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Enhancing Management Efficiency in Natural Parks Globally through Big Data Technologies

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Abstract: The adoption of big data technologies offers significant potential for enhancing the management efficiency of natural parks worldwide, a critical component in the establishment and upkeep of international conservation systems. Innovating management techniques and improving efficiency have become urgent tasks for global natural park authorities. This study examines the present landscape of natural park management and highlights primary challenges faced when incorporating big data. Using human activity data as a model, the paper discusses the processes of data collection, analysis, treatment, and deployment, arguing that leveraging big data technologies to scientifically regulate human activities is essential for boosting natural park management efficiency. In addressing challenges related to the use of human activity data for enhancing management efficacy, recommendations are provided, focusing on refining overarching strategies, creating monitoring systems, broadening talent acquisition, utilizing big data to resolve management challenges, and emphasizing data governance.

Keywords: Natural Parks; Human Activity; Big Data; Management

1. Introduction

In recent years, global guidelines have underscored the need to develop a cohesive international conservation system, with natural parks at its core. These parks, celebrated for their ecological, aesthetic, cultural, and scientific merits, are designed for sustainable utilization and span a diverse range including forest parks, geological parks, marine parks, and wetland parks. They play a pivotal role in safeguarding invaluable natural assets, such as forests, oceans, wetlands, glaciers, grasslands, and biodiversity, along with their associated landscapes, geology, and cultural nuances.

Historically, various international bodies have initiated unified management strategies for natural conservation areas, promoting the holistic preservation of ecosystems while encouraging collaborations among stakeholders to advance the growth of the global conservation system. This notable evolution in management practices has set the stage for further innovations in the realm of natural parks. With ongoing global integrations and adjustments, while the number of natural parks may fluctuate, their overall importance and scope remain vast. Therefore, pioneering new management approaches and enhancing efficiency emerge as top priorities for worldwide natural park governing bodies. A major goal moving forward is to guarantee efficient conservation while allowing sustainable development and sensible utilization, catering to the global populace's aspiration for enhanced ecological well-being.

To attain a balance between conservation and sensible utilization, it's pivotal to monitor and regulate human activities. This ensures that these activities do not trespass the environmental boundaries set by natural parks. Advances in digital technologies have been instrumental in transforming ecological

governance, amplifying the efficacy of ecological administrators. For natural parks globally, it's vital to capitalize on contemporary technology for real-time supervision of human interactions, gather extensive human activity data, appropriately manage human footprints, and thereby elevate overall managerial productivity.
Current State of Natural Park Management and Challenges Faced with Big Data Utilization in a Global Context

The concept of natural parks, encompassing areas of scenic beauty, forested regions, and other ecological assets, has been prevalent since the early 1980s, marking over 40 years of development. Throughout this period, natural park management bodies globally have actively sought to enhance operational efficacy and find a balanced approach to conservation and utilization, amassing a wealth of managerial experiences that signify a high standard of operational capability. With the profound integration of big data technology and managerial innovation, leveraging big data has become a primary method to boost managerial efficiency. However, the adoption of big data technology for the management of human activities in natural parks has been sluggish and faces several practical challenges.

2 Literature review

2.1 Current State of Natural Park Management

From the 1980s onward, various natural parks were established worldwide. Due to the constraints of the times and management structures, these parks were typically categorized based on ecological features such as landscapes, forests, lakes, grasslands, and deserts. This resulted in diverse sectors overseeing different types of parks; for instance, scenic areas might be governed by construction authorities, geological parks by land and resource agencies, marine parks by marine departments, and forest, wetland, and desert parks by forestry departments. This fragmented approach, while beneficial in some historical contexts, inadvertently compartmentalized ecosystems, hampering the development of a holistic and efficient management model for these parks and complicating the synergy between scientific conservation and rational use.

In November 2019, a guideline was issued on integrating and defining three lines of control within territorial spatial planning, emphasizing adjustments and optimization for natural conservation areas. Most natural parks, as crucial elements of the nature conservation system, were incorporated within the ecological conservation "red lines". This pivot towards prioritization of conservation signified a major shift in the original intention and positioning of these parks, reinforcing their primary role in safeguarding natural ecosystems, landmarks, and landscapes. Nevertheless, natural parks also serve unique roles in improving livelihoods, addressing surplus labor, and enhancing the quality of life for the masses. Therefore, while prioritizing conservation, sustainable development and rational utilization must also be considered, ensuring a balance in aspects like tourism, ecology, culture, and scientific research. Achieving this balance is challenging due to the intrinsic tension between conservation and utilization, especially when guidelines stress restricting human activities to preserve the parks. The crux of the issue revolves around how to strike a balance between protection and rational use, particularly when determining the extent of human activities allowed. The main challenges faced by park management are to moderately restrict the number of visitors and the frequency of their visits.

In 2013, a directive was released emphasizing the integration and innovative application of information technology in forestry, pointing towards a comprehensive merger from isolated to integrated applications. Grounded in big data technology, this direction supports information-driven approaches for natural conservation systems, focusing primarily on significant natural ecosystems, landmarks, landscapes, and biodiversity. Furthermore, it offers policy support for natural parks to monitor, collect, and utilize big data related to human activities.

2.2 Issues with Leveraging Big Data Technology

Currently, big data technology has become an effective means to enhance governance capabilities globally. National parks, despite their international prominence, have been sluggish in innovating their management approaches using big data technology. Their management often remains tethered to conventional models, with inadequate utilization of big data to improve administrative efficiency, resulting in less targeted and systematic management strategies.

There is a lag in shifting mindsets and insufficient emphasis on human activities. The establishment of a nature conservation system, primarily revolving around national parks, has integrated these parks within eco-sensitive zones. Despite facing major paradigm shifts towards conservation, park managers still harbor a preference for utilization over conservation. Some parks even prioritize economic gains, neglecting moderate restrictions on human activities and not monitoring or controlling them in real-time.

Monitoring methods of human activities are homogenous, leading to unsatisfactory results. To scientifically manage human activities, real-time big data, encompassing metrics like frequency, trajectory, and volume of human activity in parks, is essential. Due to the unique resources and terrains of these parks, diversified monitoring methods are required. However, current monitoring primarily relies on entrance checks and video surveillance, which fall short in collecting comprehensive real-time data on human activities.

Inadequate utilization of big data on human activities. Because of outdated perceptions held by decision-makers and a scarcity of expertise in big data, there's an underutilization of data on human activities. While some data is used in formulating development plans and annual work agendas, day-to-day management rarely leverages this information to elevate the overall management quality of the parks.

3. Pathways to Enhancing Management Efficiency Using Human Activity Data

Reforming management structures and operational mechanisms, strengthening the synergy between conservation and utilization, and innovative management using big data are pivotal to improving the efficacy of park management. The level of synergy between conservation and utilization acts as a barometer for management efficiency in national parks. Particularly, real-time regulation of human activities using big data to confine the intensity and frequency of activities within a permissible range is a primary approach to achieve this synergy and elevate the management standards.
Based on a search of global academic databases, there's a limited number of studies focusing on effective management of national parks based on their intrinsic features. Most research categorizes parks, such as scenic areas, geological parks, and desert parks, and studies them accordingly. Few have delved into the application of big data in managing different types of parks, mainly emphasizing the sustainable development and optimization of human activity trajectories. Hence, centered around preserving vital natural ecosystems, geological diversity, and the myriad values they hold, employing human activity data to enhance management efficiency is of great practical significance. The essence of restricting human activity lies in understanding the carrying capacity of the park's environment and continuously monitoring human activity, making environmental capacity and real-time human activity data the central elements.

Using human activity data as a foundation to moderately restrict human activities is a valid approach to further improve park management efficiency. This includes four steps: Monitoring units in national parks should employ an integrated terrestrial and aerial surveillance system to gather human activity data. The amassed data should undergo necessary cleaning and labeling, forming a value-driven database. Analysis of this data should be carried out to derive conclusions, which should be promptly submitted to the decision-making units. Management and decision-making units, based on these analyses, should formulate precise strategies for moderating human activities, effectively elevating the management efficiency of the parks.

4.Human Activity Big Data Collection, Analysis, and Application in a Global Context

The demographic in natural parks worldwide encompasses not only local inhabitants and visitors but also individuals involved in agriculture, transportation, commercial services, volunteer services, and more. As major forest and grassland tourist destinations, these parks experience an influx of visitors each year. Consequently, the primary human activities in these areas revolve around visitor movements. For instance, during the start of 2017, 14 sites within a famous natural park recorded approximately 78 million visitor location data entries over 29 days, averaging nearly 200,000 entries per site per day. As per the global forestry and grassland annual report of 2020, there were around 31.68 billion visits to these areas, with just the forest parks accounting for 7.4 billion of these visits. This paper emphasizes the count and activity trajectories of visitors entering these natural parks, highlighting the significance of choosing scientific collection methods and the real-time capture of these data.
Currently, human activity data collection predominantly relies on ticket sales systems, park entrance turnstiles, video surveillance, drone footage, online reviews, and mobile phone location services (based on GPS or other satellite-based systems, mobile network-based positioning, and WiFi or Bluetooth-based positioning). While ticket sales systems offer data, they may not account for visitors who purchase tickets but never enter, and they may lag in determining the carrying capacity of the environment. Park entrance turnstiles are infeasible for open natural parks, and even in closed parks, they could hamper emergency evacuations and fail to capture in-park congregation points. Mobile positioning, whether through GPS or WiFi, requires visitor cooperation and has its limitations. Online reviews lag in real-time data, hindering timely action. Mobile network-based location data, stored by telecommunication providers, includes positional and timestamp information, allowing for all-weather, continuous recording without disturbing visitors. This method's cost-effectiveness, expansive time span, and geographical coverage make it a preferred choice. However, its accuracy largely depends on the density of mobile towers, and natural parks might have areas with no coverage. These shortcomings can be addressed using ground-level video surveillance and aerial drone footage.

To effectively leverage mobile network-based location services, forestry and grassland authorities need to forge strategic data-sharing alliances with major telecommunications providers. This ensures real-time access to visitor location data, encompassing overall visitor count, popular sites, and visitor movement patterns. Furthermore, installing surveillance cameras at entrances, pathways, popular spots, diversion points, and rest areas would offer real-time visitor data. Utilizing drones equipped with necessary gear can capture data from areas with weak mobile signals. Combining these methods would create a comprehensive, three-tiered (sky, land, air) monitoring system, ensuring complete real-time coverage.

Natural park monitoring departments must clean and label the collected data. With a vast amount of unstructured data, including visitor location and activity data, initial steps involve tagging, cleaning, employing predefined rules to validate the data, and filtering out incomplete, erroneous, or redundant entries to ensure logic and completeness. Analysis of this data provides insights into visitor count, duration of stay, hourly visitor flow, popularity rankings of sites, historical trends, and more. By understanding these metrics, management can formulate data comparison reports catering to specific temporal and spatial needs, ensuring timely decisions and necessary adjustments to human activities. By conducting real-time monitoring of human activities in global natural parks, there is a comprehensive grasp of park visitor flow and the trajectory of big data. Statistical analysis of this data helps understand the patterns of visitor flow and the correlation of crowd aggregation between popular sites. This aids in issuing timely alerts, assisting managerial divisions in making appropriate managerial decisions.

Big data technology enhances the emergency management level of natural parks. Monitoring departments, through real-time surveillance systems, acquire big data on human activities within the park. By comparing and forecasting using historical data, alerts are sent to decision-making bodies if the predicted visitor flow in the park or at popular sites approaches or exceeds safety thresholds. Quick assessments are made, determining the need to activate emergency protocols and implement emergency measures.

Decision-making divisions constantly monitor the real-time number and movement of visitors across the park. Based on changing trends and alerts from monitoring systems, human activities are adjusted timely. For incoming visitors, strategies are devised according to their primary purposes, implementing measures like flow limitation, diversion, cutoff, or even rapid evacuation, ensuring visitor flow remains within safe boundaries and preventing overtaxing of the park's ecological and cultural capacity.

To mitigate the adverse effects of human activities on the ecology and cultural landscape, route optimization is employed based on the analysis of big data. Depending on the specific distribution of natural resources and cultural sites within the park, key locations are categorized. Theme-based routes, such as landscape routes or cultural heritage paths, are established. Visitors are guided to choose various routes, effectively diverting the crowd.

Through big data analysis, there's an understanding of whether existing or under-construction infrastructure impacts the park's natural ecosystem and landscapes. Based on sustainable development principles, eco-friendly methods are employed for infrastructure construction or remodeling. As per visitor flow monitoring, recreational stops are strategically placed, not only offering visitors rest spots but also diverting crowd concentrations. Signage and auditory cues are continually refined, elevating the park's public service standards.

Emergency medical response involves immediate assistance provided before professionals arrive at unexpected incidents. Each park establishes emergency medical centers and dedicates rescue teams. Plans are tailored according to the park's unique topography, traffic conditions, and other factors. With real-time alerts from monitoring systems, emergency protocols are swiftly activated, ensuring the safety and smooth operation of the park.

Based on the human activity patterns derived from big data, modern media is employed to promote the unique natural and cultural resources of the park, as well as its varied activities. This guides visitors to choose themed routes based on their interests, satisfying their requirements while avoiding sudden crowd gatherings at popular sites. Concurrently, a volunteer system is established, expanding the volunteer base. Volunteers, both online and offline, provide guidance, answer queries, and offer personalized services, continually enhancing the park's reputation and public image.

5 Discussion and Conclusion

In the context of establishing a conservation system, primarily composed of national parks, underpinned by nature reserves, and complemented by natural parks, the question arises: How can natural parks precisely implement strategies using big data from human activities? Moreover, how can they address the challenges of scientifically limiting human interventions, further enhance management efficiency, and progressively modernize the governance of these parks? The aim is to ensure that natural parks can achieve sustainable development and utilization while effectively protecting ecosystems and cultural landscapes. The management departments of natural parks should refine their overarching designs, build monitoring and evaluation systems, introduce top-tier talents, and fully utilize human activity big data while emphasizing data governance. By doing so, they can further optimize workflows and make science-based decisions, thereby genuinely enhancing the management efficiency of natural parks.

It's crucial to establish comprehensive regulations and standards for natural parks. Rapid introduction of specific ordinances for natural parks is essential, including clauses dedicated to monitoring human activities, non-biotic environmental changes, and biotic factors. Each natural park should have development planning and operational agendas that demand specific requirements for real-time data collection on human activities and biotic and abiotic changes, thus providing firm institutional support.

Building an integrated monitoring system for natural parks, which includes a subsystem for human activity tracking, is of utmost importance. This system should not only monitor changes in non-biotic factors like

water, air, and soil but also assess vegetation coverage and the distribution, quantity, and quality of wildlife. By gradually establishing a system composed of real-time monitoring platforms, dynamic databases, and unified evaluation criteria, parks can make informed decisions on human activities, ensuring the scientific conservation and sensible use of natural parks.

A lack of high-level professional talents in natural parks is a significant barrier to harnessing big data technology. First, the management staff of every natural park needs to adopt the idea of promoting park governance modernization using big data. Secondly, technical personnel should be trained intensively in big data technology to enhance their expertise and skills. Lastly, broaden talent recruitment by collaborating with forestry and grassland-related universities and formulating policies that attract talents, alleviating the scarcity of high-level big data experts. Through various measures, introducing big data management and technical personnel will offer vital human resource support to utilize big data technology effectively.

Integrating human activity big data in management practices, such as emergency management, human activity regulation, route optimization, scientific infrastructure placement, emergency rescue, and targeted promotions, is imperative. Additionally, employing comprehensive monitoring systems to gather large-scale data on non-biotic environmental changes and biotic factors can offer scientific evidence for effective protection, addressing management challenges, and promoting scientific conservation and sensible use of natural parks.

Data governance involves managing data utilization actions. When collecting and utilizing various data sources, especially human activity big data in natural parks, data governance becomes paramount. National-level standards related to data security and personal information protection set the regulatory requirements for data governance, laying the groundwork for using diverse big data sources in natural parks. Strict adherence to these regulations ensures the scientific and standardized enhancement of management efficiency using human activity big data.

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