Internet of Things (IoT) and Sustainability

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Abstract
Internet of Things (IoT) technologies have started to impact society as a whole and have become a key enabler for sustainable development. The purpose of this paper is to examine the connection between IoT and sustainability providing a critical reflection on current literature. The research methodology consists of a literature review in the research field of IoT technologies and their beneficial impact in various sectors, such as sustainable urban development or farming. The aim is to provide an in-depth, detailed analysis on the various ways in which IoT can help with current global environmental issues and achieve sustainable development. The paper highlights the importance of IoT technologies in protecting the environment and emphasizes the need for all stakeholders to adapt such technologies nowadays and in the future. The main value of the current paper is to help enrich the literature on IoT technologies, sustainable development, and environmental protection. The Internet of Things (IoT) is believed to be one of the enabling paradigms of sustainable digital transformation and environmental protection (Salam, 2019). IoT is emerging as a powerful enabler in many application domains, such as water and energy management, environmental monitoring, health, smart cities, smart industry and supply chain management. This paper contributes to academic literature and business by revealing a possible link between sustainability and Internet of Things. This subject sparks interest among both marketers and researchers.

Keywords: Internet of Things (IoT), sustainability, sustainable development, technology, environment.
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Introduction

Since the beginning of the 21st century scientists have been sounding the alarm on the environmental crisis we are facing. Changes are needed in the behaviors that have brought us here: spewing unprecedented greenhouse emissions into the atmosphere, the overexploitation of Earth's limited resources, and the continuous destruction of the environment and natural world. In addition, the COVID-19 pandemic, post-Brexit challenges, and the changes in corporate social responsibility have highlighted the importance of putting sustainable development at the core of current and future progress and growth (UN, 2015). Some of the most serious environmental concerns include but are not limited to climate change, biodiversity loss, and the looming water crisis. Nowadays, countries and governments across the world are working to develop sustainable solutions and plans.

Internet of Things (IoT) applications can bring benefits to the environment (Maheswar and Kanagachidambaresan, 2020; Araral, 2020). The beneficial relationship between IoT and sustainability has been studied lately (Laine, 2014; López-Vargas, et al., 2020). The current article covers the impact of IoT on sustainable urban development and smart cities, as well as resource preservation and smart farming. These concepts have evolved a lot recently, becoming part of modern society, not only as global priorities, but also as business opportunities. Through reflection and analysis, the research seeks to explore and clarify what are the real implications of IoT technologies on these sectors. Due to the increased global interest in modern technology, the link between sustainability and IoT has become a

relevant and useful research subject. The paper is exploratory and seeks to empirically analyze the level of understanding about the relationship between sustainability and IoT, as well as the stage of IoT adoption in various sectors. Firstly, the paper reviews the current literature on sustainable development and IoT technology. Secondly, it analyses the link between IoT and sustainable urban development and smart cities. Thirdly, it presents the main concerns and challenges related to resource preservation, smart farming and IoT.

The link between sustainable development and IoT: Review of the scientific literature

Over the past three decades the well-being of civilization has been placed above the protection and conservation of the environment (Attenborough, 2020). Concepts such as sustainability and sustainable development are emerging due to the global environmental crisis (Shukla and Kumar, 2020). Sustainable development can help to "preserve the world for future generations and improve quality of life" (Mohammadian and Rezaie, 2020, p. 9). Sustainability focuses on 'triple bottom line' approaches, as social, environmental, and economic responsibilities (Ferdig, 2007, p. 28) and has two main goals: "living within the ecological limits and meeting the needs of everyone" (Lorek and Spangenberg, 2014, p. 42). Sustainable development emphasizes "natural balance" so as not to compromise the "quality of life of future generations" and is at the same time oriented towards "economic and social progress" (Cătoiu, Vrânceanu and Filip, 2010), having an impact on business since 1960s (Leonidou and Leonidou, 2011).

Sustainability, as well as consumer behavior and attitudes towards sustainable development have been studied in the past years (Wood, 1991; McWilliams and Siegel, 2001; Maignan and Ferrell, 2004, Zaharia et al., 2010). Many companies have made sustainability a key pillar of their business activities (Baleanu et al., 2011). Leonidou and Leonidou's (2011) extensive research of expert studies in the field of marketing/environmental management has clearly demonstrated that in the last 40 years it has undergone a transformation, moving to an advanced stage characterized by "greater maturity and rigor". According to McDaniel and Rylander (1993), sustainability is here for "the long run". There are divergence and complexities "surrounding sustainability" (Beringer and Adomßent, 2008). One of the key issues is related to sustainability measurement and reporting. Parris and Kates (2003) demonstrated that "there are no indicator sets for sustainability" that are universally accepted. Dietz et al. (2009) mentioned that specialists have argued about how to measure sustainability. Sustainability is meaning many things to many people. This is how IoT technologies come into play. Internet of Things (IoT) applications are mentioned in that they can bring benefits to the environment (Maheswar and Kanagachidambaresan, 2020; Araral, 2020). IoT can help fight climate change, resource scarcity and species endangerment (Beier, et al., 2018; Garrity, 2015; Schneider, 2019).

It has the potential to address some of the most acute human, economic and environmental needs (IoT Forum, 2017). The beneficial relationship between IoT and sustainability has been studied lately (Laine, 2014; López-Vargas, et al., 2020). Development of the IoT with numerous applications in different industries proved to be a great advantage (Abu Ghazaleh and Zabadi, 2020). The Internet of Things is able to make a positive contribution to any environmental problem, "from reducing water related disasters and economic losses, to energy efficiency, to better and larger scale connectivity, and effective water management decision making" (Salam, 2019, p. 4). It was mentioned also that "high technologies like digitalization, Information Technology (IT), Information and Communication Technology (ICT), Internet of Thing (IoT), Internet of Business (IoB), Internet of Energy (IoE), and Internet of Manufacturing (IoM) are high technology techniques to implement strategies and solutions needed for sustainable development" (Mohammadian and Rezaie, 2020, p. 12). The IoT rapid evolution is generating "the need for a revised definition of sustainability" (Daj, 2016).

IoT can enable sustainable development in ecological engineering (Schneider, 2019), earth systems engineering (Lee et al., 2014), industrial ecology (Zhu and Zhao, 2018), and environmental sustainability and green engineering (Maksimovic, 2018). IoT can help achieve the aim of the Paris Agreement and the targets in UN Sustainable Development Goals (SDGs) (Salam, 2019; IoT Forum 2017). IoT and connected devices were considered to be the major drivers of change (Laine, 2014). Recent evolutions are forcing the business world to add a new word to its dictionary: "globality" (Thrassou and Vrontis, 2009). Digital technology is having "an increasingly pervasive impact on every

aspect of economic and social life in the European Union, from the increasing use of robots and artificial intelligence, to e-health and online public services" (European Commission, 2017, p. 3).

IoT relates to "the integration of physical objects communicating with one another and through the internet to achieve some useful objectives". It assumes the combination of three main "elements: web-based (middleware), things-based (e.g. sensors), and semantic-based (knowledge)". The term Internet of Things was mentioned for the first time in 1999. IoT is a new paradigm that connects "computing technologies, wireless sensor networks, Internet communication protocols, sensing technologies, communication and devices with embedded technologies". It is expected that IoT will have an impact on consumers, businesses, and society. (Haddud, et al., 2017) Today, IoT market revenue is $212 billion worldwide. (Vega, 2020) Digital technologies, such as IoT, are changing the way people live, are offering opportunities for the society and can improve the environment. (Mohammadian and Rezaie, 2020). IoT has been introduced as "the next Information and Communication Technology (ICT) revolution". Many initiatives on IoT are being performed in "the USA, Europe, Japan, China and Korea" (Zarei, et al., 2016). On the basis of the European Research Cluster on the IoT (IERC) report, "the three drivers for development of IoT are: increasing the economic prosperity, quality of life and environmental protection" (Smith, 2012, p.232), also mentioned in the literature on sustainable development (Zarei, et al., 2016). Translating the idea of sustainability to action implies a transformation in human "perspective and behavior" (Ferdig, 2007).

IoT and sustainable urban development: smart cities

Worldwide one clear trend is urbanization. It is estimated that two thirds of the growing world population will be made up of city dwellers by 2050 (UN, 2018). The world will experience an increased demand for, and pressure on, various kinds of resources: from water, to energy, to transportation, to sewage and garbage management etc. which come with the urban lifestyle. Modern day cities can be reinvented and developed in a sustainable manner. There are many industries that have started to incorporate IoT technologies. For example, "a large number of Internet of Things like GIS, GPS, and remote sensing are becoming popular in smart mobility for best travel routing, influencing travel choices. RFID and IP cameras are mounted in all public places in which commuters enjoy better security. Regarding public utilities like water, air, and power, the IoT technologies are deploying with these physical things to enhance efficient utilization while in different modes of the sources–transmission-destination" (Somayya and Ramaswamy, 2016, p. 841).

Sustainability, advanced technologies and digitalization employed in urban planning, could be the tools to assist in the creation of new urban areas characterized by high quality living. Sustainable and eco-friendly 'smart' cities of the present and the future should be built based on green strategies, sustainable water management and environmental care. Digitalization and high technologies could change human life through renewable energies, innovative management, "ubiquitous and smart services like hybrid vehicles" (Mohammadian and Rezaie, 2020). The use of IoT's as part of modern-day urban development is understood in terms of creating those engineered systems that act as enablers of sustainability by ensuring active protection of the natural and environmental systems (Council, 2013).

As examples of what could constitute the ecosystem of a smart city, IoT's can be used for:

- prediction of loads on smart grids (i.e. predicting energy consumption).
- prediction of water demand (by using various information sources).
- journey planning considering traffic incidents.
- prediction of parking space availability (García, Ruiz and Gómez-Nieto, 2016).
- solving the urban congestion and traffic. Optimizing transportation systems. (Oliveira, Oliver and Ramalhinho, 2020)

Amsterdam evolved from the by-gone fishing village into the present day Sustainable Smart City. The city has implemented a smart grid, smart LED lighting, smart meters, promoted the use of electric vehicles, built charging terminals, etc. These are expected to promote more efficient urban

management, innovation and economic growth, strong social cohesion, and sustainable development (Somayya and Ramaswamy, 2016). The adoption of IoT's in urban development is not without challenges. To ensure their success, coherent and integrated planning is required, as well as sizeable investments. As such, today's cities and those of the future will rely on heavy government involvement to establish the necessary means to provide citizens with services in an equal and sustainable manner, as well as ensuring quality of life (García, Ruiz and Gómez-Nieto, 2016). The role and need for involvement of local and central governments in the deployment of IoT's for sustainable city development is necessary given the existing challenges. There were noted challenges with regards to developing models and proof-of-concept implementations that align with sustainability goals. Also IoT potential to generate large amounts of data encounters difficulties to store, analyze, model and turn into decision-making inputs focused on individual privacy. Regulations, governmental incentives, monetary benefits and tax credits, industry goodwill are some of the methods to encourage consideration of the sustainability goals at the system analysis and design of the IoT projects. An efficient business model is vital for sustainable IoT development (Salam, 2019).

IoT and resource preservation: smart farming

The world population is expected to grow in the next decades. (UN, 2017). Coupled with an increase in living standards, income, and the globalization of the Western consumerist lifestyle, this will inevitably lead to an ever-increasing pressure on food supplies and the agricultural production underlying it. Intensive agriculture is already a reality in the most advanced economies of the world and a rapidly growing demand for food could act as a catalyst for: (1) employing ever more intensive methods of increasing agricultural output (through intensive land, pesticides, fertilizer and water use); (2) accelerating deforestation to clear valuable and fertile land for agriculture.

The use of technology, in the form of IoT and AI, could be the alternative towards a smarter use of existing, limited resources and delivering the required growth needed to feed the world's populations. (Dlodlo and Kalezhi, 2015) Employing technology in agriculture is not exactly new. An assortment of devices has been used for quite some time to perform at least basic duties such as: monitoring soil humidity, measuring wind intensity and direction, and detecting certain properties of the soil. The advent of IoT introduces new opportunities for a larger scale adoption of such technologies, while hitching the devices train to data transmission networks, information processing applications and solutions, and modeling algorithms that translate all of the above into smart farming decisions.

Several elements could act as catalysts of smarter agricultural practices towards more efficient resource utilization and increased output. First, 'smart' devices that can be used in agriculture – a variety of sensor types that can measure soil humidity, compaction, air permeability; air and soil temperature; wind speed and direction; atmospheric pressure. Second, wireless communication networks – to which 'smart' devices connect for data exchange purposes. Third, software solutions – server or cloud based – to collect, store and process the data generated by (1) and transmitted via (2). Fourth, Artificial Intelligence powered models and algorithms that can map and model the state of a certain crop and support or drive business decisions, such as: when to plant, when to harvest, when and where to irrigate, water, fumigate, apply pesticides, fertilize etc. (Kodali et. al. 2016; Na et. al. 2016).

Implementing and using IoT's in agriculture would generate the kind of data (rainfall, humidity, temperature, soil moisture, salinity, climate, heat and direct sunlight, pest alerts) that has the potential to support farming decisions with the aim to boost productivity and quality, optimally utilize resources and generate much needed profits for the farmer. As an example, soil humidity information can help with minimizing the risk of crop diseases and pests. Coupled with accurate weather data, farmers can decide on the optimum timing and amount required for watering or irrigation. Anticipating pest movement can enable pest control decisions to optimize the correct amount and timing for using (or not using) farming pesticides (Rubala and Anitha 2017). Regarding water management, "IoT water systems and energy technologies can help reduce water usage and offer new ways for cleaning and recycling" (Salam, 2019, p. 27).

Adding an extra layer of data modeling and analytics, through AI algorithms, IoT has the potential to increase output, reduce environmental impact and resource utilization, as well as decrease costs and boost profits. Of particular interest is the judicious use of water for irrigation, as well as deployment of

fertilizers and pesticides in the right place, at the right time, and in the right amount (Lerdsuwan and Phunchongharn 2017). IoT can promote in farming sustainable production of safe, healthy, profitable agricultural products, engaging farmers and industry groups (Salam, 2019).

IoT's have a real potential in transforming farming and agriculture. Still, these prospects are not without barriers and caveats, mostly related to cost of implementation and profitability for the farmer. But as competition increases and governments promote more sustainable development polices, the implementation of IoT's in agriculture can only increase and at a faster pace for that (Elijah, et. al. 2018). Amid some trends and predictions, the road ahead is definitely a promising one and certainly worth looking forward to (Laine, 2014), as IoT's becomes more and more integrated into our daily lives (Hristov, 2017).

Conclusions

It can be concluded that IoT technologies have great potential to support and enable sustainable development. The role of IoT in sustainability research is vast, with scientific research in many various industries. It is used in farming, water management, recycling and has the potential to play a vital role in community management and stability, through the development of smart cities. The paper concludes with implications for research, practice, and policy and future analysis and research directions. IoT technologies are undergoing continuous and real changes at the moment. This paper calls for more empirical research in order to identify consumers' awareness and openness to accommodating such devices in their daily life. As a relatively new field of research, future studies should also focus on the connection between IoT and other environmental components, for example ocean protection, hydric stress and water scarcity, or waste management.

It is important to develop an efficient business model for sustainable IoT marketing development. Lorek and Spangenberg (2014) named the adjustments of the environmental challenges to the system, based mainly on technological improvements, a disaster, summarizing that economic growth based on "technological innovation" is a necessary and important step towards sustainable development, while not being quite enough.

This paper contributes to academic literature and business by establishing a link between sustainability and IoT. Firstly, it brings fresh information into an understudied area, the impact of IoT technologies on some of the most important environmental components. Secondly, the paper covers two concepts that are extremely volatile and relevant for both present and the future: IoT and sustainability. Most importantly, the paper demonstrates that it is indeed possible to conciliate IoT and sustainability.

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