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SMART AND SUSTAINABLE PARKING SYSTEMS IN ADVANCED BUSINESS ECONOMIES: LESSONS FOR URBAN TRANSPORT PLANNING IN NIGERIA

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ABSTRACT

Smart parking systems, especially automated parking systems (APS), have become quite popular in developed nations as a solution to the challenges posed by urbanization, limited space, and the need for environmental sustainability. These systems bring a host of benefits, such as better space utilization, lower construction and operational costs, improved safety, and positive environmental impacts. This paper takes a closer look at notable examples of APS in advanced economies like the United States, Germany, and Canada, highlighting their advantages compared to traditional parking systems. Using a qualitative approach and multiple case studies, the research delves into how smart and sustainable parking systems have been implemented and their outcomes in these leading business economies, while also drawing lessons for urban transport in Nigeria. Case studies from places like Manhattan, Munich, and Toronto showcase how APS can enhance urban living by alleviating traffic congestion, reclaiming green spaces, and providing safer, more efficient parking options. The paper discusses the significance of these innovations for Nigeria, Africa's most populous nation, especially in light of its rapidly growing urban population and increasing vehicle usage. It advocates for a policy shift in Nigeria towards the adoption of APS, suggesting that lessons from developed countries could help create a more efficient and sustainable parking infrastructure. By embracing these smart solutions, Nigeria can tackle its urbanization challenges while boosting public safety, environmental sustainability, and economic growth.

Keywords: Automated parking systems, Urban parking solutions, Sustainable infrastructure, Urbanization, Nigeria urban development

1.0 INTRODUCTION

This study dives into the cutting-edge parking solutions being embraced in developed countries, with a keen eye on how they could be applied in Nigeria. One of the main takeaways from this research is the push for the Automated Parking System (APS), which stands out as a vital answer for urban areas grappling with rising population numbers that directly impact car usage and ownership. APS not only boosts parking efficiency but also tackles issues like safety, theft, and vandalism that often plague off-street parking. The study strongly advocates for a shift in policy from traditional parking systems to APS, highlighting its cost-effectiveness,

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safety, and accessibility—especially in Nigeria's bustling urban centers (Zhang et al., 2021). Car parking is a key player in urban development, and when parking options fall short, it can lead to congestion, unsafe traffic situations, and illegal parking, all of which can hurt local businesses. On the flip side, having too many parking spaces can promote more car usage, wasting precious urban land (Shoup, 2018). This research seeks to uncover smart alternatives to meet parking demand while ensuring sustainable urban land use. As vehicle ownership continues to climb worldwide, having proper parking facilities becomes crucial for keeping traffic flowing and minimizing congestion (International Transport Forum, 2020). Thoughtful design of parking facilities is essential for a smoothly operating transport system, and a shortage of adequate parking can create significant disorder in urban settings (Jain & Tiwari, 2017).

Vehicles must be parked before occupants can engage in any other activity, making parking a fundamental aspect of travel. Since the 1980s, competition between parking and other land-use needs has intensified due to increasing urbanization and environmental concerns. Rising environmental pollution and the financial challenges of municipal authorities have transformed parking from a regulatory issue into a significant aspect of urban and traffic planning (European Commission, 2021). Research shows that the quantity and location of parking spaces influence traffic conditions, public transportation demand, and environmental quality in urban areas (Rye, 2019; Stubbs, 2002).

Parking can be defined as the temporary or permanent storage of a vehicle in a designated space without disrupting traffic flow (Olatunji & Adeniran, 2016). Movement between locations is essential for human existence, as resources are not evenly distributed geographically. Over time, humanity has developed various modes of transportation to bridge these geographic distances, including road, air, and water transportation (Adeniran, 2016).

In urban centers, parking is crucial for ensuring access to goods and services. It significantly impacts a city’s economy, as inadequate parking provisions can hinder economic growth and mobility. Properly managed parking systems enhance urban performance and improve the quality of urban life (Asiyanbola & Akinpelu, 2012). Many businesses and municipalities consider a sufficient supply of visitor parking vital, for competitive growth, although parking also serves as an effective tool for traffic control in many cities (Litman, 2020).

The spatial distribution of parking facilities has been widely studied due to the increasing number of private cars, which have made travel more convenient but exacerbated parking challenges, especially in large cities. The balance between parking demand and supply is crucial for sustainable urban development and efficient traffic operations (Jia Sheng et al., 2016). Poorly planned parking systems can severely affect urban traffic flow and reduce transport network efficiency (Bates & Bradley, 1986).

To address these issues, many studies have examined parking management strategies and parking facility design. Conventional parking policies often focus solely on accommodating travel demand without considering the social, economic, and environmental implications (Meyer & Belobaba, 2020). Parking systems significantly influence urban aesthetics, traffic operations, and transportation infrastructure.

With rising car ownership and inefficient parking management, urban planners must explore innovative solutions to tackle parking challenges. To ensure efficient space utilization and improved urban quality, this paper is driven by the imperative to inform Nigerian transport policymakers and urban planners about the transformative potential of APS. It aims to explore how Nigeria can transition from inefficient parking systems as presently witnessed in big cities in Nigeria, i.e. Abuja, Lagos, and others, to a smarter, more sustainable solution as it is in Canada, United States and Germany that support broader goals of urban resilience, accessibility and environmental stewardship.

2.0 METHODOLOGY

This study takes a qualitative approach, using multiple case studies to delve into how Smart and sustainable parking systems are being implemented and what outcomes they yield in various advanced business economies. It also aims to draw valuable lessons for urban transport in Nigeria. Literature Review

2.1 Conceptual Review

Designing parking spaces involves numerous parameters, often derived from simple data and various techniques. Generally, parking patterns are categorized into two main types: on-street parking (which includes parallel and angled parking) and off-street parking (comprising surface parking, multi-story parking, rooftop parking, mechanical parking, and underground parking) (Grote et al., 2018; Zhu, 2017).

Certain factors significantly influence parking demand. These include **parking accumulation,** defined as the number of parked vehicles at a specific time; **parking duration**, which refers to the length of time vehicles occupy parking spaces; **parking volume**, which is the total number of vehicles utilizing parking spaces; and **occupancy**, the ratio of vehicles using parking spaces to the available parking facilities at a given time (Shoup, 2018).

2.1.1 Parking Policy

Understanding the impact of parking policy interventions is crucial for urban planning. Parking policies serve as a key connector between land use and transportation policies. The primary objectives of parking policies in urban areas include:

a. Restricting vehicular traffic and generating revenue through parking operations, as well as addressing how the amount and location of parking impact traffic congestion on access roads and internal streets (Marsden et al., 2021).
b. Improving the efficiency, effectiveness, and financial performance of public transport (Banister, 2019).
c. Enhancing the safety, amenity, and environmental quality of urban areas, while preserving the functional and aesthetic integrity of metropolitan regions (An & Du, 2020).

2.1.2 Parking Demand and Supply

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The parking supply refers to the ability to meet the demand for parking facilities. The availability of parking spaces is a primary indicator of parking supply. **Parking turnover rate**, which reflects how frequently a parking space is used over a certain period, is another important factor, with higher turnover indicating greater parking capacity (Jia et al., 2016).

Both parking supply and demand are influenced by costs, which may include price, travel time, walking time, and security. The parking system's supply is responsive to demand fluctuations, shaped by the generalized cost of using the facility (Litman, 2020).

2.1.3 Spatial Balance

Spatial efficiency in parking involves balancing supply and demand across different scales of urban environments. This balance must be achieved not only at the city level but also within specific zones. Properly distributing parking spaces can prevent issues such as excess demand or over-supply in certain zones (Litman, 2020; GFIVT, 2009). A spatially efficient parking system minimizes search time and improves overall urban mobility.

2.2 Theoretical Review

This section provides an overview of contemporary parking practices, distinguishing between on street and off-street parking. These methods, along with their subtypes, are explained to illustrate how they contribute to or detract from the urban environment. Furthermore, parking regulations enforced by local authorities aim to manage urban parking effectively. The challenges posed by conventional parking techniques (both on-street and off-street), as well as innovative solutions to these problems, are also discussed.

Several innovative parking techniques are being adopted in developed cities, including in-lieu fees, shared parking, centralized parking, smart parking, and private car parks. Automated and semi-automated parking systems are also gaining popularity in cities like New York, Munich, and Toronto, offering more efficient use of urban space (Parkinson & Winter, 2021).

2.2.1 On-Street Parking

On-street parking occurs along curbs and is often regulated by traffic signs, with residents sometimes requiring permits. Enforcement officers ensure compliance with parking regulations. On-street parking can be either paid (controlled) or free (uncontrolled) and can be done in different ways, such as parallel parking, angled parking, or reverse-angled parking (Litman, 2020).

a. **Parallel parking** is efficient in terms of street space but provides the fewest parking spaces. It is common in city centers (Marsden et al., 2021).
b. **Angled parking** offers more user-friendly parking but requires additional street width. It is frequently used in historic downtowns (Grote et al., 2018).
c. **Reverse-angled parking** shares many benefits with angled parking but requires less maneuvering space, making it more space-efficient (John, 2011).

2.2.2 Off-Street Parking

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Off-street parking includes both indoor and outdoor facilities, which can be public or private. It encompasses parking garages, parking lots, and parking pads, among others. Multilevel parking garages, which may employ ramps or robotic systems, are common in densely populated areas (Zhu, 2017).

Indoor parking facilities, such as underground parking garages, are often found in high-rise buildings. In contrast, outdoor parking is more typical in suburban areas. Off-street parking also varies in terms of duration, with short-stay, long-stay, or contract parking options available (Parkinson & Winter, 2021).

2.2.3 Drawbacks of Conventional Parking Techniques

Conventional parking methods, whether on-street or off-street, present numerous challenges in urban environments. These methods often have more negative consequences than benefits, as discussed in the following sections.

2.2.3.1 Issues with Off-Street Parking

Urban planners argue that off-street parking disrupts the urban fabric, particularly in historic neighborhoods. Parking lots create gaps between buildings, reducing pedestrian accessibility and diminishing the aesthetic appeal of urban areas. Off-street parking also encourages car ownership, exacerbating traffic congestion and increasing demand for parking spaces (Shoup, 2018). Moreover, off-street parking facilities often consume valuable land that could otherwise be used for housing or green spaces (Block, 2012).

A study conducted in Portland revealed that off-street parking requirements significantly impact housing affordability, as developers must allocate land for parking rather than housing units. This increases the cost of housing, as the opportunity cost of land used for parking is high (Block, 2012).

2.2.3.2 Issues with On-Street Parking

On-street parking often limits pedestrian accessibility, as vehicles parked on sidewalks can obstruct foot traffic and damage infrastructure. Congestion caused by parked vehicles also poses safety risks for pedestrians and cyclists, while parked cars limit the capacity of emergency and public service vehicles to navigate urban streets (Guo, 2013). Excessive on-street parking contributes to urban gridlock, especially in areas where street design was not intended to accommodate large numbers of parked vehicles (Litman, 2020).

2.2.4 Parking Solutions

Parking management involves balancing various interests and viewpoints, as each municipality has unique neighborhoods with different needs. Therefore, no single parking policy can address all areas effectively (Litman, 2021). According to Litman (2021), planners should consider principles such as consumer choice, efficient utilization, sharing, flexibility, user information, prioritization, pricing, peak management, quality versus quantity, and comprehensive analysis. These principles ensure that people have access to information on feasible parking and travel options. Parking facilities should be designed to serve multiple users and destinations and

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managed so that spaces are fully utilized. Moreover, parking plans must accommodate uncertainty and change, prioritize high-demand spaces for more critical uses, and ensure users pay directly for the facilities they use. It is essential to address peak demand issues and consider both the quality and quantity of parking, including aesthetics, security, and accessibility. In addition, all significant costs and benefits must be considered when planning parking facilities (Litman, 2021).

Local authorities are responsible for maintaining public spaces, including unallocated parking areas, and residents expect them to address parking issues in communal areas (Barter, 2020). With increasing car ownership and limited parking space in Nigeria, urban areas face significant parking challenges. Suburban sprawl and dependence on automobiles increase the demand for parking, which in turn escalates expenses (Barter, 2020). Providing parking in suburban areas is costly and impacts environmental protection efforts. To combat these challenges, a shift towards non-automobile modes of transport is essential. Incentives to use alternative modes and reducing the availability of parking spaces can encourage redevelopment, reduce vehicle miles travel, emissions, and congestion (USEPA, 2016).

3.1.1 In-Lieu Parking Fees

Municipalities often adopt in-lieu parking fees to cater to the demand for on-site parking spaces. This system allows developers to reduce the number of on-site parking spaces by paying a fee to the city, which, in turn, provides centralized off-site parking for tenants and visitors. Shoup (2018) notes that in-lieu fees in the U.S. range from $5,920 to $20,180 per parking space, and these fees may also be imposed as property tax surcharges. In-lieu fees benefit planners and developers by reducing construction costs and ensuring that existing parking facilities are fully utilized. This system can also preserve the character of historic buildings by avoiding the need for on-site parking. However, planners must consider potential issues related to the lack of on-site parking, which could affect the attractiveness of developments to tenants and visitors (Shoup, 2018).

3.1.2 Shared Parking

Shared parking is an effective strategy for reducing overall development costs in mixed-use areas. By allowing different types of land uses to share the same parking spaces, developers can decrease the total number of spaces required (USEPA, 2016). For example, an office with peak parking demand during the day can share spaces with a restaurant that experiences peak demand in the evening. This approach not only reduces costs but also encourages the use of large, centralized parking facilities and discourages the development of small, inefficient lots (USEPA, 2016).

3.1.3 Centralized Parking

Centralized parking facilities are often located in the center of a neighborhood and serve as a hub for residents and visitors. These facilities can reduce the overall cost of parking, as large facilities are more cost-effective to build and maintain than small, scattered lots (USEPA, 2016). Centralized parking also enhances urban design and preserves the historic character of neighborhoods. Some cities have successfully implemented centralized parking systems, such

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as Chattanooga, Tennessee, which centralized parking at the edge of the city to reduce traffic congestion in the downtown area (USEPA, 2016).

3.1.4 Parking Freezes

Parking freezes limit the number of parking spaces in a specific district, often to address environmental concerns or traffic congestion. Cities that implement parking freezes must provide viable public transportation options to ensure that residents, workers, and visitors can easily access the area without relying on automobiles. Parking freezes are most successful in cities with strong economies and attractive urban environments, where the benefits of the location outweigh the inconvenience of limited parking (USEPA, 2016).

3.1.5 Demand Reduction

In-lieu fees, centralized parking, and shared parking all contribute to reducing parking demand. Other strategies include replacing parking spaces with bus stops or reserving spaces for carpooling or car-sharing. Market-based approaches, such as charging users for parking, can also reduce demand. Programs that promote non-automobile transportation, such as public transit subsidies, pedestrian and bicycle amenities, or telecommuting options, can significantly reduce parking demand (USEPA, 2016).

3.1.6 Smart Parking

Smart parking systems use technology to inform drivers of available parking spaces in real time, often through smartphone apps. These systems help to reduce the oversupply of parking and improve the efficiency of existing facilities (European Environment Agency [EEA], 2014). Marlborough, Massachusetts, for example, has implemented smart parking measures, including shared parking, compact car spaces, and temporary reserve parking to reduce the oversupply of parking spaces (EEA, 2014).

3.1.7 Private Car Parks

Private car parks allow individuals to list their available parking spaces online through various platforms, providing users with easy access to reserve and pay for spaces. This system increases security, generates financial returns for parking space owners, and promotes smart city mobility (Carambola, 2014). Cities like Antwerp, Brussels, and Ghent have successfully adopted this model, demonstrating its viability in urban environments (Carambola, 2014).

3.2 Smart Parking Concepts

On average, cars remain parked for approximately 22.5 hours per day, as drivers typically spend only about 90 minutes driving (Guerra et al., 2020). This underutilization of vehicles highlights the need for innovative parking systems that maximize space and improve urban sustainability. Automated parking systems (APS) demonstrate environmental friendliness by turning off engines when vehicles are parked. They also offer several advantages to municipalities, such as space efficiency, enhanced visual appeal, and improved public safety (Sun et al., 2023). Additionally, automated systems reduce the need for costly infrastructure like lighting, pedestrian areas, and signs, as the entire parking process is handled mechanically.

Cars are moved automatically within the system, eliminating the need for ventilation systems, and only minimal staff are required for occasional maintenance (Park & Yoon, 2021).

3.2.3 Advantages of Automated Parking Over Conventional Parking Facilities

Automated parking systems offer multiple advantages compared to conventional parking facilities, particularly in terms of space optimization and reduced construction and maintenance costs. According to Kim and Lee (2022), APS require up to 50% less volume than traditional parking structures while handling the same number of vehicles, making them particularly advantageous in urban areas where land prices are high. The compact nature of automated parking reduces the need for expansive infrastructure such as ventilation, elevators, staircases, and fire safety features (Park & Yoon, 2021). This results in construction costs comparable to, if not lower than, conventional parking structures (Sun et al., 2023).

The cost-effectiveness of underground parking facilities is further enhanced by the lower construction volume required, compensating for the added expense of the automated machinery (Li et al., 2023). Despite requiring more electrical power due to computerized operations, APS facilities are far less labor-intensive, resulting in lower overall maintenance costs. Additionally, the lack of exhaust emissions within the facility ensures better air quality (Guerra et al., 2020). Automated systems also guarantee the highest safety standards, as vehicles are stored in secure, well-lit areas, monitored by security cameras, and protected from theft, vandalism, and accidents (Park & Yoon, 2021).

Moreover, automated parking garages can integrate various customer services, such as parking reservation systems, traffic control, and car wash facilities. These systems offer flexibility in design, with closed facades that allow urban planners and architects to create aesthetically pleasing structures (Li et al., 2023). From an investment standpoint, APS provide high returns due to their space-efficient and sustainable design, making them attractive to municipalities, parking corporations, and private investors (Sun et al., 2023).

3.2.4 Sustainability Benefits of Automated Parking Systems

Automated parking systems contribute to sustainability by reducing operational energy consumption, as minimal lighting and ventilation are required. Only two air changes per hour are necessary, unlike conventional parking structures that need comprehensive ventilation systems (Kim & Lee, 2022). APS also contribute to a reduction in vehicle emissions, including CO2, NO2, and particulate matter (PM10), as engines are turned off during the parking process. Additionally, smaller building footprints reduce the need for extensive excavation and groundworks, which minimizes construction waste sent to landfills (Guerra et al., 2020).

APS also promote the use of sustainable materials, such as high-recycled-content steel and non-toxic construction materials (e.g., paints with low volatile organic compounds). These systems offer other sustainability benefits, including reducing pedestrian accidents, providing preferred parking for low-emission vehicles and car-sharing programs, and integrating electric vehicle charging stations. Furthermore, automated parking systems improve personal security, particularly at night, by reducing noise pollution and offering accessible spaces for users, including individuals with disabilities or those with young children (Park & Yoon, 2021).

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3.2.5 Case Studies

1) Automated Parking in Manhattan: The City of Hoboken, New Jersey, introduced its first automated parking garage in 1999, which featured 320 parking spaces (National Parking Association, 2020). This facility marked the beginning of widespread adoption of automated parking in North America. In 2008, a similar facility was introduced at "One York" in Tribeca, Manhattan. The system used pallet-less technology for vehicle transfer, allowing residents to observe the automated process through a viewing window (Kim & Lee, 2022).

2) Automated Parking in Munich: In Munich, Germany, the Donnersbergerstrasse area introduced an underground automated garage for residents in 2006. This garage not only alleviated the parking congestion but also reclaimed green space for the neighborhood. The automated system significantly reduced the search for parking, lowering emissions and fuel consumption by approximately 80% (Park & Yoon, 2021). The parking facility operates efficiently, with an average car retrieval time of 137 seconds and the capacity to handle 100 car operations per hour (Sun et al., 2023). With a 100% utilization rate, this system has become a model for sustainable urban parking solutions (Li et al., 2023).

3) Automated Parking in Toronto: In Toronto, Canada's largest city, parking is a significant challenge, particularly in urban areas. The city's 2006 bylaw restricted the number of vehicles that could be parked on residential driveways, creating a need for efficient parking solutions. Automated parking systems addressed these concerns by providing secure and space-efficient parking options, particularly in high-density areas. These systems help mitigate issues related to safety, theft, and vandalism, and are expected to become more common within the next decade (Guerra et al., 2020).

4.0 NIGERIA SITUATION AND LESSONS

Nigeria's urban landscape is facing some serious challenges, marked by rapid population growth, outdated infrastructure, inefficient land use, and an increase in vehicle ownership. This situation makes a strong case for the urgent need to implement Automated Parking Systems (APS). Cities like Lagos, Abuja, Port Harcourt, Kano, and Onitsha are grappling with road congestion, environmental pollution, and a lack of public spaces. While these cities share many of the same urban pressures as places like Manhattan, Munich, and Toronto, they often do so with far fewer resources and less planning foresight.

1. Infrastructure and Urban Planning Deficits: Many cities in Nigeria are stuck with outdated master plans, weak zoning enforcement, and unchecked development. On-street parking is prevalent, leading to bottlenecks and making it difficult for pedestrians to get around. APS could revolutionize this by offering vertical, automated parking solutions that use 50-70% less land than traditional parking lots.

Practical Implications: Local councils and state governments could start pilot programs for APS in overcrowded areas like Lagos Islands, Wuse (Abuja), Dugbe (Ibadan), and Upper Iweka (Onitsha), where space is at a premium. These pilot projects could not only serve as innovative public services but also generate revenue through time-based pricing and integrated security systems.

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2. Policy and Regulatory Opportunities: Currently, Nigeria lacks a cohesive national parking policy. APS could pave the way for the development of modern parking policies that align transport planning with urban development goals. States could implement mandates for APS in shopping malls, hospitals, markets, high-rise buildings, and airports.

Practical Implications: Urban planning agencies, such as the Federal Ministry of Works and Housing and local planning boards, could incorporate smart parking solutions into building permits and city layout designs.

3. Public-Private Partnership (PPP) and Investment In Nigeria, the public sector often struggles to find the capital needed for urban renewal projects. APS presents a model that combines low labor costs with high revenue potential, making it appealing to private investors, construction companies, real estate developers, and fintech parking solution providers. Additionally, existing mall operators, estate developers, and transport unions can join forces to co-finance APS initiatives. Practical implications: Cities like Lagos and Abuja can draw in investments by offering tax holidays, land use incentives, or government guarantees for the first five years of APS implementation. Furthermore, banks and pension funds can view APS as a long-term real estate investment opportunity within the infrastructure sector.

4. Environmental and Social Benefits APS helps cut down on engine idling and emissions by streamlining the parking process. In crowded areas like Ajegunle (Lagos) or Onitsha (Anambra), this can significantly reduce urban air pollution and noise levels. APS can also feature electric vehicle charging stations, supporting Nigeria's energy transition goals outlined in the Energy Transition Plan 2060. Practical implications: Consider integrating solar-powered APS units in markets and transit hubs. Also, make room for tricycles, bikes, and electric vehicles, aligning with Nigeria's commitments under the Paris Climate Agreement.

5.0 EMPLOYMENT AND INNOVATION OPPORTUNITIES

When it comes to employment and innovation opportunities, there is the creation of high-value technical jobs in areas like ICT and customer service. This aligns perfectly with Nigeria's goal of fostering a digital economy and boosting youth employment. Practical Implication: We should consider forming training partnerships between the National Board for Technical Education (NBTE), the ITF, and smart infrastructure companies. Together, we can develop certificate programs focused on the installation, maintenance, and monitoring of APS systems.

6.0 CONCLUSIONS

Nigeria stands at a crucial juncture in its urban development journey. As vehicular traffic rises and cities expand, smarter and efficient parking options become imperative. This paper has shown that APS, successfully deployed in countries such as the United States, Germany, and Canada, holds a replicable model for sustainable urban transport planning in Nigeria. APS can ameliorate the challenges of urban parking space by reducing land pressure, lowering emissions, improving traffic flow, and enhancing public safety. The success of such a transition depends not on the level of technology but on coherent policy integration, public awareness and training, infrastructure investment, and stakeholder collaboration.

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