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Which Way to Cope with COVID-19 Challenges? Contributions of the IoT for Smart City Projects

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Abstract: Many activities and sectors have come to a halt due to the COVID-19 crisis. People and workers' habits and behaviors have changed dramatically, as the use of technologies and connections, virtual reality, and remote support have been enhanced. Businesses and cities have been forced to quickly adapt to the new challenges. Digital technologies have allowed people to have better access to public services due to improved use of resources. Smart cities have significant potential for linking people to work and services as never done before. Additionally, the technological convergence produces data that can enhance interactions and decisions toward the "new normal". In this paper, the aim is to assess how Portugal is prepared to respond to the accelerated process that this context demands from cities. Portuguese SMEs have developed a good capacity for entrepreneurship and innovation; however, they are still behind in converting the knowledge acquired in sales and exports and there is still limited collaboration at the public-private level. The acceleration of smart cities through the Internet of Things (IoT) may encourage changes in these issues. A more assertive alignment between the emergent technologies and the digitization goals of companies is required. This paper opens a discussion around major needs and trends of IoT (and related technologies) since the pandemic has leveraged them. The relationship between innovation and city smartness is approached to assess main contributing and limiting variables (through the European Innovation Scoreboard), to clarify future directions toward smarter services. The tourism sector, as the largest export economic activity in the country, is addressed in this matter. An analytical framework (using, for example, Power BI and Azure IoT Hub) around this approach can choose and support the most suitable areas of development in the country.

Keywords: smart city; IoT; AR; AI; innovation; COVID-19

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1. Introduction

Across the globe, many business operations of various types and sizes have halted due to the COVID-19 crisis, but essential sectors, such as construction, have soldiered on. Many workplaces and activities involve people going to factories, but suddenly COVID-19 has altered these habits. This is where the use of technologies, such as the Internet of Things (IoT), augmented reality (AR), and remote support of frontline workers, has accelerated. The objective has been to enable experts to be productive by helping to resolve production issues remotely.

Economies have been forced to adapt quicker to these challenges. Now, employers have an understanding of the operational and financial results that digital processes can deliver, causing a major rise in their adoption [1]. Thanks to the development of the IoT, job sites are being reimagined from the ground up. Many of the changes are here to stay, even after the pandemic outbreak is contained. With capabilities such as real-time tracking and monitoring, the IoT is creating a set of possibilities for businesses and cities. Digital technologies translate into better public services when there is an improved use of resources, with less impact on the environment [2] and when they allow more transparent communication between government and citizens.

According to [3], Portugal has effectively implemented broadband connectivity, and therefore offers a favorable environment for entrepreneurship and innovation. However, a considerable number of citizens still lack digital talent [1]. Thus, there is still a low conversion of the knowledge acquired in sales/exports. Private investments in R&D have been low, making Portugal more dependent on public incentives. The technological convergence involved in smart cities may encourage changes related to these issues. The information in this paper is intended to add to the discussion around the best directions to follow facing the national innovation index, its relationship with smarter systems, and pandemic impacts.

The remainder of this paper is structured as follows: In Section 2, the potential of smart cities through the underlying infrastructure of digital services and resulting interconnected data is described; in Section 3, some examples in the world are compared in order to identify common issues in terms of the sectors in which these services are focusing, which are important for delineating major needs and trends of the IoT (and related technologies) to cope with the pandemic challenges; in Section 4, the relationship between innovation and city "smartness" is highlighted as the national innovation index reveals that Portugal recently changed from a "moderate" to a "strong" innovator, thus, main contributing and limiting variables are assessed, through the European Innovation Scoreboard (EIS), which clarifies the aspects that should be enhanced for smarter solutions (in this context, the tourism sector, as the largest export economic activity in the country, is discussed around its "fourth level" which entails the IoT potential applications); in Section 5 conclusions, limitations of this work, and consideration for future research are provided.

2. Smart Cities' Potential

Smart city is a new trend in the development and governance of cities, which involves applying new technological platforms (TP) that allow citizens free access and use of information and applications about their city. The performance parameters of smart cities are based on aspects ranging from governance, urban mobility, environment, innovation to connectivity, and social inclusion [4,5] (Figure 1). Smart cities are distinguished by participatory governance and its monitoring, in order to plan investment resources in the most deficient areas or that require preventive maintenance actions.

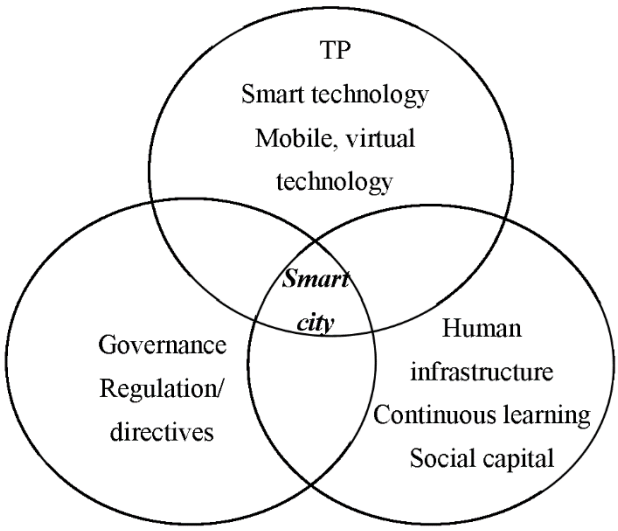

Figure 1. Performance parameters of smart cities.

A city that is more connected to its population works better. Small steps are taken towards smart cities when improving smart living in cities. Such steps are materialized through cyber-physical applications that allow citizens to be proactive about their surrounding activities. Smart cities are those cities with active policies that use technology to improve urban infrastructure and make urban centers more efficient, which means

incorporating sensors and other technologies into a destination to monitor and collect data on everything from traffic to energy use. The data are communicated through wired and wireless connections, via the well-known IoT in which everything is interconnected [6], and then the collected data are analyzed to assist decision making by the government and companies.

The Importance of Data Analytics

The results (outputs) of digital urban information systems are still static and simple. They usually appear in the form of simple queries, devoid of data analysis from various sources over time to assist the decision-making process in urban management.

One of the keys to building a smart city today is the integration of heterogeneous urban data from various sources. In addition, there is a need to manage urban infrastructure and the ability to quicky view and update multidimensional spatial and temporal data. Emerging advances in web and sensor technologies (Figure 2), in processing and storage capacity, and reduced cost of sensor production, have allowed the leap to the design, planning, and development of smart cities [7,8].

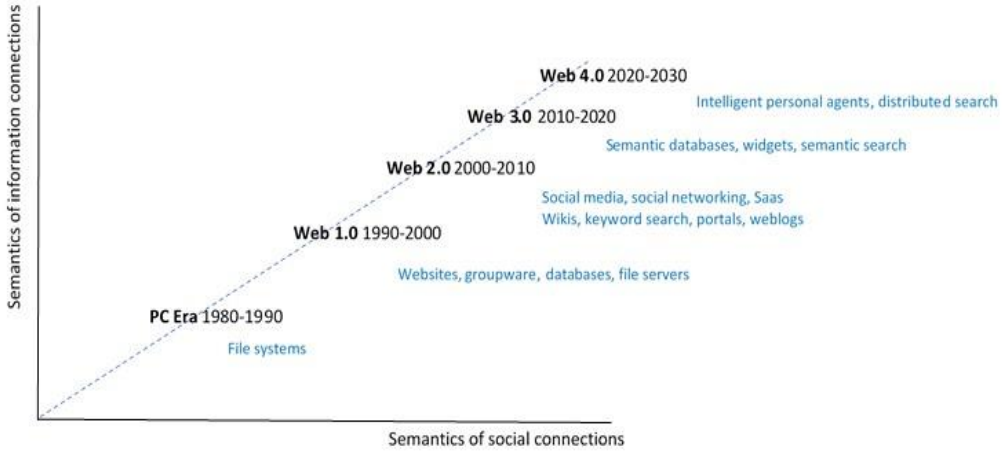

Figure 2. Advances in web technologies (http://ahmadfaizar.blogspot.com/2018/08/evolution-of-web-web-10-web-20-web-30.html), accessed on 17 May 2020.

The more technologies and systems imitate and respond to human needs in society, the higher levels of web, Wi-Fi, and connection are needed. Technologies such as big data and IoT have allowed more innovative and creative developments for smart cities [9]. In addition, artificial intelligence (AI) and machine learning (ML) have made computers able to process large amounts of such data. Extracting meaning and knowledge from the data is crucial for governments and businesses to support their strategic and tactical decision-making.

The IoT is an integral part of the future internet ecosystem (FIE) that will have a major impact on the development of e-services. It provides an infrastructure that identifies and connects physical objects to their virtual representations, on the internet [10]. As a result, any physical object can have its virtual reflection in cyberspace. This gives the opportunity to replace actions on physical objects with operations on their virtual representations, resulting in faster, cheaper, and more comfortable services, which can expand the development and implementation of new business models (Figure 3).

In this sense, several applications have been developed and some cases are briefly described in the next section.

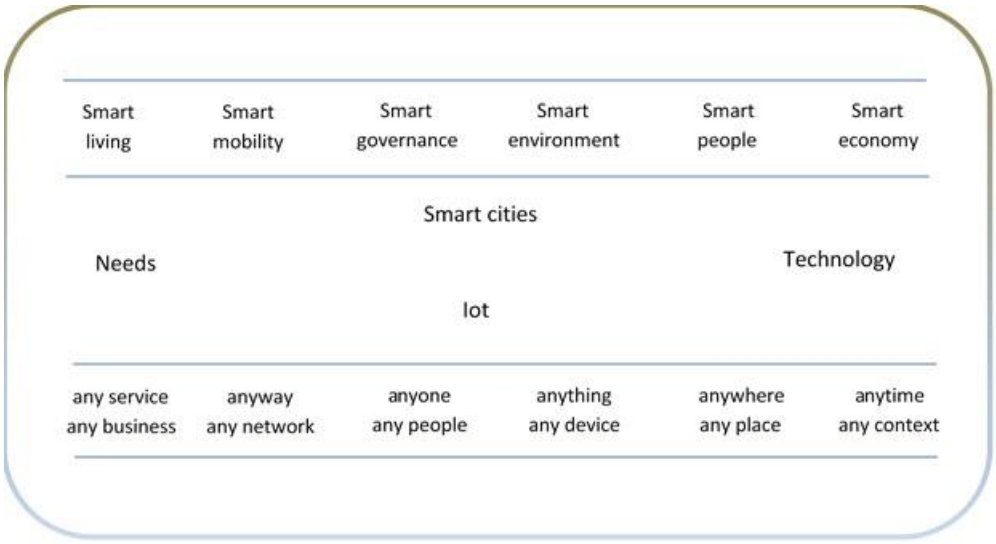

Figure 3. An expanded potential for new business models.

3. Cases of Smart Cities and Common Aspects

Some cases of smart cities in the world and their main aspects are described below [11]:

- New York was voted the smartest city in the world by the IESE Center for Globalization and Strategy. In collaboration with Cisco, the city launched an interactive platform that converted old public telephone systems to provide internet access for all residents. In addition to providing information about local events, neighborhood news, and entertainment lists, the platform also provides security alerts. In traffic, for example, the Department of Transport started to manage city traffic using real-time data. Almost 300 sensors and cameras provide statistics and modify traffic light patterns, resulting in a 10% improvement in travel times.
- The city of Amsterdam is a pioneer in Europe in terms of investing in technology and sustainability. It has a platform that offers support and incentives for institutions, companies, and citizens to develop green projects, which can benefit the quality of urban life for all inhabitants. The infrastructure department has developed innovative products and services in the field of urban mobility, providing data on traffic and available transport options, in addition to the availability of parking, taxis, and cycle paths. The city also invests in the development of mobile technologies (such as Drive Carefully, an application that alerts drivers when they are driving near a school to slow down). In addition, several houses and buildings have been adapted with efficient insulation to reduce energy costs, automatic dimming switches, smart electricity, etc.
- Tokyo is also known as the capital of technological and futuristic novelties. This includes developing efficient measures to control the amount of energy used in homes and commercial buildings. Japan's biggest companies have taken on the responsibility of developing and spreading smart technology to revolutionize the city. Panasonic, for example, built an eco-friendly neighborhood where its old factory was located. All houses are based on the use of renewable energy.

Other examples of cities with smart city initiatives include San Francisco, Vienna, Copenhagen, and Curitiba. The common aspects to these projects, in terms of the sectors in which they focus, are transportation; 'green' city (waste recycling, air quality, renewable energy), and urban mobility applications.

Regarding the pandemic and mobility issues, thermal cameras in IoT systems can capture workers' heat profiles. From there, an AI agent acting as a virtual safety inspector can help ensure that appropriate distances are maintained between people. Alongside Bluetooth-based tracking technology, this is being employed to contact trace assets and individuals in areas such as construction sites, factories, and hospitals [12]. To simplify

things, an on-site employee can capture images and videos with a camera and share them with team members and regulators. Thanks to the IoT, they are able to monitor supply chain logistics, inspect sites, and ensure the safety of on-site workers.

Even in the tourism sector, online technologies can contribute to reinvent experiences. In spite of not being the same as real travelling, they can contribute in terms of fun/entertainment and discovery/research of unknown aspects about destinations, by involving tourists with a city to make their experience memorable, through augmented and sensitive reality (AR/SR). For example, when virtually visiting a place, the use of AR/SR, in addition to being a way to replace the real visit, can also enrich the associated experience [13,14]. Here, a trend will be the intensification of smart and sensory characteristics of IoT and AR (combining image, video, audio, and ubiquity).

Urban tourism is driven, in part, by major events such as concerts, fairs, and sporting events. Intelligent crowd management is a way for smart urban tourism to take advantage of the IoT to optimize the services provided. However, due to the present pandemic context, those technologies can be used for control. If well planned, such a platform can help move people elsewhere, build services based on their behavior, and even target ads to where people will be at a foreseeable time. If several information technologies and systems interact in the IoT paradigm, it will be possible for a smart city to respond better to a more sustainable tourism because necessary assets such as public health, security, transport, and logistics will be more and better safeguarded [15].

4. Relationship between Innovation and City Smartness

Portugal is increasingly a country of smart cities, as more and more municipalities are betting on the concept of smart city. In many cases, people do not even realize that this technological infrastructure is supporting part of their lives. For example, there are those who continue to dispose of garbage at eco-points, but do not know that this eco-point communicates its capacity in real time and that this information influences the waste collection circuit [16].

The Smart Cities Section, founded in 2016 by the Association of Portuguese Municipalities (ANMP), comprises 136 municipalities from north to south of the country (in a total of 308 municipalities). Among these, 27.3% have a Smart City strategy and 16% have an urban intelligence platform. The main areas of focus by national smart cities are public Wi-Fi network (80%), 'fix my street' system (48%), intelligent public lighting (41%), intelligent management of urban solid waste (36%), intelligent tourism (36%), and intelligent management of green spaces (30%). In practice, such sustainability and efficiency efforts have implications in saving resources [17]. According to IDC, a market intelligence consulting company, the implementation of smart systems in cities allows for better management of water waste, lighting costs on public roads (with return on investment in six years), urban solids, and parking systems (smart parking, with investment recovered in two years).

From the charts below, based on Eurostat database indicators [18], we acknowledge the potential of Portugal for having more projects in this area. Recently, Portugal became a 'strong innovator' due to the values achieved in several of its innovation variables. Portugal is close to UK, Spain, and the European average itself in terms of broadband connectivity in companies. However, in relation to individuals using the internet to interact with public services, it still has values below the expected (Figure 4), but it has been evolving in the digital inclusion of its citizens.

Another aspect that Portugal has to improve is the training its companies provide to their workers in terms of information and communication technology (ICT) skills (Figure 5).

According to [3], Portugal has changed from a 'moderate' to a 'strong' innovator. The variables (of the composite innovation index used) that mostly contributed to this improvement of classification, i.e., the strongest variables of the Portuguese innovation ecosystem, are:

- Number of innovators;
- Favorable innovation environment;

- Attractive research systems;
- small and medium enterprises (SMEs) innovating internally;
- Broadband expansion;
- SMEs having product and process innovations;
- Number of foreign PhD students.

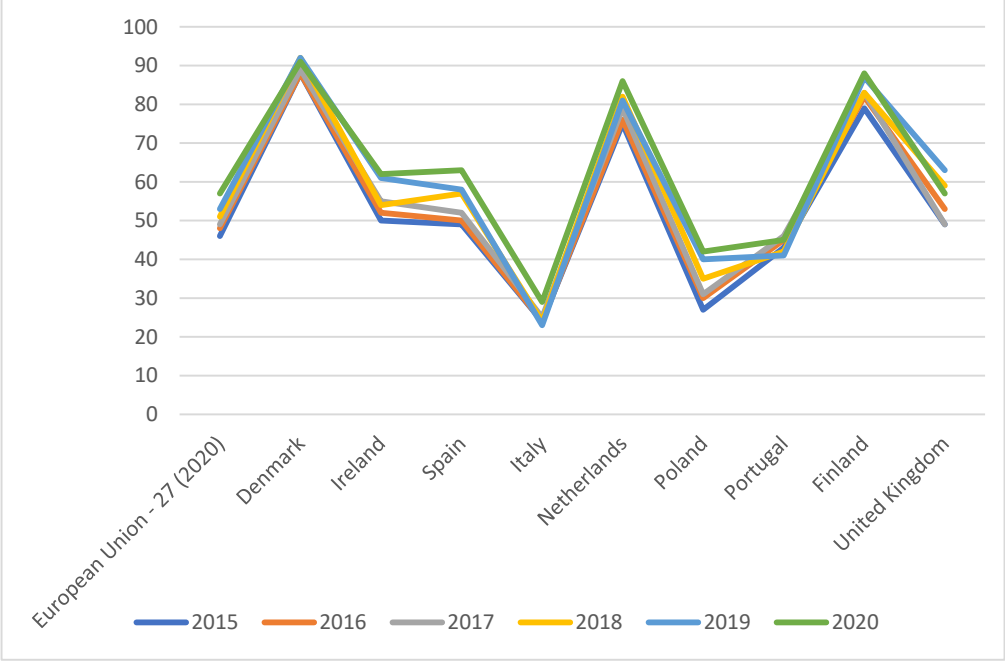

Figure 4. Internet use to interact with public services (% of individuals).

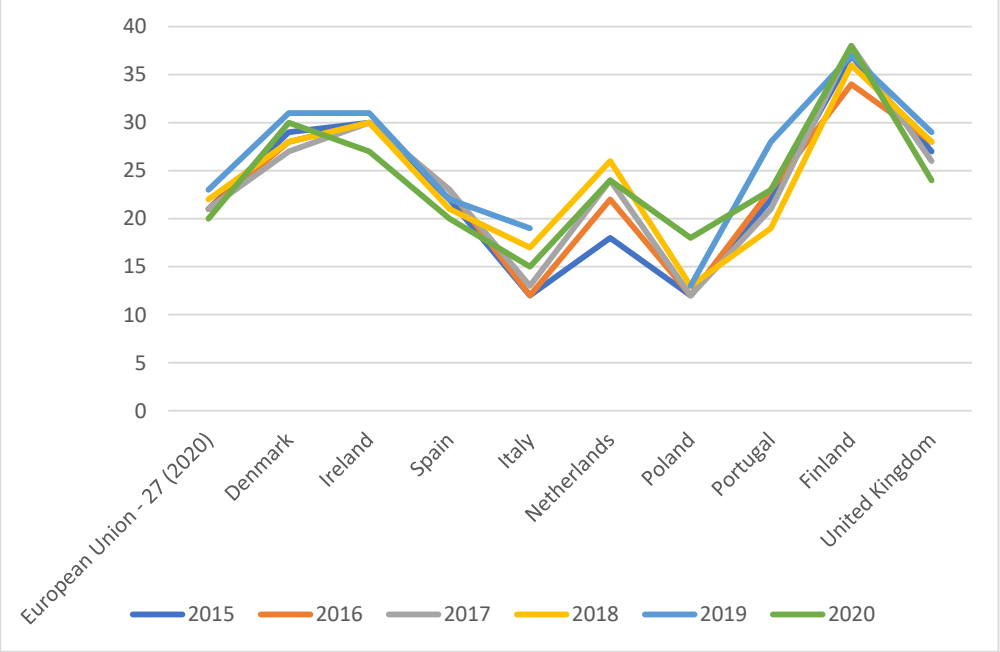

Figure 5. Training provided by enterprises in terms of technological skills (% of enterprises) with 10 or more workers. Note: value of Netherlands in 2019 was not supplied to the Eurostat database.

However, there are still dimensions to (re)analyze and improve, as they are the weakest in our innovation ecosystem, such as:

- Impacts on sales;
- Connections;
- Intellectual assets;
- Exporting knowledge intensive services;
- R&D expenses in the business sector;
- Private co-financing of public expenses in R&D;
- Public-private (co)publishing.

Portugal has been offering a favorable environment for innovation and attracting talent and SMEs have developed a good capacity for entrepreneurship and internal innovation. Where Portugal is further behind is in the translation or conversion of the knowledge acquired in sales and exports (internationalization) and there is still a low propensity for collaboration, especially at the public-private level. Thus, private investment in R&D has been low, making this activity more dependent on public incentives. The technological convergence assumed by smart cities may encourage changes in these critical aspects. The country is already taking steps in this direction, through a program called Portugal Smart Cities Summit and tourism could be the base sector for launching smart city projects.

4.1. 'Fourth' Tourism Potential

In Portugal, the tourism sector is the largest export economic activity in the country and, in 2018, was responsible for 51.5% of exports of services and for 18.6% of total exports, with tourist revenues registering a contribution of 8.2% to the Portuguese GDP. Tourism in Portugal ended in 2018 with all indicators growing [19] as follows:

- guests + 3.8%;
- global income + 7.3%;
- revenue + 9.6%;
- employment in tourism with a weight of 6.7% in the national economy.

The Tourism Strategy 2027 (ET27) is the strategic benchmark for Tourism in Portugal for the next 10 years. It is a long-term shared strategy (based on five strategic axes and ten strategic assets) with the goal of implementing actions in the short/medium term for promoting the integration of sectoral policies, with a continuous articulation between the several agents of the sector.

However, the current pandemic context has had an impact on all those aspects. The OECD estimates on the pandemic impact highlighted a 60% decline in international tourism in 2020. The sector directly contributes, on average, 4.4% of GDP and 21.5% of service exports in OECD countries. For example, tourism in Spain contributes 11.8% of the GDP while travel represents 52.3% of the total service exports, in Portugal 8.0% and 51.1%, and in France 7.4% and 22.2% [20].

Another issue is that this industry has a multi-sectoral dimension, with linkages to a myriad of other economic activities along the tourism value chain [21]. This pandemic has highlighted the interrelationship between various stakeholders and sectors (including private enterprises, communities, etc.). Tourism services are often interdependent and a crisis in one subsector (such as aviation) can have follow-on effects on the tourism value chain. A key challenge as the sector looks to re-open is how to get all these interlinked parts working together again [22]. Recovery will require they work together toward thriving businesses, healthy ecosystems, resilient livelihoods, and sustainable tourism economies.

Digital transition in tourism, now accelerated by the pandemic, portrays the Fourth Tourism (similar to the Fourth Industry) through the IoT potential. From tourists and residents' feedback in real time, through sensors and mobile apps, the systems can collect relevant information about many aspects. Data collection from the sensors and other connected objects is important to ensure that up-to-date information is available to users and stakeholders. Then, a data analysis of the associated database (cloud) can delineate

new trends in services to be explored (Figure 6). That is why this acceleration that the pandemic has triggered will require companies to have new digital business models. The supporting system and apps need to guarantee the protection and confidentiality of personal information [23].

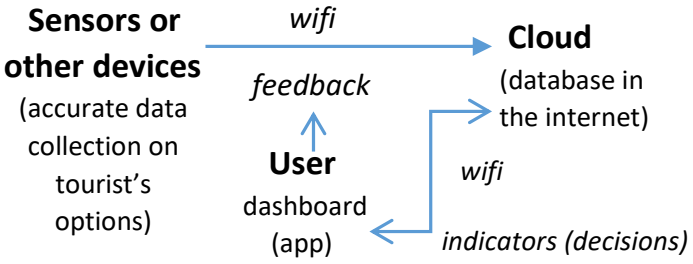

Figure 6. A cyber-physical system prototype.

This is smart tourism due to the type and degree of connection, as well as the reach and wisdom (from big data analytics) of the platform used.

4.2. Prospective Tech-Forward Solutions

The pandemic looks to be the catalyst that could force the tourism and hospitality industries to be more tech-forward [24]. Digitization and IoT-based solutions can be the basis for reactivating the productive activity of companies in the tourism sector without losing sight of competitiveness. In fact, the traveler has gone from worrying about which establishments will be open, to finding out which services will be available within the establishment and the conditions of health and occupation (swimming pool, free buffet, spa, entertainment). The more information that is provided by reservation portals offering objective data from their IoT devices, directly on the Internet, the more they will encourage reservations when choosing a destination. Customers want to buy certainty before planning a holiday. Therefore, reservation agencies and establishments need to offer confidence. Developing and applying those processes, and training their staff in security, will convey that message of assurance to customers and visitors.

In this scenario, technologies such as IoT and AI can be vital, as they can reduce physical human interactions. It is a year for tourism companies to invest in technology as a reward for customers. The customer is thinking differently, i.e., the context has changed as well as different experiences are sought. Thus, technological investments on which they should focus are the following: devices to apply the new safety protocols such as capacity control, temperature detection, parking space detection, water and air quality, crowd and traffic tracking (sensors, robots, drones, QR code, etc.); and applications to improve the tourism experience by tracking travelers during their stay. These have a dual goal: on the one hand, they can stop contagion and, on the other hand, they improve knowledge of preferences in order to analyze them with AI.

These perspectives nurture the offer of smart tourism destinations. This implies that all the attractions around an accommodation (beaches, museums, theme parks, and shopping centers) must be adapted to be smart spaces.

5. Discussion

There is still considerable space to work on these kinds of platforms in Portugal, to achieve generalized digitization, and to jump to smart cities. This was reinforced in a report by [25] on Digital Innovation to Smart Tourism Destination (especially about the Algarve region). About 65 stakeholders participated in the related online event (staged over two days) to discuss challenges and opportunities for Algarve (south of Portugal) in the field of smart tourism. They concluded the following:

- There is a lack of adequate skills, inadequate infrastructure (communication and transport), weak links between tourism services and other economic activities, and ineffective data collection/analysis are some bottlenecks.
- Regional assets, new market trends (more eco-friendly solutions), and the advantage of big data analysis are the main opportunities.
- Better data management, diversification of tourism offer, more networking and cooperation are some of the market needs.
- The sustainability dimension (circular economy and climate changes issues) in the tourism sector is one of the main themes of interest for future events.

These conclusions raise an issue, which is the need to link this 'ambient intelligence' (electronic environments sensitive and responsive to people's presence) with the country's reports on innovation and digitization. This can be the necessary framework to better outline what to do in the future (in terms of investment and development). Building an analytical framework around this link can help to envision and choose the most suitable areas of research and action in the country (Figure 7).

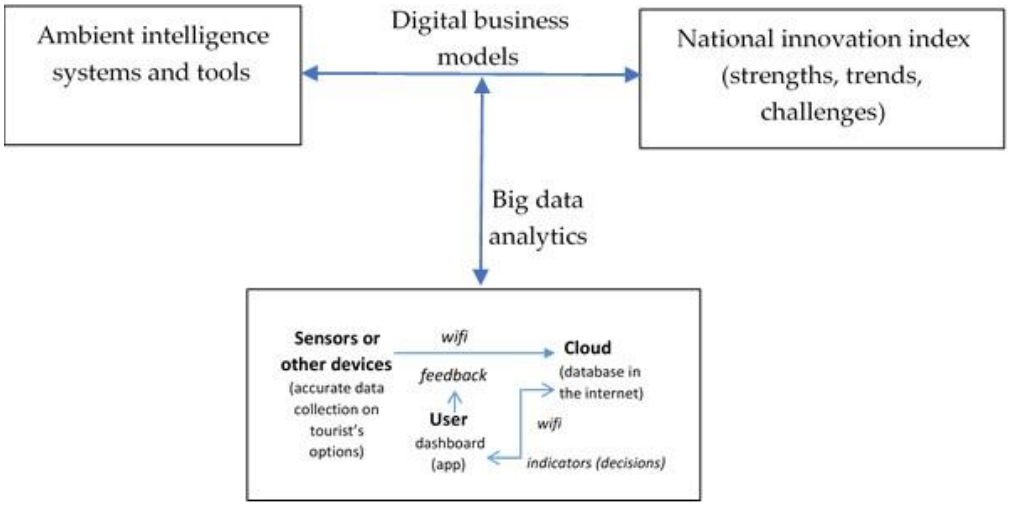

Figure 7. A framework for managing assertive digital business models.

Of course, effective protocols for the sharing of data are necessary, to replicate the aspects analyzed at the regional level, and not remain in a nationalist perspective as solely benefiting a nation's economy [26].

In technical terms (processes and implementation code), one can use interconnectable tools, such as Power BI and Azure IoT Hub, which enable extremely secure and reliable communication between the IoT application and the devices it manages. It involves a backend cloud-based solution to connect virtually any device. This cloud solution can be expanded to the edge with device authentication, built-in device management, and scaled provisioning. In addition, Power BI, as a business analytics service, enables real-time visualization and evaluation of the IoT data (Figure 8).

Using telemetry data from a device to the cloud allows one to understand its status and define message paths for other services, without writing code. In cloud-to-device messages, reliable commands and notifications can be sent to the connected devices, tracking the delivery of messages with confirmation receipts. Other processes can include updating devices for the IoT Hub, which includes the ability to respond quickly to security threats, and features that enable businesses to meet objectives without incurring additional development and maintenance costs related to creating their own updated platforms [27].

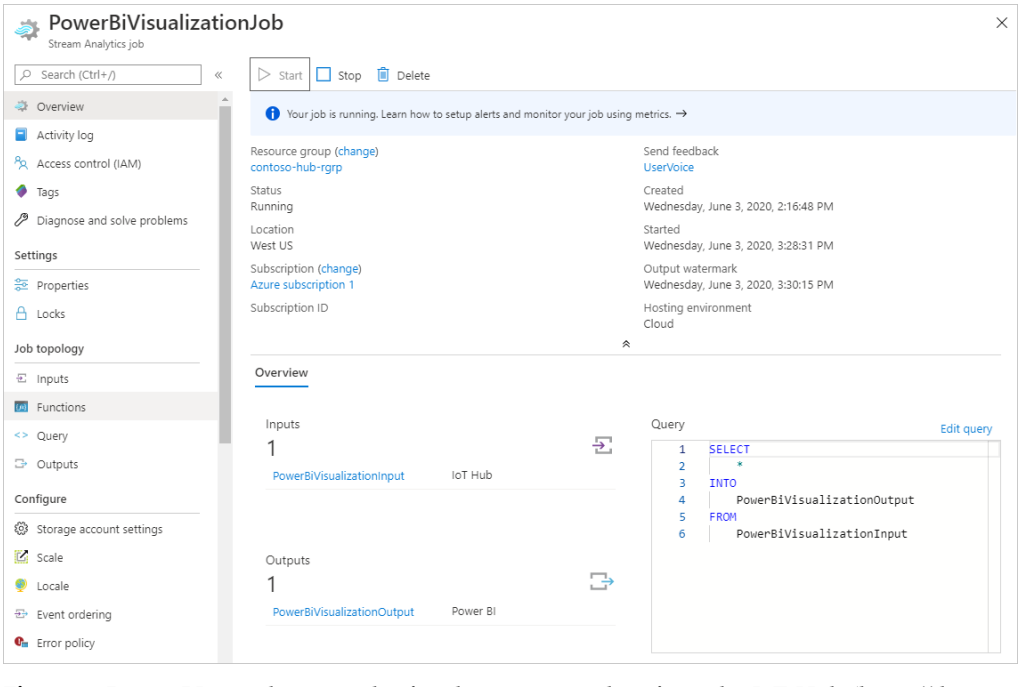

Figure 8. Power BI visualization job of real-time sensor data from the IoT Hub (https://docs.microsoft.com/pt-pt/azure/iot-hub/iot-hub-live-data-visualization-in-power-bi), accessed on 17 April 2021.

This potential for smart projects raises several questions. The lack of governance is a related dimension that has been highlighted. However, there is also a role for academics and researchers with their assessments of complex systems [28]. Only if we begin to ask more critical questions will there be a chance to unlock appropriate technology futures.

6. Conclusions

Due to the pandemic context, e-learning/work and e-commerce/business have been accelerating in a way never experienced before. Digital transition is an essential instrument of the Portuguese strategy, which aligns with the objectives of European investments. It is one of the six priorities of the Preparing Europe for the Digital Age mandate, which aims to ensure that technology is at the service of people and gives added value to daily life. Thus, Portugal is aligned with the strategy defined to face the challenges inherent in the digital evolution. However, it is important to know if Portugal is prepared to respond to the accelerated process that the change in behaviors of citizens demands to be made in cities.

Portugal has done well in terms of broadband connectivity in companies. However, in terms of internet use to interact with public services, it still has values below many other countries. The country has been offering a favorable environment for entrepreneurship and innovation. However, more than 50% of its citizens still have basic digital skills [1], which explains why the country still has a low conversion of the knowledge acquired in sales and exports. In addition, private investments in R&D have been low, making this activity more dependent on public incentives. The technological convergence assumed by smart cities may encourage changes in these issues.

A university-business school can serve as an entrepreneurial ecosystem to settle the baseline for a smart city, since it aims at creating innovative technology-based service businesses, and therefore can stimulate economic development and generate employment in the current context [29]. The emphasis should be placed on the need to develop strong collaboration and co-creation among key stakeholders for building a sustainable entrepreneurial ecosystem. This can nurture the referred link between the 'ambient intelligence' (electronic

environments responsive to people's presence) and the national innovation drivers towards the definition of most suitable areas of research and digitization.

A key trend coming out of the current context is the need for location independence. Technology leaders must provide location-independent services. The IoT edge cloud is an example of how to get there. It allows workplaces to evolve in response to pandemics, regardless of whether they are offices or manufacturing plants. Changes will include adopting remote support technologies using mobile devices; contactless and codeless interactions using IoT sensors, smart cards, and wearables will become the norm for activities and transactions.

Limitations and Future Work

The present work lacks the exploration of this kind of entrepreneurial ecosystem. Future work should analyze technological hubs in the country, by region, and the potential of a new data center at the Sines TECH-Innovation & Data Center Hub. This would be a new space for hosting technology-based companies, integrated in the Sines Industrial and Logistics Zone (ZILS). This new technological hub, in the Central Atlantic, arises from the opportunity created by the installation of the submarine cable Ella Link that will have its reception station (landing station) at the ZILS, associated with a data processing center.

The cable is 10,119 km long and connects Fortaleza (Brazil) to Sines (Portugal), passing through the archipelagos of Cape Verde and Madeira. It offers a data transmission capacity of 72 terabits per second, with low latency. Its installation is part of the Bella project, which brings together the European (GÉANT) and South American (Rede Clara) science networks and aims to provide connectivity to educational institutions and scientific research centers between Europe and Latin America. This can open interesting and challenging opportunities for consolidating this approach.

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