

Smart cities: Between technological promises and environmental challenges –A case study of Oran, Sidi Abdellah (Algeria), and Constantine

AIDOUD Fatima Zohra¹ / PME recherche et innovation, SECG, University Stambouli
Mustapha, Mascara aidoud.univ75gmail.com

TAIBI Khadidja / Investment and Sustainable Development Laboratory, SECG, University
Mohamed Ben Ahmed, Oran 2, taibi.khadidja@univ-oran2

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Abstract:

This study investigates the relationship between smart city development and the environmental challenges posed by pollution and ecological risks, within the broader global pursuit of sustainable development. With the intensification of urbanization, the imperative to reconcile technological advancement with environmental preservation has become increasingly critical. This research integrates quantitative indicators such as CO₂ emissions, air quality metrics (PM2.5, PM10), recycling rates, and resource consumption (to assess the environmental impact of smart cities. It further analyzes how smart technologies enhance waste management efficiency and promote circular economy practices. The study aims to assess the extent to which emerging smart city initiatives in Algeria (particularly in Sidi Abdellah, Oran, and Constantine) can effectively support sustainable development objectives and mitigate pollution. The significance of this research lies in its contribution to a more comprehensive understanding of the environmental dimension of smart cities, an area often overlooked in existing literature that has predominantly focused on technological and infrastructural aspects.

Keywords: Smart cities, Pollution, Ecological risks, Sustainable development.

Jel Classification Codes : O18 ; Q53 ; Q54 ; Q01

Résumé:

Cette étude examine la relation entre le développement des villes intelligentes et les défis environnementaux résultant de la pollution et des risques écologiques, dans le cadre plus large de la quête mondiale du développement durable. Avec l'intensification de l'urbanisation, la nécessité de concilier progrès technologique et préservation de l'environnement devient de plus en plus cruciale. Cette recherche intègre des indicateurs quantitatifs tels que les émissions de CO₂, les mesures de la qualité de l'air (PM2.5, PM10), les taux de

recyclage et la consommation des ressources afin d'évaluer l'impact environnemental des villes intelligentes. Elle analyse également la manière dont les technologies intelligentes améliorent l'efficacité de la gestion des déchets et favorisent les pratiques d'économie circulaire. L'étude vise à évaluer dans quelle mesure les initiatives émergentes de villes intelligentes en Algérie (notamment à Sidi Abdellah, Oran et Constantine) peuvent soutenir efficacement les objectifs de développement durable et atténuer la pollution. L'importance de cette recherche réside dans sa contribution à une compréhension plus complète de la dimension environnementale des villes intelligentes, un aspect souvent négligé dans la littérature existante, principalement axée sur les dimensions technologiques et infrastructurelles.

Mots clés : Villes intelligentes, Pollution, Risques écologique, Développement durable

Jel Classification Codes : O18 ; Q53 ; Q54 ; Q01.

¹ Corresponding author: AIDOU Fatima Zohra, e-mail address:: aidoud.univ75@gmail.com

I. Introduction

The rapid global transformations and escalating demographic growth have made it imperative to reconsider traditional urban models. In this context, the concept of the *smart city* has emerged as a strategic paradigm aimed at leveraging digital technologies and intelligent systems to improve the quality of life and advance sustainable development objectives. This study is grounded in relevant theoretical frameworks, such as the Smart Cities Model and the Triple Bottom Line (People–Planet–Profit), which provide a comprehensive basis for analyzing the interaction between environmental, economic, and social dimensions in smart urban environments.

These smart cities, which have significantly contributed to reducing pollution levels and waste generation and providing advanced environmental enhancement solutions, are nonetheless not entirely free from environmental risks. Such risks may emerge from the excessive deployment of technologies, often implemented without adequate consideration of their ecological implications. The realization of sustainable development within smart cities necessitates an integrated approach grounded in modern technologies, which carefully balances environmental, economic, and social dimensions.

In the Algerian context, the transition toward smart cities has gained momentum through initiatives in digitalization, environmental monitoring, and intelligent urban services in cities such as Sidi Abdallah, Oran, and Constantine. These

developments make the Algerian case an important field for examining the potential and limitations of smart city models in achieving environmental sustainability.

Importance of the Topic

This topic is important for linking sustainable development and smart cities by examining the compatibility of technological progress with environmental and social sustainability, offering insights for policymakers on ecological challenges. Moreover, this subject holds particular importance as it establishes a pertinent link between the concepts of sustainable development and smart cities through the analysis of the compatibility between technological progress and the principles of environmental and social sustainability. Additionally, it provides valuable insights for policymakers regarding the ecological challenges associated with the transition to smart cities.

In light of this observation, the ensuing research question maybe articulated as follows:

To what extent can smart cities achieve an effective balance between the requirements of technological innovation and the imperatives of environmental sustainability, based on measurable quantitative indicators, in a context marked by increasing pollution and ecological threats?

Based on the research problem and objectives, the following hypotheses have been formulated:

- 1- Smart transportation systems contribute to the reduction of air pollution in Algerian cities.
- 2- Smart waste management systems improve recycling rates and reduce the volume of untreated waste.
- 3- Institutional and regulatory barriers affect the ability of Algerian cities to achieve environmental sustainability within the smart city model.

Following thematic axes:

Axis 1: The smart city as a level for sustainable development and a driver of improved quality of life

Axis 2: The environmental dimension of risks in the transformation towards smart cities

Axis 3: The smart city as a solution to pollution and environmental risks in Algeria: between reality and ambition

II. The smart city as a level for sustainable development and a driver of improved quality of life

In the face of the major challenges confronting contemporary cities, and in light of scientific advancements and human knowledge increasingly grounded in Internet technologies and artificial intelligence, the need to adopt new development models that ensure sustainability and quality of life has become imperative.

It is within this context that the concept of the smart city emerged as an innovative tool combining information technologies with urban governance, aimed at optimizing city performance and facilitating the daily lives of its inhabitants.

Smart cities have contributed to the achievement of sustainable development goals by providing technological solutions that have reduced pollution intensity and improved service efficiency. This makes them an effective tool for building more sustainable cities capable of adapting to future challenges.

II.1 Conceptual Framework of Smart Cities and Sustainable Development

Definitions and characteristics associated with the concept of smart cities vary considerably due to the diversity of sectors and fields it encompasses – whether political, environmental, or economic. This diversity has given rise to multiple terms such as «**Green cities**» and «**Innovative cities**», among others. However, the common denominator among these concepts lies in using information and communication technologies as a central tool for urban management and improving the quality of life.

The term «**Digital City**» is used synonymously with various concepts such as the smart city, the information city, the fiber-optic city, the knowledge-based city, as well as electronic communities linked to digital spaces. The digital city represents a dominant form of contemporary urban organization, in which digital networks and software applications contribute to shaping the various economic and social dimensions of urban life. (Samia NEZALI, 2019)

The Smart Cities

A smart city is an innovative urban model that leverages information and communication technologies and advanced tools to enhance quality of life, optimize urban services and processes, and strengthen competitiveness. This model operates within a framework that ensures the satisfaction of present needs without compromising the rights of future generations (economically, socially, and environmentally). (FOKKNER, 2016)

It is referred to by various terms such as «**Digital City**», «**Cybernetic City**», or «**Ecological City**». This designation depends on the strategic objectives set by planners and policymakers within the framework of urban development. The priorities of the smart city are defined according to technological, environmental, economic, or social objectives. (Ahmed Housni RADOUANE, 2015)

According to the International Data Corporation (IDC), a smart city is a geographically defined urban entity governed by local authorities, utilizing advanced information and communication technologies to enhance the efficiency of urban resource and service management. It also contributes to promoting economic development, supporting sustainability goals, and expanding citizen participation in decision-making processes. (MEGA, 2016)

Smart cities are defined by advanced, intelligent infrastructure that optimizes resource use and processes to enhance residents' quality of life and overall well-being. (MAMERI & CAMILLE, 2014)

Smart cities are defined as urban environments (whether newly developed or existing) that are designed and planned through the integration of technologies and programs related to information and communication technologies (ICT), to foster development and enhance the quality of urban life. (BESSKAL & ISSAOUA, 2024)

The Characteristics of the Smart Cityies

A smart city is defined by a set of interconnected dimensions that emerge from the integration of digital technologies with active citizen engagement. These dimensions collectively contribute to sustainable urban development and improved quality of life. The core components of a smart city can be outlined as follows: (LATRECHE & LAHMARI, 2021)

Smart Economy (Competitiveness): This dimension emphasizes innovation, the strengthening of regional identity (territorial branding), high levels of productivity, and adaptability in marketing strategies. Together, these factors foster economic vitality and enhance the city's global competitiveness.

Smart Society (Human and Social Capital): Characterized by a well-educated population, strong ethical values, and high levels of creativity and skill, the smart society supports social inclusion and contributes to a dynamic and resilient social fabric.

Smart Governance (Citizen Participation): Involving citizens actively in decision-making processes, smart governance promotes transparency, participatory leadership, improved access to public services, and the formulation of long-term strategic visions.

Smart Mobility (Transport and Information and Communication Technologies): This dimension seeks to optimize transport systems at both local

and national scales, utilizing advanced information and communication technologies (ICTs) to improve efficiency, accessibility, and environmental sustainability.

Smart Environment (Natural Resource Management): Focused on preserving green spaces, reducing pollution, and managing natural resources sustainably, the smart environment dimension aims to enhance ecological health and ensure urban resilience.

Smart Living (Quality of Life): Encompassing access to culture, improved healthcare services, public safety, and equitable access to education, smart living seeks to enhance the overall well-being and life satisfaction of urban residents.

II.2 Sustainable Development

Future sustainable development emphasizes the use of ICTs to transform cities into smart, resilient, and sustainable environments that improve quality of life and optimize urban services, within the framework of a «**Smart Environment**» promoting efficient and sustainable environmental management.

The concept of the «**Smart City**» is closely intertwined with that of «**Sustainable Development**», understood as an integrated framework designed to address contemporary challenges through the implementation of balanced development strategies that simultaneously consider economic, social, and environmental dimensions. (SAYAH, 2019)

Sustainable Development is the World Commission on Environment and Development defines sustainable development as a concept grounded in four fundamental dimensions (SAOULI & BENHASSEN, 2021)

The concept of sustainability can be understood through three interrelated dimensions:

- **Social Dimension:** This dimension underscores the importance of addressing the needs of poor and marginalized populations. Achieving this goal requires the active involvement of these communities in shaping and implementing development initiatives that directly affect their lives.
- **Environmental Dimension:** This dimension emphasizes the responsible use of natural resources and the preservation of ecosystems. It calls for meeting current needs without causing environmental degradation, pollution, or compromising the regenerative capacity of nature.
- The **temporal dimension** emphasizes long-term development, ensuring that current actions do not compromise the ability of future generations to meet their needs, thereby sustaining achievements over time.

- Finally, the fourth is «**Socio-economic dimension**», which relates to the cost of current development models and the imperative to align them with sustainability and social equity principles.

Sustainable development is fundamentally based on the pursuit of a balance between the demands of economic and social progress and the imperative of environmental preservation. It is on this foundation that the concept of sustainability emerged, eventually giving rise to the notion of sustainable development, which gained widespread international recognition following the publication of the Brundtland Report in 1987. (RAOUABEH, 2021)

According to **Sato** and **Hirayama**, Sustainable development is defined as a form of governance aimed at meeting the needs of the present generation without compromising the rights of future generations to enjoy well-being and access to natural resources. This perspective also implies that a development project can only be considered genuinely sustainable if it is conceived within a long-term framework, with a minimum planning horizon of one hundred years. (ABBAS, 2021)

The Dimensions of Sustainable Development

The Environmental Dimension: This dimension focuses on the rational use of natural resources to preserve ecological heritage for future generations. It involves the conservation of natural assets and the recognition of ecosystems' limited capacity to absorb waste, all within a framework that respects long-term environmental balance. (ABBAS, 2021)

The Economic Dimension: The economic aspect of sustainable development is centered on achieving sustainable economic growth by enhancing the efficiency of capital and other factors of production. It seeks to optimize resource use to meet basic human needs while ensuring long-term economic well-being.

The Social Dimension: Regarded as one of the core pillars of sustainable development, the social dimension is grounded in the promotion of equality, social justice, and citizen participation. It includes the protection of fundamental rights such as access to education, healthcare, employment, and political participation - particularly through the right to vote. It also aims to reduce social inequalities across different segments of the population.

II.3 The Smart Cities and Their Impact on Urban Quality of Life

The emergence of the smart city concept has established itself as a strategic response to the numerous contemporary challenges facing urban environments. It reflects the growing need to rethink urban governance models to promote sustainable development, enhance citizens' quality of life, and adapt to rapid technological and social changes. Consequently, the smart city is presented as an



innovative solution to major urban issues such as pollution, inadequate public services, and overpopulation. (Sandra BREUX, 2017)

Rapid Population Growth and Urban Expansion: The swift increase in urban populations places significant pressure on infrastructure, transportation systems, and essential services such as electricity, water, and healthcare. In this context, the adoption of smart technologies has proven crucial for more efficient, sustainable, and optimised management of urban resources and services.

Improvement of Infrastructure and Public Services: Smart cities play a central role in reducing carbon emissions through the adoption of renewable energy sources, optimization of public transportation systems (such as trams, metros, and high-speed trains), and the implementation of innovative waste management and valorization solutions.

Support for the Local Economy and Job Creation: The smart city acts as a strategic lever for local economic development by leveraging technological data and fostering innovation. It contributes to strengthening the entrepreneurial ecosystem by providing a conducive environment for the growth of small and medium-sized enterprises, supported by tailored technological, regulatory, and financial assistance.

Environmental Sustainability: The rational use of natural resources directly contributes to improving the quality of life by reducing pollution and waste generation, while mitigating the environmental impacts of human activities. Environmental sustainability thus emerges as a fundamental pillar to ensure high living standards and balanced urban development.

III The Environmental Dimension of Risks in the Transformation Towards Smart Cities

The transition to smart cities advances sustainable development and quality of life but also presents environmental challenges amid increasing global awareness of ecological issues. While smart cities aim to optimize resource use and reduce emissions, the rapid expansion of technologies, digital devices, and communication networks (if not managed prudently) can lead to increased energy consumption, higher waste generation, and the exacerbation of certain environmental problems. (BOUKRITA, 2020)

III.1 The Waste Issue and Environmental Risk Management Strategies in Smart Cities

Waste management is a critical global environmental challenge, as improper disposal of human-generated residues threatens both the environment and public health, necessitating effective and scientific management solutions. The continuous increase in waste production, driven by population growth and

economic development, reflects the diversity of human activities. However, such waste can gain benefit if efficiently reused, notably as raw materials within recycling processes. (MALAS, 2024)

Waste

The term «**Waste**» generally refers to all residual materials resulting from production, transformation, or consumption processes. More broadly, it encompasses any substances or objects discarded by humans with the intention of eliminating their harmful effects. (HASSANI, 2019)

The Algerian legislator defines waste as all residues resulting from production, transformation, or utilization processes, and more broadly, as any substance, product, or movable good that the owner or holder discards or intends to discard. (Law No. 01-19, concerning the management, control, and disposal of waste., 2001)

The Ministry of Spatial Planning and the Environment previously defined «**Waste**» as the totality of residues generated by households, along with those originating from artisanal and commercial activities. (MOUKHANFER, 2014/2015)

Types of Waste

Waste is classified into several categories based on its sources of origin and has become one of the most pressing environmental challenges facing contemporary cities. Closely linked to population growth and rapid urbanization, inadequately managed waste can lead to severe environmental and public health issues, including air pollution and the spread of diseases, among other negative impacts. (AHMADOUCHE & OUZEL, 2021)

Bulky Waste: This category includes waste generated by household activities that, due to their large volume or weight, cannot be collected under the same conditions as regular household waste.

Special Waste: Special waste refers to waste produced by industrial, agricultural, medical, service-related, or other activities that, because of their specific nature or the composition of the substances they contain, cannot be collected, transported, or treated in the same manner as household waste.

Household and Similar Waste: This term encompasses all waste generated by households, as well as waste from certain industrial, commercial, or artisanal activities, provided it exhibits characteristics similar to domestic waste.

Mechanisms for Managing Environmental Risks within the Framework of Smart Urban Development

Waste management is a key component of the green economy, posing significant environmental challenges for smart cities with direct and indirect effects on health, environmental quality, and resource sustainability.

In the context of the transition toward smart cities (built upon the integration of digital and technological solutions) it becomes imperative to adopt advanced technologies to optimize waste management and minimize waste generation. (AHMADOUCHE & OUZEL, The Role of Smart Cities in Managing Municipal Solid Waste – The Dubai Municipality as a Model, 2021)

Effectively managing environmental risks in smart urban environments requires the implementation of proactive strategies based on anticipating problems, reducing sources of pollution, and promoting recycling practices. Among these strategies are the following:

Sustainable Environmental Planning: An Innovative Ecological Strategy for Smart Cities

Environmental planning is essential for guiding smart city development in line with sustainable development, involving structured programs and regulations to anticipate and mitigate future ecological risks. This approach requires proactive vigilance to formulate appropriate strategies that can prevent or mitigate potential losses associated with these emerging issues. (AKARI, 2022)

The Role of Smart Cities in Risk Management

Smart cities enhance their capacity to respond to environmental risks through the deployment of advanced technologies. Indeed, they play a pivotal role in managing and mitigating various types of risks. This role is grounded in the integration of digital technologies within urban infrastructures and services, which strengthens the ability to forecast potential threats and enables rapid response during emergencies.

Environmental Impacts of Waste in Smart Cities

Rising urban waste and environmental challenges highlight the need for intelligent waste management, as effective handling is crucial for smart cities to achieve sustainable development. As this concept emerges as an innovative technological approach in urban development thinking, its efficacy has been demonstrated across various sectors. Consequently, governments must leverage these advancements to realize a range of ambitions aimed at enhancing urban quality of life, fostering a convergence between two fundamental paradigms: the smart city and the sustainable city. (BOUKCHEIBA & ALI, 2024)

III.2 Environmental Pollution in the Era of Digital Transition

Pollution is a key environmental challenge in the transition to smart cities, amid rapid technological advancements driven by the expansion of information and communication technologies. This evolution has given rise to the concept of the «**digital transition**», which has significantly altered lifestyles as well as professional practices across various sectors. This process of digitization has directly influenced the development of the smart city model, defined as an urban space that integrates digital technologies, intending to enhance citizens' quality of life and promote sustainable development.

The Pollution

The phenomenon of pollution has expanded significantly, affecting all facets of the environment. It is now regarded as a major contemporary scourge, spreading at an alarming rate and impacting all living organisms and ecosystems without discrimination. Comparable to a destructive virus, pollution indiscriminately alters everything it encounters, thereby posing a serious threat to ecological balance and public health. (BALOUT, 2020)

Michael ALLABY defines pollution as the direct or indirect alteration of the physical, biological, chemical, or radiological properties of any component of the environment, in a manner that increases the risk of harm (whether immediate or latent) to the health, safety, or well-being of all living organisms. (ALLABY, 1983)

Classifications of Pollution

Environmental pollution is a major contemporary challenge, varying in form, severity, and origin, and can be classified by source, nature, intensity, and geographic scope to inform effective mitigation strategies. These classifications guide environmental policies, inform mitigation strategies, and support a scientific approach to managing environmental issues, ultimately promoting ecosystem sustainability. (HAWASSE, 2019/2020)

Classification of Pollution by Source and Nature

Pollution can be classified by source and nature, including natural origins, and such categorization is crucial for accurately diagnosing environmental issues and developing effective solutions, especially amid rapid industrialization and urbanization. It is especially significant in the context of smart city development, where advanced technologies can be employed to detect and respond to this type of pollution efficiently.

Pollution Based on Its Intensity and Geographic Extent

Pollution can be categorized by intensity, hazard level, and geographic scope,

representing major environmental challenges for modern cities amid uncontrolled urban growth and overconsumption of natural resources. This form of pollution is characterized by its complex and multidimensional nature: it does not originate from a single source nor manifest in a singular form. It encompasses varying levels of severity (ranging from what may be considered acceptable pollution to hazardous or destructive levels) and can be categorized by its temporal dimension, distinguishing between short-term and long-term pollution.

IV. The Smart City as a Solution to Pollution and Environmental Risks in Algeria: Between Reality and Ambition

Population growth, changing human needs, and global socio-economic transformations have fueled pollution, primarily driven by an anthropocentric mindset and mismanagement of natural resources, threatening environmental balance and ecosystems. Consequently, this problem has exacerbated several critical environmental threats, including air and water pollution and soil degradation. These challenges underscore the urgent need to reconsider urban planning and resource management approaches by implementing innovative and sustainable solutions, with the smart city model at the forefront of these strategies. (DAIF & HAMIANI, 2020)

Algeria, like many other developing countries, has recently experienced significant urban expansion, digital transformation, and the emergence of young enterprises. The country has made some efforts to address environmental risks and pollution, particularly through the adoption of public environmental policies embodied in digital projects aimed at improving waste management and directing investments towards renewable energy. However, these initiatives remain limited in scope and face challenges related to implementation and coordination among the various stakeholders involved.

IV.1 Towards a Green and Smart Algeria: Smart Cities as a Mechanism to Address Pollution and Environmental Degradation (Between Environmental, Digital, and Organizational Challenges)

The concept of pollution is generally linked to that of the environment, as pollution arises from an imbalance within the environment or one of its constituent components. Scholars widely agree that the primary cause of pollution is inherently human activity. Indeed, the environment provides humans with essential needs such as food, water, shelter, and clothing. However, the multiplicity of uses, the accumulation of environmental violations, and irrational consumption practices collectively contribute to disrupting this fragile equilibrium.

Cities, as centers of high population density and intense economic activity, are among the most vulnerable areas to environmental challenges. This reality calls for a critical reassessment of existing urban management practices and the pursuit of innovative solutions based on technology and digitalization, with the ultimate goal of fostering sustainable urban development. (HAWASSE, 2019/2020)

Within this context, the smart city model has emerged as a viable approach capable of effectively addressing environmental issues. Algeria, as a developing country, has begun to explore this pathway through the launch of digital initiatives, support for emerging enterprises, and the digitization of infrastructure and services. However, this process continues to face significant challenges, including :

Environmental Challenges

These challenges are particularly evident in the rising levels of urban pollution, especially in major cities such as Algiers, Oran, and Constantine, which are currently experiencing traffic congestion largely due to the high number of aging vehicles (one of the primary contributors to air pollution).

Although Algeria has implemented a policy aimed at expanding green spaces, spaces, these efforts remain insufficient, particularly in large urban centers where the deficit in green infrastructure is especially pronounced.

Technological Challenges

Algeria, as a developing country, has made significant progress, particularly in the fields of higher education and scientific research, largely due to advancements in digitalization. However, the country continues to face limitations in widespread internet access, which notably affects the organization of national examinations such as the Baccalaureate.

Moreover, the absence of unified platforms for the collection and analysis of data related to pollution and environmental risks remains a major obstacle. This gap was particularly evident in recent years (especially in 2021 and 2022) when recurrent wildfires led to a marked deterioration in air quality and tragically resulted in the loss of several human lives.

Organizational and Institutional Challenges

Although Algeria is making efforts to digitize all sectors of its economy, the state funding allocated to environmental digitalization remains insufficient, thereby limiting the implementation of projects aimed at environmental protection. Furthermore, the lack or weakness of coordination among local stakeholders (particularly municipalities, environmental departments, and research centers)

has resulted in a deficit of an integrated strategic vision for the development of sustainable smart cities.

IV.2 Smart Cities in Algeria: A Strategic Choice for Combating Pollution and Achieving Environmental Sustainability

In light of recent opportunities and challenges facing Algeria (particularly those related to the prospects of developing smart cities, especially in rapidly growing urban areas), it becomes evident that transitioning towards this model represents a strategic imperative. This approach is intended to foster sustainable development while mitigating negative environmental impacts. (BELKEIDOU & MAMEN, 2019)

Example of Algerian Initiatives: The «Smart Algeria» Project

➤ SIDI ABDELLAH Experience: Algeria's First Smart City (Toward a Smart City to Reduce Pollution and Environmental Risks)

SIDI ABDELLAH, located west of Algiers, represents Algeria's first concrete attempt at building a fully integrated smart city from the ground up. This initiative is part of a broader national strategy aimed at establishing an environmentally sustainable urban model that leverages modern technologies to address environmental, economic, and social challenges.

Key components of this project reflect an integrated approach to smart and sustainable urban development, and include the following:

Eco-friendly urban planning, characterized by the integration of extensive green spaces and the efficient management of energy resources to minimize environmental impact.

A smart and sustainable mobility system, designed to reduce dependency on private vehicles, lower pollutant emissions, and encourage the use of environmentally friendly public transportation options.

Advanced digital infrastructure, encompassing the installation of fiber-optic networks and high-speed internet connectivity, to enhance access to administrative, healthcare, and educational services.

A dedicated technological hub, serving as a nucleus for innovation by bringing together startups, research institutions, and universities to advance key sectors such as artificial intelligence and renewable energy.

Fig.(01): ALGERIA (Sidi Abdellah) : A Smart City



Source: Authored by two researchers

<http://dnalgerie.com/wp-content/uploads/2024/03/aadl-2-algerie-details-distribution-surplus-logements.wepp>.

➤ **The City of Oran: Toward a Smart Transformation to Address Pollution and Achieve Environmental Sustainability**

Alongside Sidi Abdellah (Algeria), the city of Oran represents Algeria's second major smart city prototype, currently undergoing a progressive transition toward sustainable urban development. This transformation gained increased visibility during the 2022 Mediterranean Games, which catalyzed the implementation of several smart urban initiatives. Key developments include:

Modernization of transportation infrastructure, notably through the introduction of a tramway system, has contributed to reducing reliance on private vehicles and promoting more sustainable mobility options.

Digitalization of public administration services, particularly in the housing and urban planning sectors, as demonstrated by the launch of the «AADL 3» digital housing platform.

Expansion and revitalization of green public spaces, exemplified by the redevelopment of the «*Es-Sedikia*» area—formerly occupied by dilapidated buildings—into the «*Garden of Freedom*», a new urban green space aimed at enhancing environmental quality and public well-being.

Fig.(02): Oran : A Smart City



Source: Authored by two researchers

<http://algeriaspace.com/up-content/uploads/2022/11ALGERIA-SPACE171>

➤ **The City of Constantine: Between Heritage and Modernization Toward a Smart and Ecological Urban Model**

Constantine also stands as a notable example among Algeria's emerging smart city initiatives. Despite ongoing challenges, the city has recently begun integrating smart city concepts into its urban planning and resource management strategies, aiming to reduce pollution and enhance the overall quality of life.

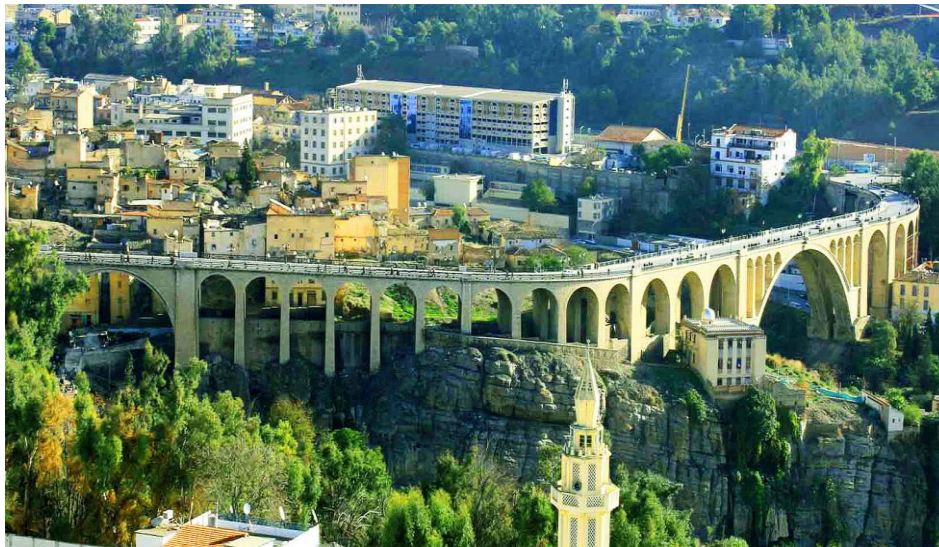
Among the most notable initiatives and projects undertaken are the following:

Rehabilitation of historic neighborhoods, with a strong focus on preserving both the city's natural and architectural heritage, including the protection and restoration of its iconic bridges.

Implementation of urban waste management strategies, particularly through the large-scale deployment of underground waste containers in selected districts, aimed at improving sanitation and reducing visual pollution.

The Constantine Tramway project, considered a key component of sustainable urban mobility, aimed at reducing traffic congestion and pollution (particularly in the city's narrow historic areas).

Fig.(03): Constantine: A Smart City



Source: Authored by two researchers

<http://i.pinimg.com/736x/3b/d4/54/3bd454ca4a41e9d75ab136d1e234639d>.

V. Conclusion

This study highlights the challenges and opportunities associated with the transition to smart cities in Algeria, within the pressing need to balance technological innovation and environmental sustainability, as outlined in the research problem: *To what extent can smart cities achieve an effective balance between technological innovation and environmental sustainability amid increasing pollution and ecological threats?*

The study was guided by a set of testable hypotheses, assuming that smart transportation systems contribute to reducing air pollution, smart waste management improves recycling rates and reduces untreated waste, digital infrastructure enhances environmental efficiency, and that institutional and regulatory barriers affect the ability of cities to achieve sustainability.

Preliminary theoretical findings indicate that smart cities hold significant potential to support environmental sustainability, provided that modern technologies are integrated within comprehensive strategies that account for environmental, social, and economic dimensions alike. The analysis also demonstrates that quantitative performance indicators enable an objective assessment of environmental impact and can inform public policies to enhance the environmental effectiveness of smart cities in Algeria.

In summary, this research provides a foundational understanding of the complex relationship between technological innovation and environmental sustainability, emphasizing the importance of adopting an integrated approach that combines

theory and practice while considering local specificities and regulatory challenges to achieve a sustainable and smart urban model.

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