants.

The main difference between a green city and a smart city is that a green city is ¨in balance with nature¨, where nature is an important component of the urban form and part of green infrastructure. Urban nature is an important aspect of a green city which includes natural elements in urban areas, for instance gardens, parks or horizontal and vertical green on buildings, among other examples (Breuste, 2020). It can be said that while a green city focuses mainly on environment related sectors like water and waste management or green transport, smart cities pay much more attention to other aspects like economy, education, culture, safety, innovation and ICT. The main difference between both concepts is that smart cities put a stronger emphasis on ICT than green cities (Ahvenniemi et al., 2016).

This research project focuses mainly on smart cities. As Figure 1 shows, smart cities are comprised by technology, institutional and human factors. It is important to highlight that a smart city relies more on the people component (people oriented approach) than the other terminologies.

Figure 1. Fundamental components of a Smart City.
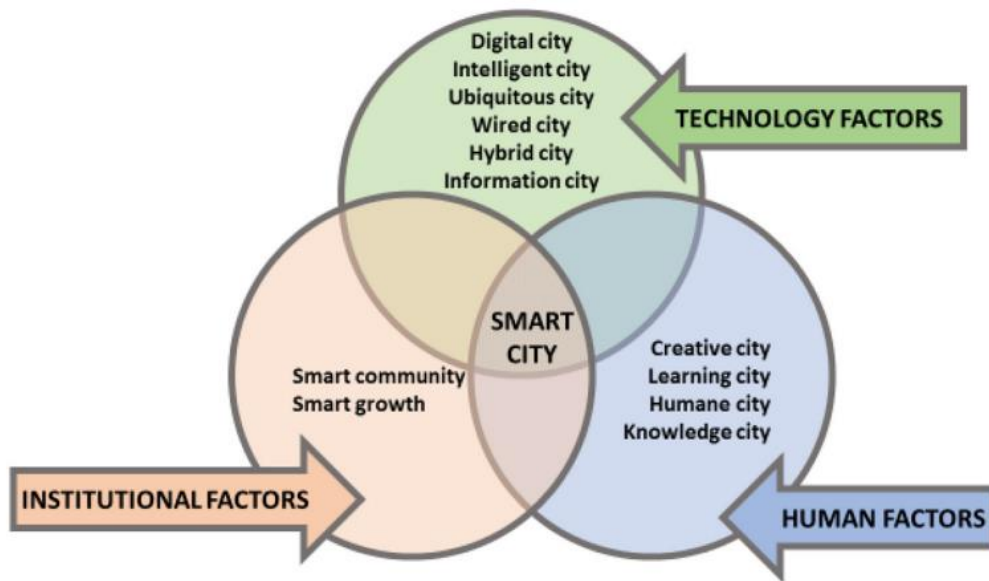
Source: Nam and Pardo (2011)

2. THE 6 DIMENSIONS OF A SMART CITY

A Smart City System comprises 6 dimensions (Kumar, 2017):

1. Smart people (knowledge)
2. Smart economy (competitiveness)
3. Smart mobility (connectivity)
4. Smart environment (sustainability)
5. Smart living (quality of life)
6. Smart governance (participation)

The capacity of any city to transform and progress towards these six components is the ability to transform the city into a smart city. As represented in Figure 2, the principal movers for this capacity to transform cities are smart people and smart economy. The growth of more and more smart people multiply the chances for engaging in the smart economy. The needs of the smart economy and smart people result in smart mobility, smart environment and smart living.

Figure 2. The 6 dimensions of a Smart City.

SMART PEOPLE	
SMART ECONOMY	SMART MOBILITY
SMART LIVING / SMART ENVIRONMENT	SMART GOVERNANCE
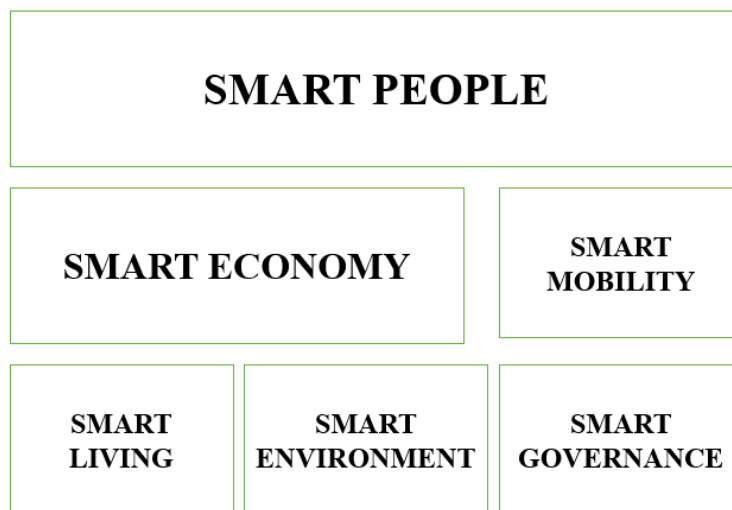
Source: Author

2.1 Smart people (knowledge)

The smart people indicator is the most important one because without the active participation and involvement of smart people, a smart city would not have an effective functioning (Kumar, 2017).

Smart people in a smart city must have a high human development index (HDI), high levels of qualifications and expertise, know how to face challenges, be flexible, open minded, tolerant, creative, multicultural, and sustainable. Citizens should take part in the transformation of the city itself since they are the ones in charge of building the city. For this to be possible, Governments must ensure that the smart city is socially inclusive. The importance of social inclusion will be discussed later on the final degree project, but some aspects include providing (free) internet access and paying attention to the affordability of technology.

Citizens in smart cities generally have a higher education, and those cities with higher percentages of qualified workers enjoy faster growth. A smart city can be thought of as a magnet for smart people (Winters, 2011). Consequently, smart cities become creative, connected, skillful and competitive, benefiting urban development (Dirks et al., 2010).

Some authors affirm that creativity is a key driver of smart cities, which increases the importance of education, culture and knowledge. Therefore, it fosters the development of intellectual capital (Thuzar, 2011).

Successful smart cities must be built for the people, enabling creativity and using technology to solve real issues.

2.2 Smart economy (competitiveness)

Cities are recognized as the engines of economic growth (Forbes, 2015). For instance, in the year 2018, the metropolitan area of New York, Newark and Jersey City had the largest GDP in the United States, around $1.8 trillion, which equaled in size as the entire Canadian economy (HowMuch, 2020). The population size of a city matters with regard to its urban economy, since large metropolitan areas are the ones that generate most of the wealth. Another example can be seen in India. Delhi is the largest city in the country and second largest city in the world after Tokyo, and has the highest per capita income in India.

As a result, urbanization has been included in national economic development policies in many countries during the last years. Smart cities offer solutions to the urbanization challenges thanks to the implementation of a smart economy associated with the ICT industry. Better access to technological information optimizes resources and provides better management. Citizens are also more informed and can access new services thanks to the use of smart technology.

A smart economy is often associated with ¨innovation economy¨, since it is based on new technologies, new business models, new services, innovative types of entrepreneurship and on improvements in digitalization in the Public Sector that improve the quality of life and standards of living of the population. Having a smart economy based on innovation improves the prosperity of developed economies, benefits those companies that invest in innovation, helps a nation to be more prepared for the future and softens the economic consequences of financial crisis. Therefore, the baseline of a smart economy is the establishment of companies which are knowledge-based, technological, software and digital media, in addition to science companies, laboratories, and research institutes. A smart economy also requires a smart workforce with knowledge occupations (characterized by the use of high technology, knowledge intensive and creative jobs) and smart connections (which has to do with FDI strategies, quality living and sustainability, among others) (Kumar, 2017).

2.3 Smart mobility (connectivity)

Urban planning centered on the use of information and communication technologies (ICT) is key in order to accomplish smart mobility. Urban mobility generates huge amounts of data that can help cities manage themselves more efficiently (Letaifa, 2015).

In order to achieve global reductions in CO2 emissions, smart technological innovation will have to work hand in hand with smart policies. Making traveling more efficient through real-time traffic information systems to improve urban traffic, real-time navigation alerts, smart parking applications and encouragement to use public transport are some aspects of smart mobility (Albino et al., 2015). Smart mobility also puts its attention on the mobility of people, not just of vehicles. Therefore, a smart city advocates walkability and cycling. Cycling has become an efficient and sustainable means of transport across cities in the world. Cycling infrastructures across cities are expected to increase in order to make urban mobility greener and sustainable. Therefore, public bicycle systems where citizens can use them whenever they want are becoming very popular for several smart communities. According to VisitCopenhagen, around 49% of Copenhagen's inhabitants commuted to work by bicycle in 2018 (Thoem, 2022). Cycling is a big deal for smart and sustainable communities around the world, because it also helps against the issue of traffic congestion and reduction of CO2 emissions.

Smart transportation electrification brings solutions to improve air quality, promote fuel independence and combat climate change by reducing emissions. The European Commission, through the ¨Sustainable and Smart Mobility Strategy¨ aims to boost the adoption of zero-emission vehicles by installing 3 million public charging points by 2030. The use of electric transportation is therefore crucial for smart communities, especially since the European Union White Paper on Transport estimated that all modern European cities would be rid of traditionally fueled motor vehicles by 2050.
The implementation of artificial intelligence for smarter mobility is also taking place, for instance by the use of drones (European Commission, 2021).

The use of smart mobility technology applications have allowed citizens to cut commuting times by 15-20% on average, although this depends on the density of the city, its infrastructure or commuting patterns, among other factors (McKinsey, 2018).

2.4 Smart environment (sustainability)

The use of innovative technologies, such as solar energy and other renewable sources of electricity, and real-time monitoring of pollution to create a clean environment are some tactics for smart environment, which generates data for environment management.

Smart cities value natural resources and biodiversity, preserve the ecological system in the region, focus on water management and an efficient system for wastewater, and stand for a low carbon environment with an emphasis on efficient and renewable energy (Kumar, 2019). Water consumption tracking through technology applications can reduce residential water usage by 15%. Tracking the sources of pollution can help in implementing more efficient measures and therefore reducing pollution levels (McKinsey, 2018).

In some parts of the world, implementing smart environment practices is challenging due to the lack of a regulatory framework and legislation. However, in the EU, there are clear objectives and priorities that guide European environmental policy according to the EU environmental legislation (European Commission, 2020). For example, smart waste management is already being implemented in Europe by means of the SMART WASTE project through the European Regional Development Fund, which will be useful for the design of new future policies (Interreg Europe, n.d.).

A smart environment should encourage green building designs and sustainable neighborhoods, utilize sustainable materials and efficiently manage waste, water and electricity use. The Government should educate the public on the importance of sustainable living and establish the right policies to control pollution. The citizens have to be educated and interested in safeguarding the environment. As an example, the city of Hong Kong is increasing its efforts in improving the environment at a strategic level. Hong Kong is one of the cities with the highest levels of transit usage in the world with over 90% of passenger trips made through public transport (Transport and Housing Bureau, 2017). Development plans on ¨Smart Hong Kong¨ aim for strategies regarding smart environment that include the building of green designs, carbon emission targets or the link of urban areas with the countryside through a more efficient public transport. Many initiatives are covered in the Hong Kong 2030+ strategic plan. By increasing the use of renewable energy, green infrastructures and the low carbon transportation, the city expects to reduce energy intensity by 40% in the year 2025. Other environmental policies and government initiatives put the emphasis on air quality management, the control of

noise pollution, the improvement of water quality, a more sustainable use of resources and energy saving, among others (Kumar, 2019).

2.5 Smart living (quality of life)

The dimension of smart living implies an improvement in the quality of life of citizens regarding the availability of services, tourism, safety and social cohesion. Likewise, smart living includes cultural and entertainment facilities, public services or e-health systems (Toppeta, 2010).

Many companies have launched projects with the aim to improve smart living in the approach to develop a smart city. Some examples can be IBM with its IBM Garage, a program to accelerate innovation and transformation in the public sector and healthcare industry. This program has improved citizen experiences, as an example in Nova Scotia, Canada, with the launch of an app to quickly locate nearby automated external defibrillators (AED), needed to control cardiac arrests, through IoT sensors (IBM, n.d.). Anther case is the company Siemens, with many initiatives for smart city development, such as the security management system by artificial intelligent engines for the Expo 2020 in Dubai, or projects for smart infrastructure (Siemens, 2020).

Concerning households, climate-neutral buildings, solar panels, district heating or multistory buildings that recycle waste have been implemented in the design of infrastructures meant to be more efficient and favoring smart living. Urban greening projects are also meant to improve citizens' living. From transforming neighborhoods and encouraging economic development to promoting a healthier lifestyle for inhabitants, there are many examples of urban greening projects around the world (like the High Line in New York, the Madrid Rio in Spain or the Atlanta Beltline). Vertical farms have increased in popularity in urban areas, since they are able to produce food for an increasing population (Lindfield and Steinberg, 2012).

Regarding public safety, applications can help reduce the death rate from homicide, traffic accidents and fire by 8-10%. Assaults, robberies and thefts could also be reduced by a significant percentage. The use of technology can improve citizens' freedom of movement and tranquility in urban areas by optimizing the efficiency of call centers and emergency vehicles. This would imply reducing the response time, which would therefore save lives (McKinsey, 2018).

2.6 Smart governance (participation)

Examples of smart governance include e-services that foster a transparent decision making, through e-government, public consultation, social media, and crowdsourcing (Letaifa, 2015). E-governance should allow better access to services to the public, while being transparent, citizen-centric and citizen-driven (Albino et al., 2015). An e-government is supposed to enhance citizens' involvement in public services, while promoting social engagement (Musa, 2016). Besides, e-governance strategies such as interactive citizen apps or the presence of the government on social media makes the public authorities more responsive, and residents more connected (McKinsey, 2018). A good example is Paris and its ¨participatory budget¨ implemented in 2014, where residents can propose project ideas, and those which receive more votes are implemented by the City of Paris (Willsher, 2020).

E-governance has been incorporated all around the world. Some examples include The Seoul Metropolitan Government website, which integrates all major administrative services, being user friendly, interactive, with a clear design and featuring numerous ways to deliver public services and engage citizens. Privacy and internet security are very important in e-government platforms (Manoharan et al., 2021). In Europe, the European Commission is developing its initiatives to develop digital public services. It is estimated that EU annual savings could exceed €50 billion. (European Commission, 2022b). Estonia is leading in e-governance since it outperforms the average of Central and Eastern European countries in the Digital Futures Index developed by Microsoft (e-Estonia, 2022).

3. TURNING CITIES INTO SMART CITIES. THE IMPORTANCE OF A SMART ECONOMY

The transformation of a city towards a smart city can sometimes be hindered by the lack of a clear plan and a short term vision of the future, poor political coordination and absence of diversity among stakeholders.

The first important step to implement a smart city is good governance. In fact, a new type of governance must be established. Leaders need to understand that interaction is key in order to become successful, so it must make a big effort to embrace all groups in the community and engage all together the private sector (local businesses and multinational

corporations), citizens, the public sector, universities (through research projects) and non-profit organizations (community activities). Besides, through technology, the government must encourage involvement across all sectors in the economy, and must also establish dialogue. E-education, e-governance and an e-community platform are great tools to achieve this. It must also provide mechanisms to keep up with technological innovations and new ways to improve efficiency. All this is vital in order to foster innovation and get advantage of cross-sectional expertise. Moreover, governments are in charge of providing and tracking data, bringing stakeholders together and communicating effectively. The main objective should be to establish a long term political commitment between the government and multinationals, SMEs, universities, public and private institutions and citizens (Letaifa, 2015).

The government must set targets to reach them in 3-5 years and must have the needed tools to achieve the goals. There must be constant communication with stakeholders. However, government action is not enough. If the aim is to build smart cities that are inclusive, it is necessary the participation of different types of enterprises in collaboration with city administrators. Private corporate firms can offer expertise and knowledge, while SMEs and social enterprises can be involved on a smaller scale but being equally important. Moreover, citizens participation is also vital, acting as smart citizens playing an active role in addressing local challenges and fostering the use of smart technologies.

Any program for smart cities has as a main goal to create social benefits for the community, such as an increase in employment, advancements in healthcare systems or an improvement in educational opportunities. An urban economy makes cities more competitive by enhancing high skilled jobs, motivating citizens to take part in local issues or focusing on environmental goals. Smart city initiatives with a focal point in smart economy can promote a greener and more efficient urban economy. It should be the focus of any government to embrace a smart economy in order to be innovative, forward-thinking and remain competitive and attractive in the global economy. The main principles of a smart economy consist of *creativity, flexibility, plurality and citizen participation* (Youssef and Hajek, 2021).

A smart economy fosters innovation, green economy and is focused on maximizing human capital, including skills and creativity. Besides e-government and the modernization of city infrastructures and utilities, an innovative economy is key for developing a smart city. An innovative economy is mainly based on three components:

intelligent city clusters, intelligent city districts and the creation of new companies as means of intelligent incubators (Schaffers et al., 2011). Clusters increase businesses' productivity, spur innovation and knowledge. Through an innovative economy, a smart city generates knowledge, by a learning and innovative culture.

For a city to become smart based on the application of a smart and innovative economy, some important factors have to be taken into account, such as: an own telecommunications network and digital inclusion, changes in employment and a more efficient labor market, and housing and cost of living.

3.1 An own telecommunications network and digital inclusion

The government must evaluate the community's needs, gain access to the vision of the community and implement the right policy for the community. This can be seen with the example of digitalization, more concretely, with the implementation of a self-driven network infrastructure which allows a community to exploit its maximum potential (Kumar, 2017). According to the Intelligent Community Forum, smart cities must create and control their own telecommunications network. Offering community-wide broadband at low prices (or, it can be provided free) is an important characteristic that turns a city into a smart city. In the Nordic European countries it is very common to have a public-run municipal network. It is the case of Sweden, by 2025 the whole country (98% of households and businesses) should have access to high-speed broadband following The Swedish Digitization strategy adopted in 2017 (European Commission, 2022a). An example of this strategy can be the Stokab network, owned by the city of Stockholm, which has enabled the city to have one of the world's largest fiber city networks with around 1.9 million fiber kilometers benefiting both citizens and companies. Smart cities work with data, and the use of sensors is a vital step towards making a city smarter. Smartphones are considered as mobile sensors, since their owners move with them, generating a wide range of data such as location. Other sensors in the urban area include the ones that measure air and water quality, the ones inside waste containers or security cameras, among other elements. Sensors can provide helpful information to improve emergency responses, transport systems, traffic management, home care services, or city planning (Berntzen et al., 2016).

Broadband and wi-fi coverage across a city are extremely important in order to bring connectivity to a smart city. As a result, it is essential for a smart city to invest in the

installation of fiber-optic in every major location. This allows to create technology parks that attract the formation of start ups and motivates high technological companies to locate there. What's more, making high speed public Wi-Fi available benefits everyone living in a smart city, fostering especially the development of smart people. Making the internet so accessible to the community makes a smart city a great place to live and do business. Moreover, a city is not smart until people consistently use technologies to increase productivity in their daily lives and businesses. Citizens are active participants in shaping the city.

Being an unconnected citizen has many disadvantages in today's connected world. It is very difficult to apply for a job when it is impossible to access online job offers. The kids cannot do their homework when they need an internet connection. What's more, online shopping, e-banking, social interaction and the access to healthcare services also cannot be enjoyed by someone who cannot afford the cost of home broadband or mobile data connections. As a result, enhancing the access, use and quality of information and communication technologies results in the economic, social and cultural development of smart cities. It is then fundamental for a smart community to engage people to use technology to transform life and work in important and positive ways. Consequently, digital inclusion in terms of digital literacy programs that teach knowledge and skills is key to make smart communities strategies successful. Digital inclusion as a way of social inclusion must be part of the smart city plan for any government.

Poorer households tend to be more unconnected, which means more digitally excluded. According to Eurostat, *in 2020, an estimated 21.9 % of the EU population — or some 96.5 million people — were at risk of poverty or social exclusion* (Eurostat, 2021). Smart communities must implement strategies to reduce poverty, and more concretely, digital poverty. In 2017, 13% of European households were living without the internet. One of the reasons that explain why citizens remain unconnected is due to the cost of internet bills. Smart community initiatives to foster connectivity among citizens must *make digital inclusion for all your citizens part of the smart city plan, and digital equity one of its key goals* (Callahan and Siefer, 2019). Most initiatives include free courses in basic training in computer, digital skills and internet use, aid with enrollment in low cost home broadband services or authorities permitting free internet access to citizens. Smart communities must be digitally inclusive as a way to fight against poverty and achieve welfare. This involves focusing on all areas of a city or region and not just high income

areas (Huang et al., 2019). In order to increase digital equity, smart communities must embrace digital inclusion. As an example, the use of geocoding technology to provide postal addresses to thousands of slum residents in order for them to obtain documentation to use government services, open bank accounts or vote (Addressing the Unaddressed, 2018). Another example of digital inclusion is the smartphone application developed by Google and the Royal London Society for Blind People to help blind people use London's transportation network. Other activities that foster digital inclusion involve initiatives like free internet courses in libraries or schools, subsidies for buying laptops and desktop systems, and free or low cost home broadband services. Digital inclusion is also measured by the high quality internet access of the population and better and faster connectivity. The rise of 5G technology enables faster data transfers, making cities a safer place. This makes it possible for governments to make better and more efficient decisions by providing smarter public services. 5G has not reached its full potential yet, but it is a great tool to grow the smart cities market (MarketsandMarkets, 2021).

It is important to highlight that even though a well-functioning optical fiber broadband and the Internet is absolutely necessary, it is not enough to become a smart community. In addition, it is essential to focus on ICT applications such as e-voting, e-learning or e-commerce for the community's activities. It must be mentioned that for becoming a smart city, citizens, public and private institutions, universities and organizations have to collaborate and cooperate (Lindskog, 2004).

In fact, e-governance is a way to enhance citizens' involvement in public services, while promoting social engagement (Musa, 2016). Besides, e-governance strategies such as interactive citizen apps or the presence of the government on social media makes the public authorities more responsive, and residents more connected (McKinsey, 2018). Therefore, any operational program for smart communities should include proposals to make smart communities more inclusive and foster residents participation. An example of motivating citizens to collaborate with local governments can be found in the Dublin City Council and its initiative ¨Beta¨, aimed to improve the lives of citizens while also enhancing the work of the local authority. An interesting Beta project asked artists to paint traffic light control boxes. This produced a cleaning cost for the council, while at the same time improving visual appearance and providing exhibits for the artist. This

initiative fostered citizen participation, trust and development in urban management. (Kitchin et al., 2018).

3.2 Changes in employment and a more efficient labor market

At this point, it is clear that smart cities and communities rely on smart technologies and digital innovation. The rise of artificial intelligence, automation and the increase in the use of smart technologies increases the economic activity and creates new jobs, affecting the job market. The Covid-19 pandemic has also exacerbated this trend. The impact of automation on employment varies according to each country, occupation and sector. An increase in automation implies workplace adjustments and changes for all workers. This has tremendous implications for the workforce, who will need to learn new digital skills, adopting a ¨never stop learning¨ mentality.

According to the 2017 McKinsey report on automatization, *up to one-third of the 2030 workforce in the United States and Germany, and nearly half in Japan* will have to develop new competences and find work in new occupations (some of which did not exist before). Countries that are not successful in managing the transition to new occupations could suffer from an increase in unemployment and decrease in salaries.

Therefore, the concept of employment as we know it now is going to change in the near future. The constant learning of new skills implies that businesses will have to focus more on mid-career retraining, on-the-job training and giving employees more opportunities to renew their capabilities as a way to increase employee productivity (McKinsey, 2017).

Another useful way to manage this labor market transition is through labor mobility, and digital talent platforms can help in fostering this mobility. A Harvard study in the year 2020 showed that out of 700 managers in the US, 60% expected to *"rent," "borrow" or "share" talent with other companies in the near future.* Companies are rethinking the way they find talent, focusing more and more on finding part-time high skilled workers outside the company. Moving into the digital area implies a more flexible mixed workforce made up of full time workers and freelancers, relying on digital talent platforms as a tool to hire employees when needed (Beckett, 2021). For example, once Deloitte got used to hiring external freelancers, the company created Deloitte MyGigs, an internal platform for matching full-time employees with new projects. Some digital

freelancing marketplaces are Upwork and 99designs, and some digital marketplaces for premium talent are Toptal or Braintrust (Harvard Business School, 2020).

Taking into account that some of the world's urban markets are larger than entire countries, companies have major business opportunities in cities. Moreover, the smart cities model opens up new business models and opportunities affecting both companies and employees.

For workers, smart cities promote mainly on-demand work, which is characterized for being more flexible, allowing the employee to have a different routine every day which helps to find a perfect work-life balance. Regarding the creation and destruction of jobs in a smart city model, an increase in digitalization can automate several administrative tasks. For instance, installing more digital payment machines in a metro station can reduce the number of employees needed. Cities could reassign these employees to more productive jobs or even create new types of services. On the other hand, the use of smart technologies could create many jobs. A more flexible public transportation in terms of more routes or frequencies adds drivers. New digital machines, real time applications or an increase in the use of sensors requires from a wide range of maintenance repair crews (McKinsey, 2018).

Entrepreneurship and the creation of startups are intensified in a smart city due to nonstop innovation and constant investment. As a matter of fact, smart cities are considered as knowledge-based clusters. Knowledge creates talent, which motivates entrepreneurial action and is a source of economic growth.

The development of startups ecosystems in cities attract external investors, affirming that startups are a viable employment opportunity and raising confidence in business. Governments should support startup initiatives, providing funds and carrying out partnerships with private venture funds. A deeper focus on digital entrepreneurship, joint venture investment opportunities, and appropriate formulation of policies by the government would lead to the innovation of new services, which implies urban transformation (Mitra, et al., 2021). Moreover, governments should also carry out policies focused on smart cities. As an example, offering tax benefits to spur the use of environmentally friendly technologies.

Entrepreneurs should focus on developing new technologies and business models. The huge amount of data that can be generated from cities through technology should be used

to foster entrepreneurial ideas by encouraging the development of new products and services. Open data allows companies and entrepreneurs to find new business models which can help to fight unemployment and boost economic activity. Several cities in the United States have been sharing open data through websites for citizens and startups to access and develop smart city initiatives. By the use of ICT, citizens in Amsterdam are encouraged to use open data in order to develop ideas for the progress of smart cities. Many of these ideas produce local employment opportunities, benefiting the whole community (Krishna, 2019).

3.3 Housing and cost of living

Most major cities all around the world are going through housing shortages. Only in the United States, it is becoming a national problem: especially since the Covid-19 pandemic, home prices and rents have considerably increased throughout the country, including in locations which were typically affordable. Lockdowns and the need to work from home increased the demand, since many households were looking for more space or moving to different cities. Nowadays, the fast rise of inflation is also raising housing costs, mainly affecting the cost of rents.

However, the problem of the housing shortage is not an actual phenomenon. After the Great Recession, there has been a labor shortage in the construction industry, which, added to the rising cost of land and materials, has resulted in underbuilding and soaring prices, leading to a big deficit of homes in the United States (The New York Times, 2022).

Europe is also suffering from a housing crisis. Especially in urban areas, the rising costs are causing many citizens to drive out of the city. Besides, in many times, the quality of the houses does not align with its price. The European Union is already acting on this through the ¨Next Generation EU Initiative¨, with a *EUR 750 Billion investment in affordable, social and energy-efficient housing*, but it is inevitable to admit that many cities of the continent are suffering housing shortages (Sparrentak, 2021).

The need for individuals to settle farther in order to afford housing increases traffic congestion and makes it difficult to fight against climate change. It also affects individuals and their job choices.

The actual housing situation is changing the current housing landscape and urban development. As a matter of fact, millennials are adapting to a more modest living

condition, like a communal lifestyle where there is more sharing among the community (co-living). From a sustainability perspective, the co-living alternative is positive because resources are shared.

For a smart city to sustain itself, housing is a requirement, since the growth of a smart city is limited and depends on housing. In many cities bureaucracy can slow down the process of land acquisition, environmental studies or design approvals. These delays prevent some projects from being undertaken, and can also increase costs. As a result, technology can be useful to accelerate the bureaucratic process. Another useful technological innovation is to create open databases to identify free parcels and plots of land in cities, generating an increase in the housing supply, which would lower costs and make it easier for individuals to move to the city (McKinsey, 2017).

For smart people to be attracted to move to a smart city, housing has to be affordable. Regulators policy making should not restrict new construction too much and should not focus only on one type of construction (Kang et al., 2021). Housing affordability is a challenge and a critical factor that supports the formation of innovation districts. Smart cities must focus on providing an environment conducive to balance both working and living locations. As a result, urban planning must foster the development of innovation districts by improving live-work zones and connectivity. In order to have housing affordability, taxation should be reconsidered, with more flexible policy regulations that offer innovative and diverse ways to finance housing. For example, flexibility in regulations concerning floor space or height controls increase the supply of housing and its affordability.

As studies show, those locations offering affordable housing, while being well connected through ICT and means of transportation to central markets, are attracting new jobs and bringing economic growth. A report made by the Australian Housing and Urban Research Institute (AHURI) shows that high housing prices and high cost of living negatively impact the productivity of businesses, startups and individuals. In fact, affordable rents and proximity to work improve productivity of startups. To conclude, government policies should focus on providing affordable housing, connectivity and a well-developed transportation system in order to foster the development of innovative districts and a smart economy. Lower housing costs increase the formation of startups in innovative districts, improving the balance between live-work environments and fostering knowledge, which is crucial for the expansion and improvements of smart cities (AHURI, 2020).

Housing energy consumption is also a concern for smart cities, which put a lot of interest in the development of new smart technologies to save energy in the residential sector. Smart homes are characterized by improving energy efficiency, since they are based on the use of ICT and AI. In brief, the home appliances in a smart home are remotely monitored and controlled. The introduction of smart home products and appliances can result in energy savings from 12% to 20% (Ford et al., 2017). Therefore, energy management is crucial for the development of smart cities, and smart homes are a key starting point. Smart homes allow individuals to save energy and reduce carbon emissions, while being more comfortable and secure. The adoption of intelligent strategies such as real-time monitoring and controlling allow users to control their power usage and decrease their electricity costs (Yadav et al., 2020).

4. FUNDING SMART CITIES

The planning of a sustainable and ambitious smart city requires addressing a main question: its funding. Usually, public and private investors fund smart city projects, but these investors are hard to secure because smart city investments are costly and extensive. Private investors mostly care about their return on investment, and the truth is that there is usually uncertainty about the eventual success of a smart city project and the true value that it will add to both the city and investor.

Stakeholders vary depending on the size and location of the smart city, but they range from residents and private company owners to the government and public corporations. The interests of investing in smart city initiatives are also different for each stakeholder, from increasing their personal income to advancing technology use or improving economic development.

There are several possible funding options for smart city investments, and in order to develop a good funding program they should all be combined and integrated (Galati, 2018).

Besides the importance of the public sector, the private sector (private companies, startups, educational institutions, foundations, non-profit organizations) is in some cases responsible for most of the initial investment of smart city initiatives. The role of the public sector in any case consists of regulating, offering subsidies and providing the

needed public goods. The ideal situation is when there are partnerships between the both the public and private sector, such as the Amsterdam Smart City (McKinsey, 2018).

The main funding possibilities are discussed and explained below:

4.1 Government funding

The government is usually the first main funding option to be considered, and it should promote transparency and interaction with citizens. Government funding is a direct and practical way to secure capital for smart city initiatives at national level.

The main return on investment for governments is the access to economic and user information. Collecting data is extremely valuable for governments to manage and supervise the effectiveness of their policies. For instance, the information given by smart public transportation systems allows the public administration to assess its effectiveness. E-governance is also another useful way to make cities and communities smarter and more efficient.

4.2 Local and community funding

Local financiers tend to be more focused on investing in smart city technologies and initiatives for regional development in order to attract more population and businesses to the area, boost the local economy or improve tourism.

Examples of community funding include environmental community groups, business investments in a specific community or local businesses. Community funding targets individual communities within an urbanized area, while local funding puts the emphasis on large to small urban areas. It is common that community investments just pay for part of a larger smart city project, so they are good as supplements and should be combined with other funding alternatives.

4.3 Public-private partnerships (PPPs)

PPPs provide significant benefits for both the public and private sector, while generating considerable economic gains. Through PPPs capital investments, risks and responsibilities are shared. Moreover, the more partners involved the better, since supervision and funding increase, making it more probable to succeed and obtain a

quicker and larger return on investment. PPPs are a useful tool to increase the quality of the services provided and guarantee economic stability.

Amsterdam Smart City is an example of a public-private partnership, bringing together 20 permanent partners which include governments, educational institutions, social organizations and innovative private companies (Amsterdam Smart City, n.d.).

Innovation districts are also a good example of a PPP, where private companies can test and show new projects to improve city services, providing new policies and tools for city governments. In the Stockholm Green Innovation District municipalities, private companies, research institutes and the City of Stockholm work together to develop innovative and sustainable ideas (Brown, 2019).

4.4 Private funding

Private funding works for both small to medium and big projects, but hardly ever private funding alone is used for entire smart city programs or large projects. Private investors have concrete interests such as economic development, increasing tourism, improving mobility or sustainability goals. The main drawback concerning private funding is that their interest in specific projects can be reduced over time, or that there can be delays or withdrawal of funds. In general, private funding is a powerful mechanism to finance smart city initiatives, but it may be necessary to reaffirm stakeholders interests over time.

It can be the case that public funding attracts private investment, as for example the companies INTEL and Cisco financing @22Barcelona, a former industrial site converted to a place for startups to develop digital platforms.

4.5 Others

Other sources of funding include loans or bonds, available for spending when necessary during the development of the project and supervised by the lenders (for example the government, investment banks or insurance companies, among others). The main disadvantage is that they must be paid back, and most probable the expected expenditure for the project is higher than what it was initially estimated.

Specific user charges and pay for performance are also other alternatives to help financing smart city initiatives. Examples include parking fees, water and utility surcharges or pay for use Wi-Fi.

Funding sources are still limited and competitive, so smart city planners must constantly be looking for new and innovative financing options. It is not enough to have great smart city projects without an appropriate and strategic funding plan from different and diverse sources (Galati, 2018).

5. ANALYSIS OF CURRENT SMART CITIES AROUND THE WORLD

What makes a city smart is motivating citizens to adopt and use the new implemented technologies efficiently and productively in the daily life and business of the city. Becoming smart has as the end goal to improve people's quality of life. As previously explained, smart cities have six dimensions: smart people, smart economy, smart mobility, smart environment, smart living and smart governance.

Many cities all around the globe are considered smart. The goal of this chapter of the final degree project is to analyze 3 smart cities and understand what characteristics enable them to be smart cities, as well as to provide a comparison among them. This analysis is done according to 4 United Nations Sustainable Development Goals (SDGs).

The Institute for Management Development and the Singapore University for Technology and Design (SUTD) have elaborated the third edition of the IMD-SUTD Smart City Index (SCI) 2021. Citizens from 118 cities were asked questions on the *technological provisions of their city across five key areas: health and safety, mobility, activities, opportunities and governance*. Some examples of these questions were the satisfaction with recycling services, air pollution, housing affordability, satisfaction with public transport, employment opportunities, corruption of city officials, citizens contribution to decision making, free public Wi-Fi, bicycle hiring, IT skills taught in schools or online voting, among many others (IMD, 2021). As stated in the annual Smart City Index 2021 and shown in Table 1, the top 10 world smart cities are:

Table 1. Smart City Rank 2021.

Smart City Rank 2021	City	Smart City Rating 2021	Structure 2021	Technology 2021	Smart City Rank 2020	Change	
1	Singapore	AAA	AAA	AAA	1	—	
2	Zurich	AA	AAA	A	3	▲	+1
3	Oslo	AA	AAA	A	5	▲	+2
4	Taipei City	A	A	A	8	▲	+4
5	Lausanne	A	AAA	A	NEW	—	
6	Helsinki	A	AA	A	2	▼	-4
7	Copenhagen	A	AA	A	6	▼	-1
8	Geneva	A	AA	A	7	▼	-1
9	Auckland	A	A	A	4	▼	-5
10	Bilbao	BBB	A	BBB	24	▲	+14

Source: IMD, 2021

7 out of the top 10 are European cities: Zurich, Lausanne and Geneva (Switzerland), Oslo (Norway), Helsinki (Finland), Copenhagen (Denmark) and Bilbao (Spain).

2 cities are Asian: Singapore (Singapore) and Taipei City (Taiwan).

1 city is from Oceania: Auckland (New Zealand).

For the final degree project, 3 out of 10 of these smart cities are going to be analyzed. The chosen cities are Oslo (3), Copenhagen (7) and Singapore (1), from 2 different continents, Europe and Asia, as a way to provide more diversity in the analysis.

5.1 Cities overview

This section presents the 3 smart cities considered for the analysis, selected from the top 10 smart cities from the IMD Smart City Rank 2021.

5.1.1 Data at country level

To begin with some background information, below in Table 2 are presented some important data at country level divided in four categories: economic indicators, social indicators, educational indicators and environmental indicators. This information is useful as a way to have some relevant basic information before reading the analysis of each city.

Table 2. Relevant data at country level

	Year	Norway	Denmark	Singapore
ECONOMIC INDICATORS				
Total population country[1]	11-2022	5,449,650	5,893,211	6,039,577
(Total population capital city)	11-2022	(1,071,062)	(1,370,131)	(5,590,859)
Unemployment rate[2]	09-2022	3.2%	2.2%	2%
Inflation rate[3]	09-2022	7.5%	10%	6.7%
GDP, PPP (Constant 2017 international $)[4]	2021	355.26 B	340.79 B	578.25 B
SOCIAL INDICATORS				
HDI value[5]	2019	0.957	0.940	0.938
Life expectancy (years) [6]	2019	82.4	80.9	83.6
Expected years of schooling[7]	2019	18.1	18.9	16.4
GNI per capita, PPP (Constant 2017 international $)[8]	2021	65,689	58,187	106,032
Social progress index (SPI) [9]	2021	92.63	92.15	84.73
EDUCATIONAL INDICATORS				
Enrollment to tertiary education (%)[10]	2017	81.99	80.62	84.79
	2018	83.02	81.18	88.89
	2019	83.23	81.84	91.09
ENVIRONMENTAL INDICATORS[11]				
Renewable energy in TES	2020	50.6%	43.5%	2.1%
Renewable energy electricity generation	2020	98.7%	84.3%	3.3%
Hydroelectric electricity generation (Gigawatt hours)	2020	141,593	16	N/A
Wind electricity generation (Gigawatt hours)	2020	9,911	16,353	N/A
Solar PV electricity generation (Gigawatt hours)	2020	27	1,181	622
CO2 emissions per capita (tons)	2020	6.7	4.4	8.3
Total CO2 emissions (Metric tons)	2020	36.1	25.6	47.4
Renewable share in final energy consumption	2019	62.4%	37.5%	0.8%
Ecological footprint (Global hectares)	2018	5.7	6.7	5.9

Notes:

Capital Cities: Oslo (Norway), Copenhagen (Denmark) and Singapore (Singapore)

HDI: *The Human Development Index (HDI) is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and have a decent standard The HDI is the geometric mean of normalized indices for each of the three dimensions* (United Nations).

Social Progress Index (SPI): It measures *the extent of which countries provide for the social and environmental needs of their citizens* (A total of 53 indicators) (Statista, 2022).

Tertiary education: *Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Tertiary education, whether or not to an advanced research qualification, normally requires, as a minimum condition of admission, the successful completion of education at the secondary level* (World Bank).

TES: Total Energy Supply

Sources: [1]World Population Review (data taken November 2022), [2,3]Trading Economics (data taken September 2022), [4]World Bank, [5,6,7]United Nations, [8,10]World Bank, [9]Statista , [11]International Energy Agency

After providing information at country level to get a general view of each city and country, it is time to provide a deeper analysis of each smart city.

5.1.2 Oslo

Norway is one of the countries with the highest share of renewable energy in the world, being hydropower the source of most renewable electricity (International Energy Agency, 2022). According to the country's Government, 98% of all Norwegian electricity production comes from renewable sources (Regjeringen, 2016).

The fight against climate change has been a priority in Norway for many years, being Oslo awarded as European Green Capital in 2019. In the year 2016, the city set as its main target a reduction in emissions of 95% by 2030 and becoming carbon neutral by 2050 (Sustain Europe, 2019). In order to achieve these objectives, since 2017, Oslo Climate and Energy Strategy has been integrating climate budgets establishing maximum emissions into the government's budget. The climate budget is modified and updated every year and relevant sector performance data is made available each quarter. This way, there is more efficiency in the allocation of funds. There is also a more transparent administration, in which every department in the government is encouraged to suggest new measures for next year's climate budget and achieve the established goals with the funding received (Smart City Press, 2019).

In October 2020, electric vehicles accounted for 65% of sales. The Public Administration provides many incentives for citizens to switch to electric cars with cuts of minimum 50% in parking fees and exemptions from several tolls. Introduced in 1990, the Oslo Toll Ring offers incentive rates for electric vehicles and finances the smart city's mobility programmes through its revenues. Authorities have also introduced emission-free vehicles for public transport (Fjord Tours, 2020). Buses, ferries and trams are electric in Oslo, operating on renewable hydroelectric power. In order to make Oslo greener and decrease air pollution, cars are completely forbidden in some streets in the city center. The number of car parking spaces in public buildings has been reduced, and some sites do not even offer parking for cars (Williams, 2019).

The city also has an efficient waste management system, which is continuously upgraded with new technological innovations. Plastic is recycled, and food waste is biologically transformed into biogas to run buses and biofertilizer supplied to medium-sized farms. Regarding the building sector, fossil fuels have disappeared from the city's heating district systems, since 99% of the energy comes from heat recovered from sewers (Smart City Press, 2019).

Established in 2010, the FutureBuilt programme brings together private and public investors in projects focused on architecture and the development of urban areas that cut carbon emissions by at least 50% (FutureBuilt, 2020). In fact, partnerships between public authorities and private investors has been a key element in the transformation of Oslo towards a smart city. Organizations such as Smart Oslo Accelerator connect local authorities with startups, through their annual contest Smart Oslo Pitch entrepreneurs and startups present their innovative ideas concerning health, mobility, climate and other urban challenges to the citizenry (The Agility Effect, 2019).

5.1.3 Copenhagen

Denmark is known for its wind power production, with a wind production per capita higher than in any other OECD country. In fact, wind is the source of most renewable electricity (International Energy Agency, 2022). Bioenergy is also frequently used as a renewable energy source, mostly coming from agricultural activities: animal waste such as manure and fats or straw used to produce biogas or biofuels. Denmark is also focusing on providing sustainable biomass, which is the basis for most Danish power plants and

comprises around 50% of the fuel for district heating (Official website of Denmark, 2021).

67% of the electricity supply is derived from renewable energy, and the Climate Act passed by the Danish Parliament in 2020, set a target to reduce greenhouse gas emissions by 70% in 2030 and climate neutrality by 2050 (US International Trade Administration, 2013).

Copenhagen wants to become the world's first carbon-neutral capital by 2025. The city was named European Green Capital in 2014 as a result of its 3 main objectives of achieving carbon neutrality: *creating a greener, more sustainable, and more livable capital city; and supporting economic growth.* One of the objectives of Copenhagen's Climate Action Plan is to guarantee that 75% of all trips in the city should be by foot, bicycle or public transport. In fact, due to the high taxes on vehicles in Denmark, commuting using the bicycle has been part of the lifestyle of citizens for a long time, intensifying Copenhagen's biking culture (Quélin and Smadja, 2021). The city is also considered as the *world's most practicable city for cyclists* (European Commission, 2012). Being such a bicycle friendly city is fundamental to become a smart city and accomplish the objective of becoming carbon neutral by 2025.

Becoming smart is a political priority for the city, and Copenhagen is Europe's largest living lab for testing new smart city technologies and solutions, with around 250 companies involved, making public-private partnerships (PPPs) very important. Some of these technologies generate data to improve citizen's quality of life, like sensors that monitor traffic or pollution to create a more livable city. A main target of the government is to optimize road traffic, by setting more car free zones and banning diesel in the city center (Findlay, 2021).

For decades, Denmark has stored basic data about citizens, businesses and real estate. The City Data Exchange (CDE) allows for private and public data exchange by creating an open data marketplace that allows companies to develop innovative solutions to make the city better manage the green transition.

5.1.4 Singapore

Being a small island with a lack of natural resources, Singapore has managed to become one of the richest nations in the world. One of the key drivers of its growth has been its continuous investment in people.

Singapore faces several challenges: a high population density and a big dependence on exports. The city uses information based technology and applications to bring solutions to these challenges and become smarter. Through its Smart Nation initiative, which brings strong assistance from artificial intelligence experts to use hyper connective modern technology in order to improve urban life, Singapore can be considered as one of the world's most advanced smart cities (Quélin and Smadja, 2021). The government has played a key important role in providing the IT infrastructure and designing policies to foster multinational IT corporations to set up operations in Singapore. The path of becoming a Smart Nation relies on 3 main components: digital society, digital economy and digital government.

According to the Digital Readiness Blueprint, the government, in partnership with the public and private sectors, ensures that *everyone can experience the benefits of technology,* focusing on the digital inclusion of the more vulnerable segments of society. The government has been providing technological devices at subsidized rates to low-income households and has been encouraging the public and private sector to help more Singaporeans adopt technology while fostering community participation. Overall, digital readiness has become a national effort (Singapore Infocomm Media Development Authority, 2022). According to a report by BusinessFibre in 2020, from the 3 analyzed cities, only Singapore is among the *Top 10 Most Internet Friendly Cities* in the world (BusinessFibre, 2020).

Following the Digital Economy Framework for Action, Singapore aims to become the leading digital economy by digitizing economic growth. Through its research institutions and highly trained workforce, Singapore has managed to attract the biggest technological companies in the world (Singapore Infocomm Media Development Authority, 2022).

Improving energy efficiency is still a relevant focus for Singapore. Carbon-intensive fuel oil has been substituted to natural gas for electricity generation and there has been a stronger focus on solar energy. However, the implementation of a renewable energy program is a challenge in Singapore for 3 main reasons: the country does not have enough space for wind turbines, tidal and hydroelectric power generation is difficult and the

country's small size, land scarcity and high population density makes it overall complicated to adopt renewable energy sources. The country is putting its effort to make solar panels a larger part of its energy mix (Strategy Group Prime Minister's Office, 2022). The solar photovoltaic electricity generation has been increasing during the last years (International Energy Agency, 2022). The Housing and Development Board (HDB) promotes and accelerates installations of solar panels on buildings (Quélin and Smadja, 2021).

5.2 Analysis of the cities based on their performance with the United Nations Sustainable Development Goals

In 2015, the United Nations launched its 17 Sustainable Development Goals (SDGs), or ¨Goals to Transform Our World¨, as seen in Figure 3. The main objective of these goals is to achieve a more sustainable economy which allows to end poverty, build economic growth and fight climate change. The 17 goals are interconnected, and the objective is to achieve them all within 2030 (United Nations). Research shows that 70% of the UN Sustainable Development Goals can be achieved through smart city technology, so that is why this final degree project considers these goals as a tool to analyze smart cities performance (Quélin and Smadja, 2021).

Figure 3. The 17 UN Sustainable Development Goals

As mentioned in the introduction of the final degree project, the focus will be put on 4 SDGs (sorted by relevance):

- Goal 11. ¨Sustainable cities and communities¨
- Goal 7. ¨Affordable and clean energy¨
- Goal 13. ¨Climate action¨
- Goal 8. ¨Decent work and economic growth¨

All these goals have numerous targets in order to assess and serve as a guide for the achievement of the goals. In practice, it is complicated to check if all the indicators and targets are being followed. For the review of each smart city, I will mention the targets which I think that suit the examples given.

Goal 11 can be considered the most relevant one to be examined, which focuses on *making cities and human settlements inclusive, safe, resilient and sustainable*. Some of the targets include affordable housing, sustainable public transportation, urban development and governance while increasing inclusiveness and participation, air quality, waste management, and access to green public spaces. Table 3 shows which were the majority of targets found, out of the total 15 targets that SDG 11 has.

Table 3. The most common targets found for Goal 11

11.1	*By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums*
11.2	*By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons*
11.6	*By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management*
11.7	*By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities*

For goal 7, *ensuring access to affordable, reliable, sustainable and modern energy for all*, targets include increasing the share of renewable energy in the global energy mix and making energy services universal, reliable and affordable. Goal 7 has a total of 6 targets, and Table 4 shows which of these targets were the most common in the analysis provided of the smart cities.

Table 4. The most common targets found for Goal 7

7.1	*By 2030, ensure universal access to affordable, reliable and modern energy services*
7.2	*By 2030, increase substantially the share of renewable energy in the global energy mix*
7.b	*By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support*

Source: United Nations

Goal 13 emphasizes on the *urgent action to combat climate change and its impacts*, with targets such as integrating climate change measures into national policies, raising awareness regarding climate change and increasing the capacity to face natural disasters. Goal 13 has a total of 8 targets. In Table 5 it can be seen which targets were mostly found.

Table 5. The most common targets found for Goal 13

13.2	*Integrate climate change measures into national policies, strategies and planning*
13.3	*Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning*

Source: United Nations

Finally, goal 8 aims to *promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all*, focusing on targets such as promoting entrepreneurship, creativity and innovation, achieving full and productive employment by 2030 and promoting sustainable tourism. (United Nations). Goal 8 has a total of 16 targets but those to be taken into consideration for the smart cities analysis can be found in Table 6.

Table 6. The most common targets found for Goal 8

8.2	*Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labor-intensive sectors*
8.3	*Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services*

Source: United Nations

5.2.1 Oslo

Oslo has several projects in accordance with SDGs, many of them directed to the goal of reducing emissions of 95% by 2030.

An example of accomplishing SDG 11 in urban development can be found in Oslo's zero-emissions construction sites, as in the transformation of Olav Vs gate into a car-free pedestrian street. This example can be associated with target 11.6 Moreover, this project can also be linked to target 13.2 for being an environmentally friendly initiative, replacing diesel with electricity in all the machinery used. Other benefits of this measure include that the area is quieter and overall less polluted (Gundersen, 2019).

Oslo is considered as the electric vehicle capital of the world. Around 70% of commuters use public transport, and the city aims to have zero emission public transportation from 2028. Currently, 38% of buses are electric. All taxis must be zero emission from 2024 on. Another target is to reduce the use of private cars, providing initiatives like car-sharing and increasing the number of e-scooters around the city. Oslo is also investing in cycling and the development of more bicycle lanes, which is financed by toll roads. As a matter of fact, the number of private vehicles in Oslo is declining due to the expensive toll roads

(which become even more expensive during rush hours) (Arval Mobility Observatory, 2021). The rise of electric vehicles is clearly related with SDG 11 in terms of achieving greener and more sustainable transport solutions and SDG 13 in reducing greenhouse gas (GHG) emissions. Moreover, it can be associated with target 11.2 because there is an increase in the available electric and sustainable public transport.

Hovinbyen, the new fringe city of Oslo, aims towards creating a base for social and safe smart cities, making Oslo more sustainable, attractive and inclusive, and raising citizen's awareness. The whole Hovinbyen project fulfills many of the SDG, while making Oslo smarter. Urban development in the area focuses on providing more housing and businesses and ensuring short distances between basic services, so that the use of cars is not necessary (City of Oslo, n.d.). Again in this example, especially SDG 11, with target 11.1 and SDG 13 are met, more specifically following targets 13.2 (being Hovinbyen a city strategy) and 13.3, because the objective is to have more informed and conscious citizens.

Oslo is energy efficient since 80% of the city's heating system is powered by renewable energy, mainly from biomass from residual waste, fulfilling targets 7.1 and 7.2.

Regarding SDG 8, innovative organizations such as SmartOslo Accelerator connect the city of Oslo with the startup community. Entrepreneurs and startups can bring up creative and smart ideas concerning mobility, climate or health through organized activities like the SmartOslo pitch. This is a clear example of targets 8.2 and 8.3, because it emphasizes on increasing productivity thanks to technological improvements, entrepreneurship, creativity and innovation.

5.2.2 Copenhagen

Copenhagen has many initiatives and projects which can be linked to the SDGs.

Through its testing living labs, many projects involving sensors to control traffic, waste, pollution, or garbage can be included under target 11.6 of SDG 11, because they tend to make Copenhagen a more sustainable and livable city by reducing its environmental impact.

The Nordhavn project, which aims to be Scandinavia's largest and most ambitious urban development project, also contributes to achieving target 11.1, since it deals with the city's future need of housing, with environmentally friendly buildings and energy supply.

The project also contributes to accomplish SDG 7, through EnergyLab Nordhavn, demonstrating how *electricity and heating, energy-efficient buildings and electric transport can be integrated into an intelligent, flexible and optimized energy system* (Energy Lab Nordhavn, 2020), contributing to target 7.1. SDG 13 is also addressed, since the Nordhavn project also focuses on fighting climate change by fostering journeys by foot, bike or public transport, with new openings of metro stations and a ¨super bikeway¨ to reach the city (Danish Architecture Center, n.d.). This example can be linked to target 13.2.

Copenhagen's bicycle strategy success is highly unique. The installation of new cycling highways following the Super Cycle Highway is a big part of the city's Sustainable Urban Mobility Plan (SUMP). Fostering the use of the bicycle highly contributes to reaching the goal of reducing carbon emissions, which is a big part of SDG 11 and 13. As a matter of fact, Copenhagen ranks second as the city with the best air quality among 23 European cities (Quélin and Smadja, 2021). Copenhagen's approach to become a smart city puts its main focus on its objective to become carbon neutral by 2025, providing mainly environmental initiatives associated with this commitment.

Regarding SDG 8, Copenhagen is one of the easiest places in the world to do business, according to the World Bank 2020 Ease of Doing Business Index, with shorter working hours and one of the most productive workforce in Europe. It is worth mentioning Copenhagen's fast growing startup ecosystem, with a value of around $4.6 billion in 2019. The PPP Digital Hub Denmark works to make Denmark the best digital growth environment in Europe. The city also hosts several technological focused events, such as Tech BBQ, where thousands of entrepreneurs meet and share knowledge (Startup Genome, 2021). This is in accordance with targets 8.2, 8.3 and 8.5, since there is a focus on productive employment through technological upgrades and an entrepreneur culture.

Also linked with SDG 8, Wonderful Copenhagen, the official tourism organization of the Capital Region of Denmark, launched its first strategy for sustainable tourism in 2018, contributing to the UN sustainable development goals.

5.2.3 Singapore

With the aim to become a Smart Nation, Singapore is carrying out many strategies which are aligned with the UN SDGs. More concretely, its efforts towards solar energy and greening of buildings contribute to SDGs 11, 7 and 13.

The Housing and Development Board (HBD) manages the installation of solar panels in around 10,000 residential blocks. The government has indeed executed an initiative to convert Singapore into a ¨city in a garden¨ with solar powered super trees reaching up to 50 meters, and smart and sustainable towns (IMD, 2021).

In alignment with the Sustainable Singapore Blueprint, the HBD is committed to sustainable building and urban living. Through its Building Research Institute, a lot of work is being done to provide more energy efficiency, implement more urban greenery, bring more efficient solutions to water conservation and waste and develop new building technologies. All this commitment clearly follows targets 11.1, 11.6 and 11.7. New technologies include using energy from the elevators to generate power to use in other parts of the building. Singapore also has the first net zero energy building in Asia, building SDE4 from National University of Singapore's (NUS) School of Design and Environment, which produces energy through rooftop solar farm and includes other innovative sustainable building strategies (Jenie, 2019). Moreover, bank DBS has opened in Singapore its first net zero building, DBS Newton Green. This contributes to the nation's target of greening 80% of Singapore's buildings by 2030 (as of end 2021, 49% of Singapore's buildings have been greened), which aligns with the UN SDGs 11, 7 (in particular targets 7.2 and 7.b) and target 13.2 (Singapore Building and Construction Authority, 2022).

The Singapore Green Plan 2030 also has as an objective to increase the amount of electric vehicles in the long run, in its vision to have 100% cleaner energy vehicles by 2040. As an example, all public buses will be electric by 2040 (US International Trade Administration, 2021).

Regarding SDG 8, there is an achievement of targets 8.2 and 8.3, since Singapore's ultra-high speed broadband and high mobile and internet penetration makes it a perfect place for developing startups and doing business. As a matter of fact, a study conducted in 2022 has revealed that Singapore is the world's most entrepreneur friendly city (CompareMyJet, 2022). Many government based agencies provide financial aid to

startups, and the country has been committed to cybersecurity in its target to become a smart nation.

5.3 Summary and comparisons

Overall, it can be said that the 3 cities contribute to increasing the quality of life of their citizens by carrying out several smart cities initiatives aligned with the UN Sustainable Development Goals. This research project focuses on 4 SDG and some of their respective targets, and the findings of how the studied smart cities approach them can be summarized in Table 7:

Table 7. Summary of city initiatives and targets related to SDGs 11, 7, 13 and 8

Target	OSLO	COPENHAGEN	SINGAPORE
11.1 (SDG 11) Adequate, safe and affordable housing	Hovinbyen project: more adequate housing and businesses ensuring short distances between basic services	Nordhavn urban project: future housing, environmentally friendly buildings and energy supply	Sustainable Singapore Blueprint: sustainable building and urban living
11.2 (SDG 11) Sustainable (public) transport systems for all	More bicycle initiatives and more electric vehicles in public transportation	Bicycle as a central strategy: Super Cycle Highway	All buses will run on clear energy by 2040
11.6 (SDG 11) Reduce environmental impact of cities (air quality and waste management)	Zero-emissions construction sites and parts of the city becoming car free.	Testing living labs: Sensors to control traffic, waste, pollution, or garbage	Fostering the use of private electric vehicles
11.7 (SDG 11) Safe, inclusive and accessible, green and public spaces	Car free areas in the city are more accessible to the public		Building Research Institute: implementing more urban greenery
7.1 (SDG 7) Universal, reliable and modern energy services	A considerable increase in the use of renewable energy (biomass from residual waste)	The whole Nordhavn project (including the EnergyLab)	Solar pannels strategy, ¨city in a garden¨

7.2 (SDG 7) Increasing the share of renewable energy in the global energy mix	80% of the heating system powered by renewable energy	EnergyLab Nordhavn: Efficient electricity and heating, energy-efficient buildings and increase in electric transport	First net zero energy building in Asia (target of greening 80% of Singapore's buildings by 2030)
7.b (SDG 7) Expand infrastructure and upgrade technology for supplying modern and sustainable energy services	Replacing diesel with electricity in all the machinery used for the transformation of Olav Vs gate	EnergyLab Nordhavn: A more intelligent, flexible and optimized energy system	Greening 80% of Singapore's buildings by 2030 New technologies include using energy from the elevators to generate power to use in other parts of the building
13.2 (SDG 13) Integrate climate change measures into national policies, strategies and planning	Hovinbyen as a strategy to make Oslo smarter, more sustainable and attractive Main goal of reducing emissions of 95% by 2030	Bicycle as a central strategy: Super Cycle Highway (among top cities with best air quality) Target of becoming carbon neutral by 2025	Carbon-intensive fuel oil has been substituted to natural gas for electricity generation
13.3 (SDG 13) Improve education and awareness-raising on climate change mitigation	Raising citizen's awareness through the Hovinbyen strategy	Fostering journeys by foot, bike (¨super bikeway¨) or opening new metro stations	Overall efforts of society to use more renewable solar energy
8.2 (SDG 8) Higher levels of economic productivity through diversification, technological upgrading and innovation	SmartOslo Accelerator: connecting the city of Oslo with the startup community	Fast growing startup ecosystem Hosting technological focused events, such as Tech BBQ	Ultra-high speed broadband, high internet penetration, cybersecurity
8.3 (SDG 8)			

| Policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation | SmartOslo Accelerator (SmartOslo pitch: Entrepreneurs and startups can bring up creative and smart ideas) | One of the easiests place in the world to do business

PPP Digital Hub Denmark | Many government based agencies provide financial aid to startups

World's most entrepreneur friendly city |

Source: *Author*

It must be mentioned that the 3 countries differ among each other, therefore, some smart city strategies might be very similar while others are different, but the important aspect is to realize that 3 different countries have been able to convert their main cities into smart cities. As a result, it can be possible for any other city from another country to become smart.

While hydropower the source of most renewable electricity in Norway, wind power production is the source of most renewable electricity in Denmark. Singapore is so small that it is complicated for it to adopt renewable energy sources, but the country is putting a lot of effort into its solar panels strategy. The importance of increasing the share of renewable energy contributes to approaching SDG 7.

From the 3 nations, only Denmark has been decreasing its total CO_2 emissions during the last years, from 1990 on the country has lowered them 49.82%. However, Norway has increased them 31.45% and Singapore has increased them 63.55%.

The 3 countries have been decreasing their CO_2 emissions per unit of GDP and have been rising the share of renewables in final energy consumption. Only Singapore has been increasing its natural gas final consumption over the years. Singapore has steadily increased its solar photovoltaic electricity generation, and both Norway and Denmark have increased it as well (IEA).

Each city has its own initiatives regarding housing, waste management, air quality or water conservation, among others, as it has been shown with the Hovinbyen project in Oslo, the Nordhavn project in Copenhagen and the Smart Nation initiative in Singapore. These different initiatives aim to achieve SDG 11.

They all have an important focus on increasing the number of (public) electric vehicles and the reduction of emissions as a way to fight against climate change, which contribute to the United Nations SDG 13. Oslo aims to have zero emission public transportation from 2028 and expects that all taxis must be zero emission from 2024 on. Through the

installation of new cycling highways following the Super Cycle Highway plan, Copenhagen is contributing to its target of guaranteeing that 75% of trips inside the city should be made by foot, bicycle or public transport. Singapore also expects to accomplish 100% cleaner energy vehicles by 2040, with all public buses being electric by this same year. The analyzed 3 cities are committed to the reduction of greenhouse gas emissions, but each one has a different end goal: Oslo aims to reduce emissions of 95% by 2030, Copenhagen wants to become carbon neutral by 2025 and Singapore is working towards greening 80% of buildings by 2030.

The 3 studied cities are great examples of places suitable for the development of innovative and technology related startups and businesses, which at the same time enables them to become smarter. It is important to recall that Norway, Denmark and Singapore have low unemployment rates, and that their HDI, percentage of population aged 25-34 with tertiary education and GNI per capita are quite high. As a result, the smart cities of Oslo, Copenhagen and Singapore are expected to be inhabited by smart people. As previously emphasized in the final degree project, among all 6 dimensions, the smart people dimension is the most important for the development of a smart city. This can explain why workers in these 3 cities tend to be more productive, why startup communities are established in these locations, or why it is just easier to do business in these places, as Copenhagen being categorized as one of the easiest places in the world to do business. A special mention has to be made to Singapore, recognized as the world's most entrepreneur friendly city. Overall, it can be concluded that Oslo, Copenhagen and Singapore contribute efficiently to SDG 8.

6. CONCLUSIONS

Smart city initiatives are becoming more common in cities all around the world. This final degree project aimed to explain what is behind this concept and how a city can become smarter, following some real city examples.

We are living in a world full of challenges, and urbanization is becoming a big challenge for some city authorities. In a world in which 5 billion inhabitants are expected to live in urbanized areas by 2030, technology is becoming a key element to make government measures more efficient and can at the same time increase the quality of living (United Nations Population Fund, 2022). For instance, the use of sensors to monitor pollution and

air quality based on real time data allows authorities to implement strategic plans for urban development which would otherwise take more time to be developed. Throughout the final degree project, it has been emphasized that technology and ICT are extremely important for a city to become smarter, and how they influence the 6 smart city dimensions: smart people, smart economy, smart mobility, smart environment, smart living and smart governance.

However, no matter how technological a city can become, it will not be totally smart until it ensures citizens involvement and participation. Smart people is the most important dimension, and it has been proven how the 5 remaining dimensions depend on it. Citizens are the ones capable of changing the city. Nevertheless, governments have the responsibility of bringing the initiatives and resources to make possible the advancement of the smart city planning. What makes a city smart is the compromise of its community, so a smart government must foster participation and must make citizens willing to take part in the activities and proposals.

All government plans to transform the city into a smart city must at least include strategies to make the economy smarter. As emphasized throughout the project, an innovative economy is essential in order to ensure economic growth, efficiency and competitiveness. Consequently, authorities must consider building its own communications network and must work towards achieving digital inclusion. Cities with a high speed broadband and internet (also 5G) attract companies and startups, mostly technological, which at the same time attract a high skilled workforce willing to settle in the city. As a result, a good government plan must also make an effort to provide available, affordable and convenient housing options that ensure good living conditions to citizens.

Regarding financing options for smart cities, even though there are several possibilities, public-private partnerships (PPPs) tend to have the most successful outcomes. Some PPPs examples have been provided when analyzing the smart cities of Oslo, Copenhagen and Singapore, which usually consist of bringing together entrepreneurs, researchers, experts or citizens to foster the development of smart city initiatives.

I must mention that I am aware that throughout all the final degree project there has been a too optimistic view of the smart city concept. All the available literature that I found only considered the positive aspects of smart cities, and it was difficult to find possible disadvantages of them. Many questions can arise after reading this project: ¨When is a city fully smart?¨, ¨How can a city start becoming smarter?¨, ¨What does smart people

really mean?¨, ¨What about data privacy, when everything is so connected?¨, ¨What happens with waste in a smart city?¨, and many other questions. I think it is pretty difficult to answer to all of these questions, but we can observe some smart city initiatives adopted by cities across the globe and draw some conclusions. The analysis and comparison of the 3 aforementioned smart cities shows the path that other cities must take when working towards becoming smarter. None of these cities is a perfect smart city, and it practice it might be very difficult, even impossible, to find a perfect example of a smart city, but these 3 cities are great examples of policies, initiatives and visions, which are aligned with the United Nations Development Goals, to be more sustainable and efficient, fight against poverty and be more environmentally conscious, while at the same time ensuring economic growth.

In short, I hope this final degree project brings more clearance and understanding towards smart cities and its implications, as a way for urban areas to be more sustainable, productive, inclusive and technological in order to increase the quality of life of citizens.

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