Adopting Smart Technology in Rural Regions

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Smart Technology is a quickly and constantly evolving concept; it has different applications that cover a wide range of areas, such as healthcare, education, business, agriculture, and manufacturing. An effective application of these technologies increases productivity and performance within complex systems. Researchers targets Rural Regions and their Sustainable Development.

smart technology sustainable development rural regions smart city

1. From Smart City to Rural Areas

Smart City is commonly defined as an integration of Smart Technology with city elements (people, information, and other technology) to promote sustainable development practices that address the urbanization growth challenges [1][2]. According to this approach, people, information, and technology must be integrated to define a smart ecosystem that enhances quality of life [3][4][5]. Initially, Smart City was oriented to sustainable urban development with the goal of integrating and optimizing the use of resources [6]. More recently, the Smart City model has been applied more broadly to improve different aspects of life [7].

The Smart City approach has been widely accepted as a successful model for Smart Technology adoption. This model is often considered a reference to be adapted to address different challenges [8]. It is probably the case for rural regions that need to enhance their sustainability and foster development [9]. Therefore, there is a potential for the Smart City model to be adapted in rural regions to address major sustainable development challenges [9][10][11][12].

As far as the authors know, there is no application-oriented model that explicitly targets rural regions. Although applications may be considered the same as for Smart City (e.g., [13]), the Smart City model cannot be directly applied to rural regions due to the significant differences and peculiarities. Hence, existing solutions are expected to be adapted and customized to face sustainability challenges, improve quality of life, foster the economy, support social welfare, and enhance the stability in rural communities for people and organizations [11][14][15][16].

The United Nations reports that over 45% of the world’s population still resides in rural areas, so rural development remains a compelling challenge as many macro indicators points out low performance in rural development. For instance, it is estimated that the 80% of the world’s poverty comes from the population who live in the rural regions [17]. Additionally, the United Nations explicitly addressed concerning trends looking at the main pillars [18].

2. Rural Areas: Application Domains

2.1. Smart Farming

Smart Farming can be defined as an integration of Smart Technology with agricultural equipment to manage and automate farming activities [19]. The recent development of Smart Technology has made considerable changes to traditional farm activities, which are usually time and effort intensive [20].

Smart Farming aims to mitigate human intervention by automating the agricultural processes [21]. The significance of Smart Farming has recently increased due to its important role in addressing the global challenges of sustainable food supply [22]. These challenges result from the increased global population and food prices caused by a decreasing number of workers in traditional farms [23].

The applications of Smart Farming can contribute to enhancing sustainable development [24][25][26]. Smart Farming can provide numerous advantages to the agricultural industry, including increased crop yield, time and labor savings, reduced costs, and improved crop quality and quantity [27][28][29][30][31]. In general terms, adopting Smart Farming can offer unique benefits in rural regions by promoting a sustainable development approach [32]. In this context, Smart Technology in rural agriculture can perform multiple tasks automatically instead of using traditional approaches, which are time and energy intensive [33][34][35].

Smart Farming impacts different tasks, such as irrigation, fertilization, temperature control, and harvesting [28][36][37][38][39]. Moreover, Smart Farming can involve cattle activities by monitoring the nutrition process and health status of the entire herd [40]. In addition, it has the potential to improve e-commerce in a rural context by exploring new markets and enhancing the ability to connect with potential buyers, monitor market patterns, receive real-time pricing data, and gain deeper insights into consumer preferences, enabling the farmers to customize their products accordingly [41][42][43][44][45].

As urbanization continues, more people move from rural areas to urban cities in search for better employment opportunities. This trend causes a decrease in the number of farmers [46]. That is likely to happen in more developed countries, where cities are the preferred places for majority of people.

It also causes a decline in the number of farms and a reduction in the amount of land being used for agriculture, which might be converted to non-agricultural uses. The consequences of this action could be reflected in increases in food prices and additional challenges for supply chains [47].

2.2. Smart Healthcare

Smart Healthcare is defined as a process of integrating Smart Technology within healthcare to improve the efficiency and quality of services, including better medical solutions and the development of proactive steps, through patient data analysis [48].

Smart Healthcare usually relies on cutting-edge technology [49][50][51][52]. The role of this type of technology is oriented to supporting treatment, such as improving the interaction between patients and doctors, monitoring and forecasting the patient's condition, illness prevention and diagnosis, medical decision-making, and minimization of human mistakes in complex operations [49][53][54][55][56].

Smart Healthcare is also expected to play a significant role in creating more sustainable systems by improving access to services (telehealth), optimizing healthcare resources and their efficiency, and promoting preventive healthcare [57][58][59].

There is concrete evidence of effectiveness documented in the literature for opportunities like smart wearable devices [17][19][20][60] and Cloud solutions for data storage [61][62]. Big Data and AI are advancing the capability of diagnosis and interpretation and, more holistically, to medical research development [63]. Moreover, recent studies show the contribution of AI and Robotics in critical surgery operations [64][65][66].

The Smart Healthcare model could play a key role in addressing and bridging the gap with cities, given the historical shortage of qualified structures and services [67][68][69][70]. For example, a solid implementation of remote and more integrated services defines an explicit mainstream for development [71]. Smart Technology can facilitate remote access to patients' data, especially for older people who require periodic check-ups [72][73]. Additionally, it can contribute to healthcare by predicting health developments so that more proactive solutions can be devised [74][75].

As people move from rural regions to urban cities in increasing numbers, rural regions are experiencing a further crisis in terms of healthcare facilities, providers, and resources [76]. This is consolidating gaps, especially in more and less developed countries. It reflects a more general focus on populated areas and a consequent lack of attention to rural regions. On the other side, in the least developed countries, rural regions usually receive healthcare services that are comparable to those offered in urban areas [77][78].

2.3. Smart Energy

Smart Energy can be defined as the ability to adopt Smart Technology to optimize energy production, distribution, and consumption to create more sustainable and reliable energy systems for both the consumer and the environment [79].

Smart Technology in the energy sector has recently expanded to reduce the construction of power stations that normally cause an increase in pollution [80].

The application of Smart Energy is gradually becoming part of our daily life. For instance, smart meters can dynamically optimize energy consumption [81][82]; electrical appliances can avoid peak hours to reduce costs [83]; outdoor lights can be controlled automatically to adapt to actual needs [84].

Moreover, with the recent increase in global demand, Smart Technology is expected to contribute to sustainable energy systems [85], which should be efficient, affordable, and aligned with environmental challenges [86]. Smart Energy Systems are expected to push the diversification of energy production toward an optimized use of renewable energy systems [87][88][89][90] and contribute to a decrease in the number of power stations [91].

From a rural region perspective, the application of Smart Energy is expected to enhance sustainability to provide systems that are clean, reliable, and affordable. Large and open areas normally characterize the ability of rural regions to generate clean energy in a way that is friendly to the environment at a lower cost [92][93][94]. Solar and wind energy systems are potential applications for Smart Energy to supply rural communities that use smart inverters to optimize energy production [95][96][97][98].

The characteristics of rural regions make them suitable for generating renewable energy: firstly, they have a surplus of open spaces, which is often necessary for renewable energy resources. Secondly, there is less obstruction for the sun and wind, allowing for better performance. Thirdly, rural regions have lower population densities than urban areas, meaning fewer concerns about disrupting habitats exist. Fourthly, lower electricity demand makes it easier to meet the local energy needs with renewable technologies [99].

Another example is a smart microgrid, which is a small, self-contained energy system that can operate independently to easily provide minor communities with energy supply. Its primary focus is to provide reliable and sustainable energy access to isolated areas [100][101].

The migration trends still play a key role as, in general terms, cities are becoming larger and more dense with an intrinsic additional pressure on the urban energy networks. This is particularly evident in both more and less developed countries that are characterized by highly densely populated cities [102]. On the other side, the decreasing population in rural regions might cause difficulties for energy supply over scattered areas and cause rising costs.

This scenario is different in the least developed countries, where rural regions are highly populated, and people live in big communities that are concentrated in a few places. Moreover, rural regions in the least developed countries can have more options for energy supplies, such as the common energy network, renewable energy, and traditional sources [103].

2.4. Smart Education

Smart Education can be defined as the ability to adopt Smart Technology in the education system to enhance effective, suitable, and sustainable learning approaches through innovative methods for more efficient outcomes [104]. It focuses on integrating smart learning technology into the education system [105][106][107][108]. It can provide an accessible and lifelong learning system with contemporary lifestyles [109][110][111][112][113]. Smart Technology can generate, store, analyze, and visualize massive data from a given domain to provide the best learning content [114][115].

Smart Education is usually characterized by an innovative environment that integrates Smart Technology in its infrastructure to provide interaction in real-time to the learners [116][117]. It also known as a self-directed and self-motivated system that is often enriched by resources that can provide learners with many advantages, such as connection, openness, and independence [118].

Smart Education is an appealing system compared to traditional education because of the novelty in teaching styles. Smart Education usually includes unique learning methods, such as gamification, interactive and collaborative groups, tactile-auditory presentation, and simulations [119][120].

Smart Education systems are expected to contribute to sustainable education systems that should be more efficient and accessible, and providing contemporary teachers with a more sustainable teaching lifestyle and allow for learners to gain the necessary knowledge and skills [121][122][123][124][125].

From a rural region perspective, the application of Smart Education is expected to enhance sustainability to provide accessible, comfortable, and sustainable learning systems that can address the challenges of disparity with urban areas. This is especially true for students with limited access to educational resources or constraints to move rural [126][127].

From a practical perspective, Smart Education can provide an accessible and comfortable way of learning through content and resources accessed via e-portfolio platforms that can be connected to remotely with common devices [115][128][129][130][131][132][133][134], enhancing remote activity [115][135][136][137]. For instance, augmented reality technology (AR) has a specific potential impact on rural education settings by enhancing actual practices and avoiding expensive travel [138][139][140][141][142].

Education is essential for human life. In both more and less developed countries, most educational resources and infrastructures are in cities [143], while there is a tangible gap with rural areas. The most influential factor in more and less developed countries is the drain of qualified educators to urban areas [144]. In the least developed countries, there is a much less tangible gap as the few resources are normally available in rural regions [145], where the quality of education is comparable to that available in cities [146].

2.5. Smart Government

There is no unique and universally accepted definition for Smart Government, as it is still a relatively new and emerging domain. Still, it is often understood as adopting Smart Technology and innovative solutions to enhance the efficiency of government services, performance, and responsiveness [147].

The Smart Government approach focuses on integrating new, emerging technology into its systems to improve government services and make them more efficient, effective, and sustainable [148]. Smart Government aims to find innovative solutions that allow for easier methods of connecting with the public that are increasingly responsive in the shortest time possible [149][150][151]. By utilizing Smart Technology, Smart Government can understand the different needs of people and organizations through the analysis of vast volumes of data from their transactions

[152]. This can increase the efficiency of transparency of services and help create policies that are relevant to real-life situations [153][154].

Smart Government is expected to contribute to sustainable development by ensuring the minimum level of quality of life through leverage of Smart Technology to create programs, policies, and services that promote sustainable practices. These practices can become a sociotechnical approach to sustainably address the gap challenges between government and other stakeholders [155][156][157].

From the rural region perspective, the application of Smart Technology is expected to enhance sustainability by leveraging Smart Technology and innovative solutions to address the connection challenges between rural areas and the government. Therefore, the adoption of Smart Government has a potential impact on rural regions through enhanced online services that may encourage development. Moreover, Smart Government is expected provide accessible ways for rural residents to engage with government decisions making [148][158][159][160]. Rural people can then challenge to the government to provide better solutions that look to improve the quality of life and increase the prosperity of their regions [161][162].

Considering the current level of urbanization, in both more and less developed countries, governments can manage and provide services to their citizens in a relatively easy way in major cities [163]. Rural regions require a smart approach to receive a comparable level of service [164]. Again, in the least developed countries, the gap between urban and rural areas is much less evident [165].

2.6. Smart SMEs

Small and Medium Enterprises (SMEs) are classified based on business capacity and number of employees [166]. Smart SME can be defined as the approach of a SME business to adopt Smart Technology into its business strategy to optimize the daily business operations, services, and production [167].

Smart SMEs focus on integrating Smart Technology into business systems to increase the efficiency of business performance [168][169][170]. This process can improve decision-making that is based on data analytics and help improve weakness of the business and anticipate coming risks [171][172][173][174].

The Smart SMEs approach could bring many benefits to traditional business. Smart Technology might address business challenges and optimize business performance, such as cost reduction. It could enhance the quality of services and products and better understand customer needs [175][176].

SMEs are shaping most segments of the global business sector and have a significant impact that directly influences the gross domestic product (GDP). This is particularly true in developing and less developed countries, according to the World Bank [177]. Therefore, the significance of SMEs is growing due to their role as major job creators that require low capital to start the businesses [178].

Smart SMEs are expected to contribute to business sustainability to remain competitive in the market, ensure long-term economic growth, and support national economic growth that can improve the society's social welfare. Moreover, Smart SMEs can efficiently improve resources to maximize production with minimal waste [179][180].

From the rural region perspective, the application of Smart SMEs is expected to enhance business sustainability and economic growth for rural communities [181][182]. For instance, rural SMEs can adopt Smart Technology, such as Cloud Computing, to overcome the unaffordable costs of buying new business software, especially those with limited IT capability [183][184]. Moreover, Smart Technology can help rural SMEs manage their business resources effectively to automate different activities that require more workers. Smart SMEs can also provide stable job opportunities for skilled people and educated people that cause them to remain in rural areas rather than moving away [185][186][187].

In urban and rural areas, SME presents an intrinsic and significant gap [188]. This is very evident in both more and less developed countries, where SME performance and probability of success in major cities clearly overcomes that in a rural context. This occurs because SMEs can become more competitive in highly populated areas due to larger markets and number of potential customers, the ability to produce goods and services at lower costs, the availability of labor, and the infrastructure required to operate efficiently. SMEs are not likely to have the same opportunities in rural regions [189].

Because of the different characteristics of rural regions, SME businesses might find relatively more favorable conditions in this context in least developed countries [190][191].

2.7. Smart Manufacturing

Smart Manufacturing adopts Smart Technology to optimize manufacturing processes and, accordingly, increase efficiency [192]. Smart Manufacturing integrates the different resources to enable connection and collaboration, which results in increased productivity at a lower cost [193][194]. The Smart Manufacturing approach focuses on managing multi-manufacturing activities within the manufacturing ecosystem [195][196], which aims to automate operations, reduce costs, and increase productivity [197][198][199][200].

In general terms, Smart Manufacturing fosters a Sustainable Development approach by improving efficiency and driving product innovation [201]. That is relevant in rural regions where a smart approach is expected to contribute to innovative solutions that can overcome current challenges, such as the lack of skilled workers [202][203]. By enhancing industries' performance in rural regions, Smart Manufacturing contributes to enhancing resilience and adaptivity to gain a competitive advantage [204][205].

Additionally, a tangible impact is expected on employment, given the current critical difficulty in attracting people. Smart Technology can play a significant role in automating processes that require or involve a large number of workers [206][207][208]. Similarly, Smart Manufacturing can holistically improve the socio-economic condition of communities by creating job opportunities for educated people in a more attractive context. It has a direct effect on improving stability and driving economic growth.

Finally, Smart Manufacturing can provide training opportunities for rural residents who graduate from universities or schools and seek training opportunities in the local community [209][210].

In general terms, high population density is favorable to manufacturing [211], and the shortage in the labor market may negatively affect a business, particularly in more developed countries. Smart Manufacturing has an opportunity to become determinant in the rural regions of the least developed countries, where population density is high and labor resources are usually available [212]. Smart Manufacturing solutions are expected to be designed as a function of the population density and other available resources [213].

2.8. Smart Living

Smart Living is a generic concept that refers to the application of Smart Technology to improving lifestyle so that it is more convenient, efficient, and sustainable [214]. In general terms, Smart Living plays an important role in enhancing sustainable development [215]. It leverages technology for most life aspects to improve the quality of life and sustainability for social communities to make daily life more efficient and more accessible [216][217].

Because of its broad purpose, Smart Living includes different sub-categories/applications, which are briefly discussed in this section.

Smart Homes refers to the application of Smart Technology to domestic environments to better address people's needs [218][219]. For instance, it can involve lighting, heating, and ventilation, as well as energy and security management; automation and remote control are also typical functions [220]. These applications allow residents to control various appliances and devices in their home via smartphones or voice commands. For instance, doors are automatically unlocked using facial recognition, lights are managed through presence sensors, temperature is automatically adjusted to a comfortable level, etc. [221][222].

Smart Waste Management is the corresponding Smart Technology adoption to foster a sustainable approach in this area [223]. Smart Waste Management is a key and central concept for public health, people's well-being, and the environment [224]. An example of Smart Waste Management applications include Smart Bins [225], which can optimize overhead costs. For instance, trucks can collect bins where the waste level is over 80%, and they can be directed via GPS to reach their destination using the shortest possible route to reduce consumption and costs [226].

Smart Safety Systems address general safety issues by incorporating sensor data and data analysis into safety operations to deal with and anticipate threats [227]. The most intuitive example is a smart approach to surveillance [228][229][230]. Smart Climate and Environment System refers to an advanced use of technology to address the challenges of climate change and environmental degradation by enhancing sustainable development for a livable future [231][232]. In the last decade, climate change and environmental degradation have hugely impacted agriculture, landscape, and natural resources [233][234]. Smart Technology has therefore gained more and more relevance to face sustainability challenges [217], for instance, given the enhanced capabilities in terms of monitoring and analysis [232][235].

Smart Living is evidently a critical concept also in the rural context, where it is expected to play a significant role in enhancing sustainable development and improving the people's quality of life [16][236][237][238].

Smart Living is likely to be successfully implemented in the more and less developed countries, where the population density is high in urban areas [239]. More and less developed countries present a generic competitive advantage because of the availability of infrastructure and resources. In contrast, this is perceived to be much more challenging in rural regions of more and less developed countries due to the lack of infrastructure and ICT availability [240]. In the least developed countries, Smart Living could find opposite conditions [241], as mentioned in previous discussions.

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