

Remote Work and Smart Cities: A Strategy for Algeria's decarbonization

العمل عن بُعد والمدن الذكية: نحو استراتيجية جزائرية للحد من الانبعاثات الكربونية

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Abstract:

This paper examines the role of smart cities and remote work in reducing carbon footprints and promoting sustainable urban development. As climate change and urban pollution become critical issues, adopting digital technologies and flexible work arrangements can improve human well-being while lowering environmental impact. Globally, nations show different levels of progress, with some leading in smart-city implementation and green digital solutions, while others face challenges due to limited resources or weak infrastructure. In Algeria, efforts are underway to modernize public services, develop intelligent urban systems, and promote remote work. Although the country lags behind global and some African peers, its ambitions include building smarter cities, improving digital infrastructure, and fostering sustainable practices.

Keys words: Smart-Cities, Remote-Work, Carbon-Footprint, Digital-Transformation, Sustainable Urban Development, Algeria

JEL classification codes: R58 , J21 , Q54 , O33 , R11 , N96

ملخص:

تتناول هذه الورقة دور المدن الذكية والعمل عن بُعد في تقليل البصمة الكربونية وتعزيز التنمية الحضرية المستدامة. مع تصاعد تأثير التغير المناخي وتفاقم التلوث في المدن، يمكن لتبني التقنيات الرقمية وترتيبات العمل المرنة أن يحسن رفاهية الإنسان مع الحد من التأثير البيئي. على المستوى العالمي، تظهر الدول مستويات مختلفة من التقدم، حيث تصدر بعض الدول تنفيذ المدن الذكية والحلول الرقمية الخضراء، بينما تواجه دول أخرى تحديات بسبب محدودية الموارد أو ضعف البنية التحتية. في الجزائر، تُبذل جهود لتحديث الخدمات العامة، وتطوير نظم حضرية ذكية، وتشجيع العمل عن بُعد. وعلى الرغم من تأخر البلاد مقارنة بالدول العالمية وبعض الدول الإفريقية، تشمل طموحاتها بناء مدن أكثر ذكاءً، وتحسين البنية التحتية الرقمية، وتعزيز الممارسات المستدامة. وتبرز الورقة أهمية الاستثمار المستمر، والتنسيق، ودعم السياسات لتحقيق هذه الأهداف.

الكلمات المفتاحية: المدن الذكية، العمل عن بُعد، البصمة الكربونية، التحول الرقمي، التنمية الحضرية المستدامة، الجزائر

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Introduction

Smart cities and remote work are becoming important topics as countries try to deal with climate overheating and growing environmental pressures. Many cities around the world are now searching for new digital solutions to reduce pollution, limit traffic, and manage resources more

efficiently. At the same time, remote work has expanded and is helping reduce daily commuting, fuel consumption, and urban congestion. These changes show how digital tools can support more sustainable lifestyles and improve the quality of life in large urban areas. For countries like Algeria, the move toward smart-city models and wider use of remote work represents a promising direction. However, it also requires strong digital infrastructure, better coordination, and clear policies. As climate challenges become more urgent, adopting smarter technologies and promoting remote work can play a key role in lowering the carbon footprint and preparing cities for a more sustainable future.

1- The smart cities :

The concept of « smart cities » has been the subject of numerous definitions in the literature, reflecting different disciplinary perspectives and strategic priorities. According to (Caragliu, Del Bo, and Nijkamp ,2011), a city can be considered smart when it invests in human and social capital, as well as in communication infrastructure, in order to promote sustainable economic growth and an enhanced quality of life through participatory governance. (Albino et al.,2015) argue that the smart city represents an evolving paradigm, often characterized by the integration of information and communication technologies (ICT) into urban services, while also emphasizing sustainability and social inclusion. In another perspective, (Anthopoulos,2017) and (Kommunos,2013) highlight the organizational and institutional dimension, defining smart cities as complex systems where digital solutions must be accompanied by innovation in governance models. These definitions differ mainly in the weight they give to technological, social, or institutional factors: while some emphasize the role of digital technologies in optimizing urban services, others underline citizen participation and sustainability as essential criteria. This plurality of approaches demonstrates the multidimensional nature of the concept, which cannot be reduced to mere technological implementation but should instead be understood as a systemic transformation of territories.

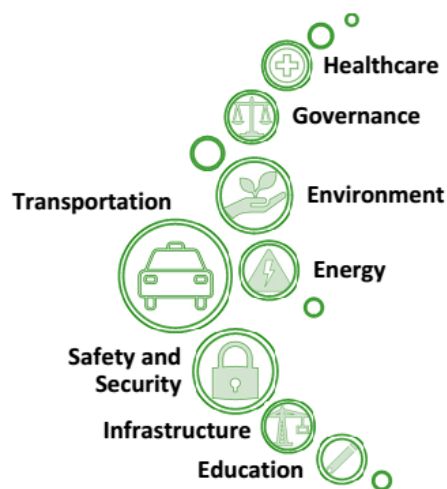
1-1- Smart City Applications :

Rapid diffusion of Smart technologies, powered by IoT and AI, have reshaped modern life by enhancing Smart City efficiency and quality of life across key domains:

- **Healthcare:** IoT enables remote monitoring and predictive analytics to improve patient outcomes and lower costs.
- **Governance:** Digital sensors optimize urban management and road traffic while improving transparency and strengthening direct interaction between citizens and local authorities.
- **Environment:** Smart grids and waste systems combat climate change by promoting energy efficiency and circular economy practices.
- **Transportation:** Intelligent systems and autonomous vehicles make urban mobility safer, cleaner, and more efficient.

- **Energy:** Smart grids integrate renewable sources and balance supply to drastically reduce carbon footprints.
- **Safety:** AI surveillance and emergency detection systems strengthen crime prevention and rapid response.
- **Infrastructure:** Smart buildings and sensors monitor structural integrity and optimize energy use for sustainable environments.
- **Education:** AI platforms personalize learning and use analytics to bridge performance gaps and expand access.

Fig.1 : Smart cities application domains



Source : (Garcias et al., 2023)

In summary, the convergence of these applications within the Smart City framework creates an inclusive, resilient, and sustainable urban ecosystem, using data-driven insights to solve complex societal challenges.

2- Remote Work :

2-1- Definition:

The term "remote work" is sometimes used, although it may not always be entirely precise (Tremblay, 2020). Remote work generally refers to performing professional tasks outside the main office using an internet connection (Scaillerez & Tremblay, 2016). Studies on remote work distinguish several forms: a satellite office hosting employees of the same company is one example; a call center located separately from the main office is another. Some authors even include work performed by company representatives in various locations, such as salespeople or field technicians. Others expand the definition to include workers without a company office, performing their duties as client representatives or from their homes (Scaillerez & Tremblay, 2016).

According to the International Labour Organization (ILO), remote work is defined as the use of information and communication technologies (smartphones, tablets, laptops, and desktop computers) to carry out tasks outside

company premises. Remote work must be based on a mutual agreement between employer and employees, detailing aspects such as working hours, communication methods, tasks to be performed, and monitoring arrangements (ILO, 2020).

2-2- Evolution of remote work:

The concept of remote work emerged in the United States in the 1950s, inspired by Norbert Wiener's work on cybernetics. However, it only became widely recognized in the 1970s with the rise of telematics and information highways. According to (Largier ,2001), predictions in the 1970s were highly optimistic; for example, AT&T anticipated that twenty years later, Americans could work from home. By the early 21st century, however, optimism regarding the widespread adoption of remote work had decreased (Largier, 2001).

The global development of remote work also shows disparities due to differences in definitions, making it difficult to quantify the phenomenon (Tremblay & Najem, 2010). Nevertheless, Anglo-Saxon countries are leading, with the United States showing more than 30% of the workforce engaged in remote work, while rates in the European Union range between 10 and 20%.

2-3- Advantages and Disadvantages:

(Tremblay et al., 2006) highlights a balance between individual flexibility and organizational challenges:

- **Primary Advantages:** The main benefit is schedule flexibility, which allows for a better work-life balance, particularly for families. Employees save time and money by avoiding commuting, leading to increased productivity and a perceived improvement in quality of life.
- **Key Disadvantages:** While many report no drawbacks, some face social isolation. Potential risks mentioned by (Tremblay et al., 2006) include the work-family conflict, overworking, or a lack of self-discipline, often compounded by inadequate home equipment and poor connectivity.

2-4- Legal Framework:

As early as 1996, the ILO (International Labour Organisation) adopted a convention on home work. Although it does not address all remote work-related issues, it provides a legal foundation for further developments (Scaillerez & Tremblay, 2016).

In the United States, there is limited legislation regulating remote work; similarly, Canada has no specific federal measures, and neither country has ratified the ILO convention (Scaillerez & Tremblay, 2016).

In the European Union, the situation is somewhat more advanced. In the 1990s, France, Italy, and Belgium adopted remote work legislation. From the 2000s onwards, with the integration of information and communication technologies into the workplace, the EU encouraged member states to promote remote work, particularly to improve the quality of life for workers with disabilities (Scaillerez & Tremblay, 2016).

3- Carbon footprint of organisation :

According to (Turek et al. ,2021), climate change has triggered a wide range of actions aimed at protecting the environment, taken by governments, non-governmental organizations, cities, municipalities, and businesses. These actions usually include efforts to reduce greenhouse gas (GHG) emissions—mainly carbon dioxide CO₂—lower energy consumption, and monitor, analyze, report, and forecast the impacts of climate change. One of the most commonly used tools for assessing these impacts is the carbon footprint (CF), which estimates the contribution of a specific product, activity, individual, organization, or even an entire country to environmental change.

The concept of the carbon footprint is derived from the ecological footprint and was introduced during the 1990s. It focuses on the measurement of human activities' impact on the environment, particularly through greenhouse gas (GHG) emissions. Essentially, CF provides a way to quantify the total amount of carbon dioxide released both directly and indirectly by an activity or accumulated across the life cycle of a product. By offering this measurement, the carbon footprint allows organizations and individuals to better understand their environmental impact and identify key areas where improvements are possible.

In recent years, calculating the carbon footprint has become increasingly common not only for individuals and organizations but also for cities, regions, and even entire countries. This growing interest is largely linked to the increasing awareness of sustainable development and the importance of reducing human impact on the environment. Determining the CF helps identify areas with high emissions, which is the first step toward implementing strategies to cut greenhouse gases. Sharing carbon footprint data also contributes to an organization's public image, as it highlights a commitment to environmental responsibility. Consumers today are more informed and conscious about the ecological effects of the products and services they choose, and they often consider environmental impact when making purchasing decisions.

A widely recognized approach for measuring and verifying carbon footprint is the ISO 14067 standard, along with its 2013 technical specification, this standard evaluates the potential environmental impact by considering the entire life cycle assessment (LCA) of a product, service, process, or system. It covers all stages, including raw material extraction, design, production, distribution, use, and disposal. By using this approach, organizations can not only measure emissions accurately but also identify opportunities to reduce them at different stages of the life cycle, contributing to a more sustainable and environmentally responsible operation.

3-1- How Smart Cities Reduce Carbon Footprint

Cities that adopt smart-city strategies manage to reduce their CO₂ footprint by coupling technological, infrastructural and governance-level measures oriented toward energy efficiency, renewable integration, and

optimized urban systems (Fu, Yang & Li, 2024). In effect, by replacing traditional, fragmented energy and urban-planning models with integrated “smart energy” systems — combining electricity, heating, storage, and information flows — cities can respond more dynamically to energy demand, better absorb variable renewables and reduce losses and waste across supply and distribution chains (Fu, Yang & Li, 2024).

Moreover, smart-cities often deploy Internet-of-Things (IoT), data platforms and ICT-based management tools to monitor and modulate consumption in real time: these technologies enable optimized control of buildings (lighting, heating/cooling), adaptive transport and mobility management, and efficient urban services (waste, water, public utilities). As a result, operational emissions from buildings and services are significantly lowered, improving resilience and sustainability of urban infrastructures (Okonta & Vuković, 2024).

Empirically, a recent large-scale study covering many cities shows that smart city construction (SCC) is associated with a statistically significant reduction of urban CO₂ emissions — on average around 11.4% in pilot cities compared to non-pilot ones — with effects especially marked in industrial activities, waste treatment, transportation and building-related emissions (An, Yang, Zhang & Zeng, 2024). This suggests that smart-city initiatives — when properly implemented — can deliver noticeable decarbonization benefits at the city level.

Furthermore, the mechanism behind that reduction appears to be mediated by technological change and “green innovation”: smart city policies tend to foster improvements in total factor productivity (TFP), increased green-tech patents, and a structural shift toward cleaner production and consumption patterns. These systemic changes help decouple urban growth from emissions growth, indicating that the benefits of smart cities go beyond simple optimization toward enabling a longer-term transformation of urban economies (An, Yang, Zhang & Zeng, 2024).

3-2- Remote work as a Carbon Footprint Reducer: Mechanisms and Limits

One of the most direct environmental benefits of remote work is the reduction in commuting: substituting home-based work for office-based work eliminates or reduces daily commute trips, particularly in contexts where commuting is car-dependent, thus cutting transport-related CO₂ emissions by a substantial margin (Ríos Villacorta et al., 2025). This effect can be especially significant in sprawling cities, where commutes tend to be long and car-intensive.

However, the net effect of remote work on emissions is not always positive, increased residential energy consumption (heating, cooling, lighting, ICT, appliances) during working hours can offset part — or sometimes all — of the commuting benefits, especially in homes with poor insulation or where heating/cooling systems are inefficient (Silva et al., 2025). In addition,

behavioral “rebound effects” (e.g., more frequent leisure trips, energy-intensive domestic habits) further complicate the picture and may reduce or negate gains from transport-related emission cuts (Ríos Villacorta et al., 2025).

A recent systematic review of literature (2020–2024) found that under favourable conditions (efficient housing, short commutes, low-carbon electricity), remote work can reduce generalized corporate- and commuting-related emissions by roughly 29–54%, depending on the intensity and extent of remote work deployment — but the authors stress that these reductions are heavily moderated by context (housing conditions, energy mix, organizational and societal factors) (Ríos Villacorta et al., 2025).

Therefore, while remote work offers clear potential as an emissions-reduction tool, its success depends on coupling with supportive infrastructure and energy-efficient housing, as well as policies or incentives aimed at reducing household energy demand during working hours. Without these complementary measures, remote work may deliver limited or even negative climate benefits.

The environmental implications of remote work are complex and depend on how transport, household energy use, and behavioural changes interact. While remote work is frequently promoted as a way to reduce emissions, empirical assessments show that its net carbon impact can vary significantly across contexts.

3-2-1-Potential Carbon-Reduction Advantages:

- **Reduced commuting emissions**, especially in car-dependent regions, remain the most direct and consistent benefit. Eliminating daily travel to workplaces decreases vehicle-kilometres travelled and reduces CO₂ and local air pollutants on a per-worker basis (Ríos Villacorta et al., 2025).
- **Lower peak-hour congestion and cleaner urban air**, since fewer commuters lead to measurable short-term improvements in nitrogen dioxide concentrations in dense city centres, which indirectly supports climate and public-health objectives (Ríos Villacorta et al., 2025).
- **Opportunities for systemic energy efficiency**, where remote work policies are combined with low-carbon energy supply and targeted home retrofits, ensuring that increased residential daytime energy use does not offset transport gains (Sepanta, Sirati & O’Brien, 2024).

3-2-2-Potential Carbon-Related Disadvantages:

- **Increased household energy consumption**, especially in colder climates where full-home heating is required during working hours, can partially or completely offset commuting savings (Shi, Sorrell & Foxon, 2023).
- **Rebound effects (indirect consequences)**, such as additional non-work travel, increased use of inefficient housing, or relocation to larger

suburban homes, can reduce or reverse the expected climate benefits (Sepanta, Sirati & O'Brien, 2024).

- **Scenario sensitivity**, meaning the carbon outcome of remote work depends strongly on housing characteristics, heating systems, and electricity carbon intensity—conditions that vary widely across cities and households (Shi, Sorrell & Foxon, 2023).

4- Remote Work Embedded in Smart Cities — Synergies, Risks, and Policy Alignment

Integrating remote work within smart-city ecosystems provides significant opportunities to enhance carbon reduction while also introducing new complexities. Smart-city infrastructures — such as smart grids, IoT-enabled buildings, and data-driven mobility management systems — allow urban systems to optimize energy flows, synchronize commuting patterns, and efficiently manage public services. In this context, remote work becomes part of a **systemic decarbonization strategy**, complementing other measures rather than functioning in isolation (OECD, 2023).

- **Synergistic Advantages** (UN-Habitat, 2024)
 - **Optimized energy demand:** Smart grids can shift residential energy use associated with remote work to off-peak periods, integrating more renewable energy and reducing reliance on carbon-intensive backup generation.
 - **Reduced transport emissions:** With fewer workers commuting, urban congestion decreases and public transport operations become more efficient, lowering fuel consumption and local pollutants .
 - **Enhanced building efficiency:** IoT-enabled homes and offices allow precise control of heating, cooling, lighting, and device usage, ensuring that daytime occupancy does not proportionally increase emissions.
- **Risks and Challenges:** (IEA, 2021)
 - **Digital infrastructure energy use:** Supporting remote work requires data centers, servers, and broadband networks that can consume substantial electricity. If not powered by low-carbon sources, these systems can offset part of the commuting-related carbon savings.
 - **Residential energy rebound:** Remote working increases daytime household energy consumption. Poorly insulated houses or inefficient heating/cooling systems may reduce net carbon savings.
 - **Policy misalignment:** Without coordinated urban policies — including energy-efficient building standards, renewable-powered grids, and sustainable mobility strategies — remote work's environmental benefits remain partial or uneven.
 - **Socio-spatial inequality:** High-income households often benefit more from remote work due to better housing, digital connectivity,

and access to low-carbon energy. Conversely, lower-income households may experience smaller carbon reductions or even net increases, highlighting the need for inclusive policy interventions.

- **Strategic Policy Recommendations:** (UN-Habitat, 2020).
 - **Invest in renewable-powered smart grids** and energy-storage solutions to supply both residential and digital loads sustainably.
 - **Promote energy-efficient residential buildings**, including insulation, zoning of heating/cooling, and smart meters, to minimize rebound effects.
 - **Optimize urban mobility** by leveraging remote work to redesign public transport schedules and encourage active travel.
 - **Ensure energy-efficient digital infrastructure** with low-carbon data centers and load-shifting capabilities.
 - **Implement adaptive governance**, monitoring remote work patterns, residential energy use, and urban emissions to refine policies continuously.

When these strategies are implemented together, remote work embedded within smart cities can deliver durable, substantial, and equitable reductions in urban carbon emissions. It reshapes daily mobility patterns, redistributes energy demand efficiently, and strengthens the impact of broader smart-city decarbonization measures. (UN-Habitat, 2020).

5- Global Smart Cities: Criteria, Rankings, and Regional Dynamics

The development of Smart Cities is a complex and multidimensional response to the challenges posed by global urbanization. However, the evaluation of their success remains fragmented. According to analysis by (Chai Keong Toh ,2022), the lack of a universally accepted evaluation methodology leads to persistent confusion when comparing urban performance, as each index uses its own specific criteria. An academic understanding of this concept requires breaking down the evaluation criteria, identifying the major rankings, and acknowledging the importance of the human factor.

5-1- Key Criteria and Evaluative Dimensions

The Smart City concept is built upon multiple pillars that extend beyond the mere integration of digital technology. A recent systematic literature review consolidated the identification criteria for Smart Cities into three main categories, which define the scope of urban performance (Dashkevych & Prtnov,2022):

- **Smart Digital Technology:** Focuses on digital infrastructure, communication networks, and the use of big data to optimize urban services (mobility, energy, etc.).
- **Living Conditions:** Encompasses aspects of residents' quality of life, such as education, culture, healthcare, and safety.

- **Environmental Sustainability (Ecological):** Measures energy efficiency, resource management, pollution reduction, and sustainable urban practices.

5-2- Famous Global Rankings and Top Performers

In-depth study by (Toh ,2022) compared six major Smart City indexes, including the IMD-SUTD Smart City Index (SCI), the IESE Cities in Motion Index (CIMI), and the Mori Foundation Global Power City Index (GPCI). The SCI is particularly relevant because it emphasizes the "human factor" and citizen perception.

Taking the SCI 2021 ranking (analyzed by Toh, 2022) as a reference, the top-performing cities are those that successfully harmonized technology and well-being.

Top 10 Global Smart City Ranking (IMD-SUTD SCI 2021)

Global Rank	City	Country	Overall Alphabetical Grade	Group (Based on HDI)
1	Singapore	Singapore	AAA	Group 1 (Very High HDI)
2	Zurich	Switzerland	AA	Group 1
3	Oslo	Norway	AA	Group 1
4	Taipei	Taiwan	AA	Group 1
5	Lausanne	Switzerland	AA	Group 1
6	Helsinki	Finland	AA	Group 1
7	Copenhagen	Denmark	AA	Group 1
8	Geneva	Switzerland	A	Group 1
9	Amsterdam	Netherlands	A	Group 1
10	New York	United States	A	Group 1

Source: Adapted from (Toh ,2022), based on the IMD-SUTD Smart City Index 2021 data.

5-3- The Human Factor and Smart Governance

The success of a Smart City is measured by its impact on citizen well-being. It has been established that effectiveness does not depend only on infrastructure, but on how technology supports inclusive governance and citizen participation (Smalec, 2025). Leading cities like Singapore, Zurich, and Oslo demonstrate that successful cities manage to develop a stable socio-economic environment and a strong commitment to citizens, confirming that the human factor is an essential pillar of the Smart City concept.

5-4- Smart City Dynamics in Africa and the Arab World

The Smart City landscape in the Arab and African regions is shaped by strategies that often rely on large projects or on practical, low-cost solutions designed to quickly fix shortages in infrastructure and basic services (Toh, 2022).

5-4-1-Arab World (GCC): Massive Investment and New Cities

Initiatives in the Gulf Cooperation Council (GCC) countries are marked by major government investments in new cities built entirely from the ground up or in upgrading existing ones. The main objective is to support economic diversification and strengthen their position in global competition.

Cities like Dubai (UAE) and Saudi mega-projects like NEOM (The Line) illustrate this ambition. These projects focus on cutting-edge infrastructure and sophisticated digital services, often integrated into sustainable development strategies (Mutambik et al., 2023). This "smart governance" approach is typical of the region, where the transition is driven by the government for efficiency and improved quality of life.

5-4-2-Africa: Frugal Innovation and Digital Inclusion

In Africa, Smart City development is more focused on solving urgent socio-economic and environmental challenges. Technologies are often deployed as tools for inclusion and access to basic services in constrained environments.

Cities like Cape Town (South Africa) and Nairobi (Kenya) are recognized for the rapid adoption of mobile technologies and e-governance platforms (African Smart City Index, 2023). These initiatives aim to improve transparency and citizen engagement. The main obstacle remains building local capacity and the need to strengthen regulatory frameworks to ensure the long-term sustainability and inclusivity of these technologies (African Smart City Index, 2023).

6- Remote work, Smart-City Development, and Carbon Footprint Reduction in Algeria

In Algeria, remote work is addressed in the Labor Code by Decree 97-474 of 8 December 1997. Article 2 defines home workers as individuals performing paid activities at home for one or more employers, either alone or with family members, using their own materials or those provided by the employer, without intermediaries. The decree also defines home employers and outlines their legal obligations, including social security registration.

6-1- Remote work and the Digital Transition in Algeria

The expansion of remote work and the broader digital transition in Algeria have become central components of administrative and territorial reform efforts since the early 2010s. The COVID-19 crisis in 2020 accelerated these transformations by compelling public and private institutions to adopt new work organization models rapidly. Despite this acceleration, existing analyses show that progress remains uneven due to differences in sectoral readiness, technological capacity, and levels of governance.

According to (Benghebrid et al., 2022), the pandemic served as a catalyst by demonstrating the ability of certain enterprises and public administrations to experiment with remote work under emergency conditions. However, the same study highlights structural constraints linked to the limited

availability of digital infrastructures, weak organizational practices within teams, and the persistence of traditional managerial cultures. Their assessment, which draws on a panel of public and private institutions, shows that large-scale remote work adoption would not have been possible without exceptional temporary measures, especially Executive Decree No. 20-69 (2020), which authorized special work arrangements during the fight against COVID-19.

In the longer term, the main legal framework remains Executive Decree No. 97-474, which defines home-based work as a specific work modality. Nevertheless, this decree does not match contemporary digital remote work practices. Its limited scope explains the absence of a dedicated legal framework emphasized by (Benghebrid et al., 2022), who argue that Algeria still lacks a regulatory architecture adapted to remote, ICT-based work environments.

The digital transition running parallel to the evolution of remote work forms a central pillar of public service modernization. As stated by (Arribi & Boutarfa, 2024), various administrations have begun digitalizing procedures to reduce physical mobility requirements, simplify administrative interactions, and improve service delivery. According to their findings, digitalization has advanced most notably in commerce, taxation, civil status services, and higher education, although progress remains gradual and dependent on the availability of secure national digital platforms.

6-2- Smart-City Initiatives and Urban Digitalization in Algeria

The concept of smart cities remains emerging in the Algerian context. Research conducted by (Benaouda, 2024) shows that several major cities—such as Algiers, Oran, and Sétif—have initiated local efforts to exploit digital data, introduce intelligent urban mobility systems, and expand digitalized municipal services. These initiatives illustrate a growing interest in smart urban management, yet the approach remains fragmented and primarily driven by small-scale pilot projects rather than a unified national strategy.

This fragmentation is consistent with findings from (Okil & Boudraham, 2019), who argue that the development of smart cities requires the consolidation of three fundamental pillars :

- Strong intersectoral coordination,
- Modernized and decentralized local governance,
- Reliable and resilient digital infrastructure.

These components are still under construction in the Algerian institutional landscape, which slows the transition toward integrated smart-city systems.

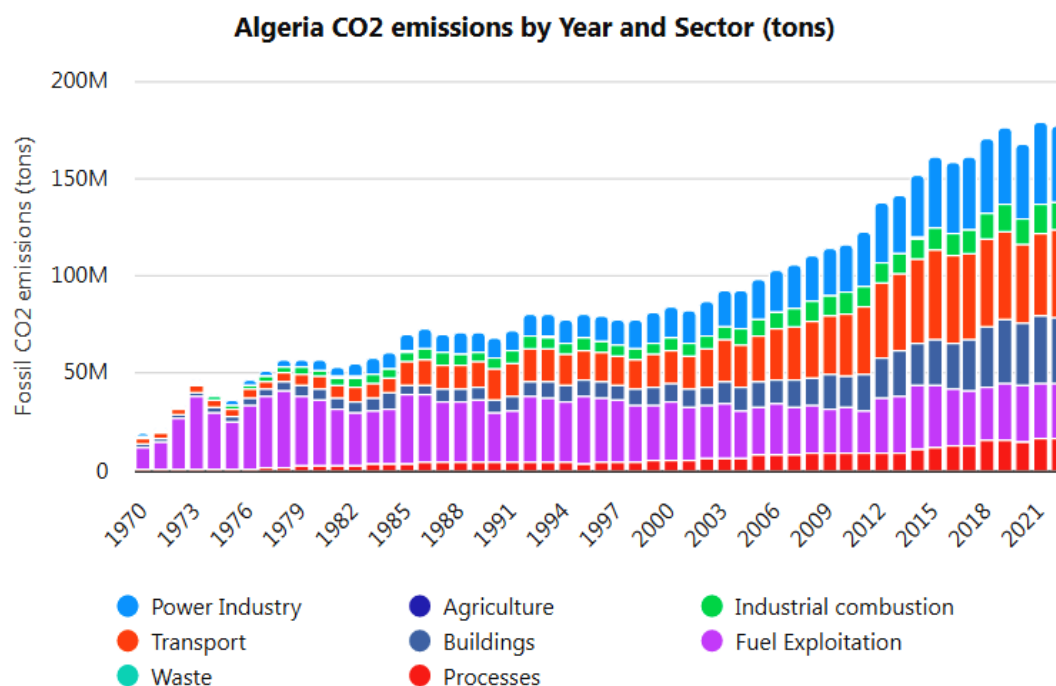
6.3–Synergy between Telecommuting, Smart Cities, and Urban Decarbonization in Algeria

The link between digital technologies and environmental protection in Algeria is based on a straightforward substitution mechanism: leveraging Smart Cities as a structural support for telecommuting to reduce the national

carbon footprint. In 2022, Algeria emitted a total of 179.08 million tonnes of CO₂. Sectoral analysis reveals that transport and buildings alone account for more than 44% of this national balance, approximately **79 MtCO₂**. This section demonstrates that the digitalization of tertiary activities is not merely a gain in time or comfort, but a fundamental mathematical lever. By eliminating millions of kilometers of unnecessary daily commuting, the dematerialization of work acts as a virtual filter against atmospheric pollution.

The following graph shows the evolution of GHG (Greenhouse Gas) emissions, mainly CO₂, for Algeria from 1970 to 2022. We can see that emissions increased sharply starting in 2010, and the share of the transport sector also grew during this period

Fig.2 Algeria CO₂ emissions by year and sector



Source : <https://www.worldometers.info/co2-emissions/algeria-co2-emissions/>

From this graph (on the Worldometers page), we extracted data¹ for specific years to perform a comparative study. This allows us to see the evolution of the carbon footprint for different sectors, especially transport. We believe that transport is closely linked to the possibility of reducing GHGs in

¹ The graph on the page is a dynamic graph where the mouse pointer shows a legend with emission figures for each sector every year. We took screenshots of several years and transcribed the numbers into the table-2

smart cities by replacing commuting to and from workplaces (or government services) with remote-work.

Table.2 : Carbon Emissions by sector and by year

In Million Tonnes of CO2 (Mt-CO2)											Ton- CO2 / pers
Year	Popul ation	Power Industr y	Tran sport	Fuel Exploi tation	Buildi ngs	Indust rial Comb ustion	Proces ses	Agricu lture	Waste	Total	CO2 / Capita
1980	19,22	4,12	6,22	3,15	4,2	1,85	0,65	0,2	0,14	20,53	1,07
1985	22,43	9,8	10,45	5,6	6,1	2,9	1,1	0,31	0,24	36,5	1,63
1990	25,51	16,5	14,8	8,2	8,5	4,1	1,45	0,4	0,32	54,27	2,13
1995	28,48	21,3	18,6	11,4	10,2	3,8	1,6	0,45	0,4	67,75	2,38
2000	31,04	28,4	22,1	14,3	12,4	4,2	1,9	0,48	0,46	84,24	2,71
2005	33,46	35,6	26,45	15,8	15,6	5,3	2,45	0,55	0,55	102,3	3,06
2010	35,98	41,2	29,91	16,4	18,32	6,45	2,88	0,62	0,58	116,36	3,23
2011	36,66	43,8	31,54	16,1	19,31	8,2	2,46	0,68	0,62	122,71	3,35
2012	37,38	49,6	35,28	16,8	21,6	9,8	2,75	0,76	0,68	137,27	3,67
2013	38,14	51,2	36,38	16,2	22,28	10,4	3,55	0,82	0,72	141,55	3,71
2014	38,92	55,4	39,06	17,1	23,92	11,2	3,64	0,88	0,77	151,97	3,9
2015	39,73	59,1	41,46	17,8	25,39	12,05	3,7	0,98	0,85	161,33	4,06
2016	40,55	58,4	40,59	17,2	24,85	11,4	3,6	1,02	0,87	157,93	3,9
2017	41,39	59,8	41,47	17,45	25,4	11,7	3,65	1,02	0,88	161,37	3,9
2018	42,23	62,3	43,8	17,9	26,82	13,1	4,55	1,06	0,9	170,43	4,04
2019	43,05	64,15	45,21	18,25	29,19	12,3	5,1	1,12	0,92	176,24	4,09
2020	43,85	62,8	39,53	16,9	31,13	10,2	5,02	1,15	0,93	167,63	3,82
2021	44,61	65,4	43,15	18,5	32,8	11,85	5,15	1,17	0,95	178,97	4,01
2022	44,9	64,2	45,93	17,4	33,04	11,2	5,18	1,18	0,95	179,08	3,99

Developed by author from the Worldometers graph : <https://www.worldometers.info/co2-emissions/algeria-co2-emissions/>

The combined analysis of the graph and table shows a worrying carbon path for Algeria, with a fast increase after 2010. While the **Power Industry** (64.20 MtCO₂ in 2022) is the biggest contributor, the **Transport-Buildings** duo shows the urgent need for a new urban model. In forty years, combined emissions from these two sectors grew from 10.42 Mt to over 78 Mt. This shows the energy inefficiency of urban sprawl based on physical movement.

Because of this, Smart Cities should not be seen as just a technology update, but as a necessary strategy. As (Mazouzi ,2025) states, the smart city acts as a regulator: it allows urban growth without increasing greenhouse gas emissions. By using Smart Grids and making remote work common, new cities like Boughzoul or Sidi Abdellah aim to neutralize the individual carbon footprint—which has quadrupled since 1980. They do this by replacing polluting transport with clean digital flows. According to the (TCN

,2020), this digital transition is the best way to stabilize the national balance while managing population growth.

6.3.1 – Evolution of Land Use and Transport Needs (1980–2019)

To understand why the digital transition is urgent today, we must analyze how Algerian cities grew over the last forty years. Since 1980, the country followed an « extensive » development model. This means cities grew physically much faster than transport or communication networks were planned. This period of « Carbon-intensive growth » (Fossil-fuel-based growth) made the country dependent on fossil fuels. Every new resident became forced to use a car or bus to access basic services. This history shows how a lack of digital tools directly increased the national carbon footprint.

6.3.1.1 – Population Growth and Urban expansion

Between 1980 and 2019, Algeria's population grew from 19.22 million to 43.05 million. This 123% increase led to massive and often uncontrolled urban expansion. According to (Boumedine and Signoles ,2017), housing policies created "dormitory towns" (cités-dortoirs) on the outskirts of big cities. This urban expansion separated where people live from where they work.

Today, as described by (Boumedine and Signoles ,2017), life is difficult for Algerian workers. A resident of Bouinan or Sidi Abdellah must travel 25 to 40 km every day to reach the offices and businesses in central Algiers. This created a flow of hundreds of thousands of vehicles that did not exist in 1980. In forty years, the average distance traveled per person has tripled. This transformed the area into a network of crowded « corridor cities² » where physical movement is a major environmental problem.

6.3.1.2 – Increase in Car Ownership and Pollution

Because there were no digital alternatives for thirty years (no high-speed internet, no online services), the private car became the only way to connect new urban areas to city centers. Worldometers data is very clear: transport sector emissions rose from 6.22 MtCO₂ in 1980 to 45.21 MtCO₂ in 2019.

This massive 626% increase shows the system is failing. Transport pollution grew five times faster than the population during this period. This happened because of many short trips, constant traffic jams at city entrances, and old cars. Without remote work, the "road-only" mobility model became the main cause of the national carbon footprint increase, using up more and more of the country's energy resources.

6.3.1.3 – Carbon Intensity per Capita Analysis

The best way to see this problem is through the individual carbon footprint. In 1980, the average Algerian emitted 1.07 tonnes of CO₂ per year. In

² **Corridor cities** are long cities built next to big roads. People are **forced to use cars** because everything is too far to walk.

2019, this number reached 4.09 tonnes. This 300% increase in individual carbon intensity is a direct result of inefficient urban travel and a service economy that grew without digital tools.

Comparing data from the World Bank and Worldometers confirms a dangerous trend: the average Algerian uses more and more energy just to "exist" in a spread-out urban system. Without a major technological change, like the spread of remote work, population growth will push emissions to record levels. This will make Algeria's climate goals impossible to reach. Remote work is no longer just a luxury for office workers; it is a tool to regulate every citizen's carbon footprint.

6.3.2 – Algiers, a Capital Facing Asphyxiation

The study by (Hachaichi and Baouni ,2019) is a crucial academic reference for understanding the specific problems of Algiers. By modeling the capital's carbon footprint, these authors highlight a striking sectoral imbalance. Because of its difficult geography and high concentration of administration, Algiers has become the country's energy bottleneck. Transport there generates over 813,591 tonnes of CO₂, which is 51% of the city's total footprint. This is much higher than global averages for cities of a similar size.

With a service and administrative sector that accounts for 9% of direct emissions (heating and office lighting) but drives the 51% of transport pollution (commuting by employees and citizens), Algiers is in a deadlock. The historic city center and business districts like Bab Ezzouar can no longer absorb new roads without destroying the urban fabric.

Remote work acts here as a virtual decongestion solution. According to projections based on (Hachaichi and Baouni ,2019), if only 30% of Algiers' service sector employees switched to a hybrid mode (two days of remote work per week), we would mathematically eliminate over 100,000 tonnes of CO₂ per year. This reduction would require no heavy investment in concrete, only an acceleration of the digital transition already started in hubs like Sidi Abdellah.

6.3.3 – The 2020 Remote Work Experience

To prove that remote work is an ecological tool, we must examine the exceptional data from 2020. The health crisis served as a real-life "crash test" for Algeria's digital infrastructure. By forcing an end to non-essential travel, it allowed us to measure the carbon reduction potential of removing the daily commute with surgical precision.

6.3.3.1 – Analysis of the Historic Drop in Emissions

The strict application of Decree 20-69 in 2020 caused an unprecedented statistical break in Algeria's environmental records. We observe a 12.56% drop in transport sector emissions in one year, representing a saving of 5.68 million tonnes of CO₂.

This is the first time in the country's modern history that an organizational policy (lockdown and remote work) has reduced pollution so

massively, more than any past industrial regulation. This figure of 5.68 Mt validates the theory that a large part of Algerian transport is « forced transport » caused by inefficient work organization.

6.3.3.2 – Energy Transfer to Homes

However, an honest analysis must consider the « rebound effect ». By moving activity from the office to the living room, remote work transfers the energy load. The Buildings sector saw its emissions rise by 6.64%, from 29.19 Mt to 31.13 Mt of CO₂ in 2020.

This increase of 1.94 Mt is explained by higher use of home computers, lighting, and especially individual heating or air conditioning, which are often less efficient than central systems in large office buildings. This transfer shows that the remote worker becomes an isolated unit of consumption that must be managed through "Smart Home" technologies.

6.3.3.3 – The Net Environmental Balance

Despite this domestic increase, the gain for the planet and for Algeria remains very positive. By subtracting the residential increase (1.94 Mt) from the massive drop in transport (5.68 Mt), Algeria achieved a net environmental benefit of 3.74 million tonnes of CO₂ in 2020.

This calculation proves that remote work is 2.9 times more efficient for the environment than traditional office work. Why? Because it eliminates the « pure » energy waste of traffic jams (idling engines) and heavy travel logistics. This ratio of nearly 3 to 1 is the strongest argument for turning crisis-driven remote work into a permanent climate strategy.

6.3.4 – The Role of Law and Digitalization

The transition to carbon-free cities cannot depend only on technology; it must be supported by a strong legal foundation. As Algeria modernizes its laws, adding sustainability standards to urban planning is now a priority.

6.3.4.1 – The Legal Framework for Sustainability

According to (Mazouzi,2025), Algeria has formalized environmental sustainability as a legal obligation for new urban zones. Legislation for Smart Cities now goes beyond technical infrastructure, requiring integrated mechanisms to monitor and reduce pollution. To meet these legal standards, urban planning must prioritize digital solutions that minimize the environmental footprint of administrative and economic activities.

6.3.4.2 – Digital Administration and Its Benefits

A major pillar of urban sustainability is the total digitalization of administrative procedures. E-governance is not just about modernity; it is a strategic tool to fight climate change. By shifting services like document renewals or birth certificates to online platforms, the state directly reduces the volume of "forced mobility."

The data analysis of CO₂ emissions in Algeria between 1980 and 2022 shows that the country has reached a critical point. Physical mobility can

no longer keep up with population growth without hurting climate goals. The historic drop of 5.68 MtCO₂ in the transport sector in 2020 proved that digitalizing work is the most powerful tool for fast decarbonization.

However, this transition can only last if it is part of efficient Smart Cities. These cities must be able to manage home energy through smart grids and provide the necessary digital infrastructure. By stabilizing the carbon footprint at 3.99 tonnes per person, Algeria is setting the foundation for a modern urban model where digital technology guarantees environmental sustainability.

Conclusion :

The Smart City model uses digital mobility to significantly reduce urban carbon footprints. By replacing physical travel with remote work, this system transforms cities into low-carbon ecosystems where connectivity substitutes for high-emission infrastructure, decoupling economic growth from environmental damage.

Algeria's CO₂ emissions have surged since 1980, with transport growth outpacing demographic expansion. This trajectory led to an unsustainable footprint of 3.99 tonnes per capita. Current national strategy now recognizes the necessity of digital sustainability to break this cycle.

It is urgent to transform the 3.74 MtCO₂ gain observed in 2020 into a permanent benefit. By 2030, generalizing remote work and smart grids is essential to stabilize emissions below 3.8 tonnes per capita, ensuring climate resilience through integrated digital governance.

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