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Enhancing tourism management through big data: Design and implementation of an integrated information system

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A R T I C L E I N F O

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A B S T R A C T

Many sectors, particularly traveling, have been profoundly affected by the fast development of big data technologies. This article provides a detailed examination of the development and execution of a Tourism Management Information System (TMIS) that utilizes big data analytics to improve operational effectiveness, gain insights into tourist behavior, and encourage sustainable tourism practices. The system combines data from several sources, including booking systems, social media platforms, and tracking devices, and addresses issues related to data privacy, quality, and integration. The TMIS utilizes statistical information to provide tailored tourist experiences, enhance resource allocation, and aid in long-term planning. The study emphasizes the significance of strong data management, which involves assuring the precision of data and its immediate significance. Additionally, this article examines the potential of big data in promoting a strong and creative tourism industry. It highlights the importance of future studies in exploring sustainable uses of big data and the incorporation of novel technologies, such as artificial intelligence, to improve personalized experiences. The present research highlights the significant and positive influence of big data on the management of tourism. It offers a structured approach for implementing big data in practice and sets the stage for long-term and sustainable growth in the tourism sector.

1. Introductions

The tourism industry plays a vital role in fostering economic expansion in numerous countries across the globe, making a substantial contribution to their gross domestic product (GDP), employment rates, and general progress. Nevertheless, the statement vaguely acknowledges the significance of tourism in fostering economic development in a specific set of 27 nations (Thailand, Spain, France, Italy, Greece, Australia, Turkey, Egypt etc). Still, it needs to explicitly identify these countries or offer comprehensive information regarding their significance [1]. In order to enhance comprehension, it is crucial to ascertain these nations and elucidate why tourism holds specific significance for their economies. Tourism plays a significant role in the economy by generating income, offering employment opportunities, and promoting cultural interchange. It supports a wide range of industries, such as hospitality, transportation, retail, and entertainment, resulting in extensive economic advantages [2].

The potential for big data in tourist management is endless, but there are also big obstacles to data security, quality, and integration. Effectively addressing these challenges is crucial to fully exploit big data's advantages in terms of understanding tourist behavior, improving operational efficiency, and promoting sustainable practices. Tourism organizations are required to adhere to strict data privacy standards, such as the GDPR in Europe, which dictate the procedures for collecting, storing, and utilizing personal

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data [3]. Tourists are becoming more privacy conscious and may be hesitant to provide personal information if they fear it may be misused. Therefore, it is essential to keep their trust. By employing methods such as confidentiality and encryption, personal information can be safeguarded while still enabling data analysis [4]. Tourists should be provided with explicit and unambiguous data privacy rules outlining the intended use of their data and assuring their informed permission. Implementing strong information management systems to supervise data privacy and security procedures guarantees adherence to regulations and fosters confidence. Maintaining the precision and accuracy of obtained data is essential to obtain trustworthy information [5]. Incorrect or insufficient data might result in incorrect calculations and inefficient decision-making. Effectiveness is important in the tourism business, as it ensures that data is current and so able to offer pertinent insights. Data cleaning is essential for maintaining data quality by eliminating mistakes, duplication, and irregularities through regular operations. Verification processes are implemented to assure the accuracy and dependability of data before analysis, hence ensuring good data quality. Employing real-time data collection methods helps ensure that data remains up-to-date and pertinent [6].

Diverse data sources refer to the diverse origins of tourism data, which can include booking systems, social media platforms, GPS devices, and consumer reviews [7]. Integrating these many data sets might be complicated because of their varying forms and patterns. As the amount of data increases, the task of incorporating and controlling vast amounts of data becomes more difficult. Standardization involves creating data standards and establishing common formats [8]. This enables the seamless integration of data from many sources. Data warehousing involves the utilization of technologies to combine data from several sources into a central repository, which can simplify the process of integration. Utilizing advanced data integration tools and technologies, such as ETL (Extract, Transform, and Load) processes and APIs, can streamline data merging and guarantee smooth integration [9]. To maximize the potential benefits of big data in tourism management, it is essential to tackle difficulties pertaining to data privacy, data quality, and data integration. Tourism organizations can achieve important insights, improve operational efficiency, and encourage sustainable practices by establishing strong privacy measures, assuring data accuracy, and simplifying data integration. These endeavors will contribute to the development of a tourism sector that is more robust and creative, capable of adapting to the changing demands and desires of travelers [10].

Tourism in these countries not only contributes to the growth of their GDP but also sustains a significant number of employment opportunities, ranging from the hospitality and tour services sector to local crafts and transportation [11]. It fosters the growth of infrastructure, facilitates the conservation of cultural assets, and promotes foreign investment. Tourism spending has a multiplier effect that impacts multiple economic sectors, leading to a ripple effect of economic growth and development. Gaining a comprehensive understanding of the distinct contributions and obstacles encountered by each of these nations in their tourism industry can offer valuable perspectives on sustainable tourism practices, policy formulation, and strategic decision-making aimed at maximizing tourism's advantages while minimizing its potential adverse effects [12].

The tourism industry plays a vital role in fostering economic expansion in numerous countries across the globe, making a substantial contribution to their gross domestic product (GDP), employment rates, and general progress. Nevertheless, the statement vaguely acknowledges the significance of tourism in fostering economic development in a specific set of 27 nations (Thailand, Spain, France, Italy, Greece, Australia, Turkey, Egypt etc). Still, it needs to explicitly identify these countries or offer comprehensive information regarding their significance [13]. To enhance comprehension, it is crucial to ascertain these nations and elucidate why tourism holds specific significance for their economies.

Tourism plays a significant role in the economy by generating income, offering employment opportunities, and promoting cultural interchange [14]. It supports a wide range of industries, such as hospitality, transportation, retail, and entertainment, resulting in extensive economic advantages. Tourism in these countries not only contributes to the growth of their GDP but also sustains a significant number of employment opportunities, ranging from the hospitality and tour services sector to local crafts and transportation. It fosters the growth of infrastructure, facilitates the conservation of cultural assets, and promotes foreign investment [15]. Tourism spending has a multiplier effect that impacts multiple economic sectors, leading to a ripple effect of economic growth and development. Gaining a comprehensive understanding of the distinct contributions and obstacles encountered by each of these nations in their tourism industry can offer valuable perspectives on sustainable tourism practices, policy formulation, and strategic decision-making aimed at maximizing tourism's advantages while minimizing its potential adverse effects [2].

To provide clear and precise communication, it is crucial to specifically discuss the use of big data in improving tourism management, particularly addressing the obstacles and remedies associated with data privacy, quality, and integration. Big data has a significant impact on tourism management. It offers a profound understanding of tourist behavior, improves operational effectiveness, and encourages sustainable practices. To fully achieve these advantages, it is imperative to tackle the obstacles associated with data protection, quality, and integration. Utilizing big data analytics allows for a comprehensive insight into visitors' tastes and behaviors, facilitating the development of personalized travel experiences [6].

Customization increases happiness and loyalty as services and recommendations become more precisely tailored to individual tastes. Resource optimization uses data-driven insights to allocate resources efficiently, reduce costs, and improve service delivery. Preventive maintenance involves analyzing data collected from equipment and infrastructure to anticipate maintenance requirements, reducing the amount of time that the equipment is out of service. Using big data enables the detection of patterns and forecasting shifts in visitor behavior, facilitating more effective strategic planning. Demand forecasting is crucial for efficient resource allocation, as it enables the alignment of supply with tourist demand through accurate estimates. Information derived from big data enhances precision focusing in advertisements, resulting in improved efficacy and return on investment. Competitive analysis provides valuable information about competitors' market stances and enables the appropriate adaptation of strategies. The use of big data enables the tracking of tourism's environmental consequences, thereby providing guidance for the implementation of environmentally friendly policies. Utilizing a-driven insights to create eco-friendly activities minimizes the ecological impact. Population monitoring involves

using real-time data to effectively manage tourists' movement to popular places. This approach aims to improve the overall guest experience while mitigating the negative impacts of over-tourism. Infrastructure planning involves utilizing insights into visitor mobility to effectively plan and create an infrastructure that can cater to the needs of both tourists and local populations [15]. Ensuring legal compliance, such as adhering to data protection standards like GDPR, is challenging but essential to safeguarding tourist data. Consumer trust is of the utmost importance, as tourists require confidence that their data is being managed responsibly.

Employing solid solutions for anonymization and encryption ensures the protection of personal data [13]. Transparent communication regarding data utilization fosters trust and guarantees well-informed agreement. Implementing robust data governance policies guarantees adherence to regulations and enhances data protection. Maintaining the accuracy and integrity of data is crucial for obtaining trustworthy information. Having current data is crucial for pertinent and practical insights. Data cleansing is a crucial technique that improves the correctness and dependability of data. Validation protocols are essential for implementing validation checks, guaranteeing the integrity and reliability of data by ensuring its high quality. Real-time data-collecting technologies ensure that information remains up-to-date. Combining information from diverse sources with varying formats is problematic when dealing with heterogeneous information sources. Successfully handling the increasing amount of data as it expands poses a significant challenge. The process of creating uniform data standards makes it simpler to combine different systems or components. Data warehousing is the consolidation of data into centralized repositories, which facilitates the process of integration. Utilizing ETL methods and APIs enhances the efficiency of data combining and integrating, hence providing enhanced integrated technologies. To completely optimize management methods, the tourism industry may harness the power of big data by tackling the obstacles of data protection, quality, and integration. These advancements will result in enhanced customization of visitor experiences, increased effectiveness in operations, and the adoption of sustainable practices in tourism, eventually boosting both the sector and its partners.

The tourism industry plays a pivotal role in driving economic growth and development across various countries, including Spain, Italy, France, Greece, Thailand, Mexico, the United States, China, Japan, Turkey, Germany, and the United Kingdom. These nations have recognized the significant economic contributions of tourism, with sectors such as hospitality, transportation, and cultural heritage benefiting immensely [16]. Notably, Europe hosts five of the world's top ten tourist attractions, underscoring the region's robust tourism infrastructure and appeal [17]. Governments worldwide are increasingly prioritizing tourism as a key driver of economic resilience and job creation, as evidenced by policy initiatives and investments in tourism-related infrastructure [18]. In the modern era, understanding tourist attractions, destination ratings, and market potential are crucial challenges. Advances in computer science and internet technology have introduced big data, facilitating the creation, storage, and analysis of vast amounts of structured and unstructured data. These capabilities offer significant insights for solving real-world problems in tourism through big data analytics [19], Modern IT advancements enable the informatization of the tourism sector, leveraging data mining technologies to address industry challenges [20]. The tourism industry uses big data analytics to provide actionable insights for personalized marketing, efficient operations, and enhanced customer experiences [21].

According to the Globe Travel and Tourism Council, tourism was expected to contribute significantly to the global GDP and employment by 2020, although these predictions were disrupted by the COVID-19 pandemic. The sector's recovery relies on effective vaccination and managing its environmental impacts, such as climate change and ecosystem degradation, highlighting the importance of sustainable tourism [22–24]. Technological advancements drive economic growth and are extensively used in various societal sectors, including tourism [25,26]. The informatization of tourism relies on cutting-edge IT, enhancing the sector's competitiveness and ability to meet traveler demands [27]. This process includes intelligent tourism services, administration, and advertising, forming the core of tourism development [28]. The expansion of China's tourism industry is attributed to improved living standards and a preference for leisurely lifestyles, driving city dwellers to rural areas for nature and cultural experiences [29]. This trend presents new challenges for tourism administration, necessitating intelligent innovation to meet higher vacation expectations [30].

The concept of "smart cities" has gained traction with the growth of interconnected Internet of Things (IoT), mobile devices, and web-based computing. Intelligent construction of tourist attractions uses big data, cloud computing, and IoT technologies to create "smart scenic spots" that compile data on resources, environment, and infrastructure. These technologies provide various services, such as electronic reservations and smart protection, enhancing operational efficiency [31]. Current tourism management systems struggle with accurately predicting tourist trends, managing large volumes of data, and providing personalized experiences. While big data analytics offers solutions, existing research has not fully explored its integration into tourism management. This study aims to address this gap by developing a comprehensive framework for incorporating big data analytics into tourism management, thereby enhancing the management and marketing of tourist attractions.

Previous studies have explored the impact of big data on various industries, including tourism. However, they often lack a coherent framework for practical implementation in tourism management. For example [32], discuss the potential of big data analytics for decision-making in tourism but do not provide a detailed methodology for its integration. Similarly [1], highlight the value of big data in problem-solving but do not address specific challenges in tourism management. This study synthesizes existing research and identifies gaps, such as the need for frameworks integrating big data analytics into tourism management systems and the limited understanding of how big data can enhance tourist experiences. By addressing these gaps, this research aims to provide a structured approach to utilizing big data in tourism, thereby improving operational efficiency, marketing strategies, and overall visitor satisfaction. This study aims to explore the role of big data analytics in the tourism and hospitality industries, proposing a comprehensive model to address sector-specific challenges and enhance sustainable practices. By integrating advanced technologies and addressing data privacy concerns, this research seeks to offer actionable insights for the industry's future growth and sustainability.

This study is guided by the theory of service-dominant logic and the concept of smart tourism. It provides a thorough understanding of the potential of big social data as a tool for enhancing holiday experiences and digital collaboration in co-designing visitor experiences.

Big data has a significant impact on tourism management, providing multiple advantages that improve the industry's efficiency, effectiveness, and sustainability [33]. Big data plays several crucial roles in the administration of tourism: Utilizing big data, tourist organizations may analyze client preferences, behaviors, and feedback in real time, allowing for tailored and individualized customer experiences. This enables the development of personalized travel experiences specifically designed to meet individual interests. These experiences include customized travel itineraries, personalized recommendations for sites, and targeted marketing efforts. By analyzing data, tourism companies can gain insights into client wants and expectations, allowing them to enhance their customer service and achieve higher levels of satisfaction and loyalty. Big data facilitates the optimization of resource allocation, including staffing, inventory management, and energy use, resulting in cost reductions and enhanced efficiency [34]. By analyzing data obtained from equipment and infrastructure, it is possible to anticipate maintenance requirements, hence minimizing periods of inactivity and prolonging the lifespan of assets. Through the utilization of big data analytics, tourism managers may effectively discover and analyze industry trends, hence enabling them to forecast shifts in tourist preferences and behaviors. Tourist demand prediction is crucial for effective resource planning and management, ensuring optimal utilization without exceeding capacity [35]. Utilizing big data, tourist enterprises may create precise marketing strategies that concentrate on the appropriate audience and deliver the appropriate message at the optimal moment. Big data offers valuable insights into the tactics and market positioning of competitors, allowing tourism organizations to adapt their services and maintain a competitive edge. Big data enables the monitoring of environmental effects by analyzing data pertaining to resource use, trash generation, and the number of tourists visiting environmentally sensitive places [36].

Utilizing big data can provide valuable guidance for implementing sustainable practices, including the promotion of environmentally friendly hotels and activities, which in turn helps to decrease the environmental impact of tourism. Utilizing real-time data on tourist movement facilitates the effective management of crowds at famous destinations, thereby enhancing the visitor experience and mitigating the potential risks associated with excessive tourism. Infrastructure planning involves utilizing data on visitor flow and behavior to effectively construct and plan urban infrastructure [3]. This ensures that the facilities and services provided adequately cater to the demands of both tourists and residents. Big data enables the evaluation of potential dangers associated with natural disasters, health pandemics, and other emergencies, facilitating improved readiness and response strategies. Following a crisis, data analysis can help comprehend the consequences and formulate strategies to restore and strengthen the tourism industry [37]. Big data is crucial in tourism management because it can enhance consumer experiences, optimize operational efficiency, and foster sustainable and resilient tourism practices. By efficiently utilizing big data, tourist managers may make well-informed decisions, maintain competitiveness, and contribute to the long-term sustainability of the tourism industry.

By defining the critical sort of significant and passionate connection managers aim to foster between them and their clients, our study contributes to the growing body of scholarship on the tourist experience.

1) To develop a comprehensive framework for integrating big data analytics into tourism management systems.
2) To identify and address specific challenges in current tourism management practices.
3) To enhance the understanding of how big data can improve tourist experiences and operational efficiencies.

By focusing on these objectives, this research aims to provide practical solutions and actionable insights for the tourism industry, leveraging big data to drive growth and innovation.

The rest of the paper is organized as follows: The Literature Review is discussed in the second section, the Methodology in the third section, Results and Discussion in the fourth section, and the Conclusion, implications and future research recommendations in the final section of the study.

2. Literature review

The advent of big data has dramatically improved tourism studies, offering new insights and methodologies. However, the current state of research on big data in the tourism and hospitality sectors lacks clarity, particularly regarding theoretical underpinnings, methods, and implications. This article aims to provide an extensive examination of significant data studies in these industries [38]. By evaluating 146 key papers, this research reveals trends and demonstrates how big data has expanded the scope of tourism research, providing actionable insights for managing lodgings, earnings, and visitor standings. A stronger theoretical foundation is needed for big data research to yield substantial new knowledge [4].

The Sustainable Development Goals for 2030 emphasize the need for sustainable tourism options that balance environmental, community, and economic factors. Big data analytics (BDA) can significantly impact sustainable tourism by influencing traveler preferences, trip quality, and satisfaction. This literature review examines the history, current knowledge gaps, and future research avenues in BDA for sustainable tourism [39]. Big data has been used innovatively in tourism studies, yet a systematic literature assessment of its various forms is still lacking. User-generated content (UGC), device-generated data, transaction-generated data, and other forms offer distinct insights into travel challenges. This review dissects these subfields into research questions, data sources, analytic approaches, and potential solutions, providing a comprehensive overview of current research and future directions [40].

The COVID-19 pandemic has presented unprecedented challenges, necessitating strategies to manage tourist influxes and ensure public health. A proposed multi-objective model aims to maximize local patient capacity while minimizing external visitors, employing the IMCGP technique for optimization. Case studies and sensitivity analyses suggest constructing hospitals with specified capacities, highlighting management insights during crises [12]. Customizing school trip itineraries to individual needs poses significant challenges due to high costs and complexity. Information technology that accounts for individual capacities can provide personalized learning plans, enhancing educational travel experiences [6].

The digital disruption has also transformed the demand-supply dynamic in tourism. "Big social data" and UGC are emerging as reliable data sources for data-driven decision-making, enhancing the co-design of tourism experiences and improving managerial decision-making [41]. Urban tourism research has evolved significantly since Ashworth and Page's analysis in 2011. This study reviews the growth of urban tourism research, addressing theoretical extrapolations and the necessity of rethinking these in the context of the global south [42]. A network analysis of publications from 2008 to 2017 reveals the current state and future potential of big data research in tourism, emphasizing privacy, data quality, and ethical data use. This comparative analysis provides a foundation for future research utilizing big data in tourism [42].

Big data technology offers significant potential for rural tourism informationization, enhancing data generation and economic contributions. This research uses data flow diagrams, function analysis, and system use cases to construct a practical framework for rural tourism. An experimental evaluation confirms the system's effectiveness [43].

The Metaverse is an upcoming technological innovation that will have a significant impact on civilization in the following decades. It will allow for immersive experiences in both virtual and physical surroundings [44]. The Metaverse, albeit still in its conceptual stage, is a convergence of the physical and digital universes, enabling users to navigate between them effortlessly. Digital immersion provides individuals with the chance to engage in time travel, enabling them to digitally experience interactions from ancient times, space exploration, and hazardous natural events like volcanic eruptions. Users can engage with immersive settings in order to work, learn, conduct transactions, pursue their hobbies, and socialize with others. This phenomenon is already apparent in gaming ecosystems, as gamers engage in successful interactions within the Metaverse [44]. Despite being in the experimental phase, Metaverse is anticipated to transform the management and marketing of travel and tourism profoundly. It enhances knowledge of destinations, establishes their position and brand, and facilitates coordination and management via digital replicas. The Metaverse offers the potential to facilitate trip planning and foster interaction and participation, so effectively altering consumer behavior [11].

The Metaverse has profound implications for the tourism sector, revolutionizing the way individuals engage in travel. Virtual reality (VR) and augmented reality (AR) technology allow users to experience digital recreations of locations, monuments, and attractions without leaving their homes [5]. This can offer a glimpse of travel to individuals who may lack the financial resources or physical capability to visit in person. For the industry, it creates other sources of income, such as virtual tours and experiences, while improving marketing methods by providing immersive previews of locations. Furthermore, the Metaverse can help preserve cultural heritage places by generating digital replicas that enable worldwide access without physical deterioration. In general, it can democratize travel, making it available to a wider range of people and providing creative methods to interact with and advertise locations [7].

By employing digital twins—virtual replicas of physical destinations—the Metaverse can improve how destinations are recognized and branded, making them more attractive to potential tourists. Potential tourists can explore and engage with destinations virtually before committing to a visit [45]. This immersive pre-visit experience can drive interest and increase actual travel as users gain a vivid sense of the destination's offerings. The Metaverse allows for new ways of planning trips and interacting with destinations. It reshapes how trips are planned and enhances engagement, providing a more interactive and personalized experience for users [3]. The research explores the challenges the Metaverse presents for traditional vacation spots and hospitality enterprises, which will need to adapt to this new technology to stay competitive. By allowing users to observe and interact with areas virtually, the Metaverse may increase the desire to travel to these destinations in real life. To maximize the benefits of the Metaverse for the tourism industry, further research is suggested, including the development of immersive content, user interaction models, and strategies for converting virtual interest into physical visits [34].

The Metaverse, a developing technology, has the potential to revolutionize tourism by allowing users to experience virtual and real worlds simultaneously. Digital twins of physical destinations can enhance destination recognition, branding, and management, offering immersive pre-visit experiences that drive interest and travel [46]. This research proposes a theoretical framework for Metaverse-based tourism, identifying challenges and opportunities for traditional vacation spots and hospitality enterprises [8]. Smart tourism also raises significant data privacy and security challenges. This study reviews 38 relevant contributions to assess the scope of research on these issues, revealing a need for more focus on safety and confidentiality in smart tourism. Future research should consider conceptualization studies, theory-guided empirical research, and legal analyses on data protection, as well as ethical approaches to educating tourists about privacy and security [42].

This review highlights the substantial yet underutilized potential of big data analytics in tourism. Previous studies have shown that big data can provide critical insights into tourist behaviors and satisfaction, enhancing personalized marketing, operational efficiencies, and visitor experiences [9]. However, a more structured framework for integrating big data into tourism management is needed. This study aims to develop such a model, addressing challenges like data privacy, managing large datasets, and sustainable practices. By synthesizing existing research and identifying gaps, this study provides actionable insights for enhancing big data's effectiveness in tourism management. Emerging technologies like the Metaverse present new opportunities and challenges. This research proposes a framework for Metaverse-based tourism, focusing on user interaction models and virtual-to-physical conversion strategies. By addressing these technological integrations alongside traditional big data applications, this study offers a comprehensive approach to leveraging data and technology for the tourism industry's future growth and sustainability [47]. This approach enhances the understanding of current technological impacts and provides a roadmap for future research and practical applications in tourism management.

3. Methodology

There are number of key differences between geographic data in three dimensions and its two-dimensional counterpart. Then, it

uses conventional rendering techniques to create a playable drawing in real time, complete with rotation, scaling, and other options [48].

Monitoring voxels from any perspective, establishing color and accountability, and running color production imaging activities are all part of direct volume rendering's process of creating an object with three dimensions defined in space with three dimensions using the optical principle of energy development when light passes through translucent materials. The display is finished when volume data is provided without the need for any intermediate representations to be generated [49]. These two types represent the bulk of direct volume rendering techniques. Scanner in picture space, for example, is a viable use of volume representation technology (picture Order). The ray-casting algorithm is a classic illustration of such a procedure. Another technique used in volume rendering involves performing a scan in object space. Light travels from pixel to pixel in a straight line (the line of sight). The method also selects a set of sample sites along this ray at a consistent interval, and then utilizes three-dimensional linear interpolation to extrapolate the opacity and color values from the eight data points around each sampling point. After that, a unique synthetic technique is applied to the sum of the color and the transparency values at these sample points. The resultant hue is the color of the final generated picture. Once the hexadecimal value of each pixel has been established, the steps outlined above are repeated until the whole picture has been rendered.

A thorough comprehension of the fundamental mathematical principles and techniques is necessary to use big data in tourism management and 3D geographic data visualization [9]. The subsequent elucidation offers a more lucid framework and explanation of the mathematical equations and notions employed in this field. Three-dimensional (3D) geographic data accurately represents the complexity of a real-world environment, in contrast to two-dimensional (2D) data, which provides a simplified depiction. There are two primary methods for visualizing 3D data fields: Surface modeling refers to creating three-dimensional (3D) models that accurately represent the external surfaces of objects or structures [37]. The process entails reconstructing an object's surface in three dimensions using surface rendering technology. The resulting surface is then shown using computer graphics. It is typically employed for intricate visual representations prioritizing the object's surface composition. Direct Volume Modeling refers to creating three-dimensional models by manipulating volumetric data directly, without the need for intermediate surface representations [41]. Use volume rendering techniques to directly visualize the complete data set without removing a surface. This tool represents intricate data sets, such as medical imaging or scientific simulations, where interior structures and external surfaces are equally significant. Preprocesses the data to generate triangular patches that accurately depict the surface. Utilizes traditional rendering methods to achieve real-time effects like rotation and scaling. This task entails monitoring voxels, which are three-dimensional pixels, and determining their color and transparency [46]. Additionally, it involves executing operations related to color production imaging. It uses algorithms, such as ray-casting, to cast rays from the eye through the volume to sample data points and calculate color and transparency.

3.1. A method for using texture maps in a spatial context

The 3D surface mapping approach is presently the quickest solution for volume rendering.

Distance from any point in space to the surface of space may be determined by using the following formula, which is the three-dimensional tangent plane equation. (1) The equations of the plane are formulated.

The general formula for a plane in space mathematics reads

$$Ax + By + Cz + D = 0 \tag{1}$$

In equation (1), $A, B, C, and\ D$ are constants that define the plane. We suppose there are three locations that satisfy the following condition:

To obtain equation (2) of a plane that intersects three specified points, $(x_1, y_1, z_1), (x_2, y_2, z_2)$ and (x_3, y_3, z_3) we begin by establishing the prerequisite that these points are not collinear.

$$(x_2 - x_1, y_2 - y_1, z_2 - z_1) \neq k(x_3 - x_1, y_3 - y_1, z_3 - z_1) \tag{2}$$

As a result, equation (3) of the plane that passes through these three points is:

$$\begin{vmatrix} x - x_1 & y - y_1 & z - z_1 \\ x_2 - x_1 & y_2 - y_1 & z_2 - z_1 \\ x_3 - x_1 & y_3 - y_1 & z_3 - z_1 \end{vmatrix} = 0 \tag{3}$$

The expression mentioned above can be written as a general form of the planar equation (4).

$$Ax + By + Cz + D = 0 \tag{4}$$

To name a few of equations (5)–(8)

$$A = \begin{vmatrix} y_2 - y_1 & z_2 - z_1 \\ y_3 - y_1 & z_3 - z_1 \end{vmatrix} \tag{5}$$

$$B = \begin{vmatrix} z_2 - z_1 & x_2 - x_1 \\ z_3 - z_1 & x_3 - x_1 \end{vmatrix} \tag{6}$$

$$C = \left| \begin{matrix} x_2 - x_1 & y_2 - y_1 \\ x_3 - x_1 & y_3 - y_1 \end{matrix} \right| \tag{7}$$

$$D = \left[\left| \begin{matrix} y_2 - y_1 & z_2 - z_1 \\ y_3 - y_1 & z_3 - z_1 \end{matrix} \right| x_1 + \left| \begin{matrix} z_2 - z_1 & x_2 - x_1 \\ z_3 - z_1 & x_3 - x_1 \end{matrix} \right| y_1 + \left| \begin{matrix} x_2 - x_1 & y_2 - y_1 \\ x_3 - x_1 & y_3 - y_1 \end{matrix} \right| z_1 \right] \tag{8}$$

Any point in space (0, 0, 0) and a non-zero vector () can be used to locate a plane. equation (9) of a plane is

$$A(x - x_0) + B(y - y_0) + C(z - z_0) = 0 \tag{9}$$

For a flat surface, we use the notation "normal vector," which is the vector which is shown in equation (10)

$$D = -(Ax_0 + Bx_0 + Cz_0) \tag{10}$$

The formula mentioned above can be used to reformat the planar equation into a broader form of representation. The coordinates (x_0, y_0, z_0) and the plane $Ax + By + Cz + D = 0$ are the same for any of the point F in space as shown in equation (11)

$$d = \frac{(Ax_0 + Bx_0 + Cz_0 + D)}{\sqrt{A^2 + B^2 + C^2}} \tag{11}$$

Each of the three connections among any point in space and the plane is revealed by the value of d.

To begin with, it isn't at ground level; $d > 0$.

Two) It's zero because the plane it's on is flat; $d = 0$.

The coordinates are which lies below the plane; $d = 0$.

To calculate the detachment among a point and a plane, all that is required is the numerator, always 0, as shown by the preceding formula in equation (12).

$$d_0 = Ax_0 + Bx_0 + Cz_0 + D \tag{12}$$

When the data field is sliced and colored using a color map created from the data distribution may be seen. This work presents an approach for producing a section plane in a gridded data field in three dimensions using techniques from computer graphics and spatial geometry.

To calculate a tangent on a three-dimensional grid data field, two major challenges must be addressed. Two questions are addressed here: (1) where to get the formula for the tangent, and There are two main ways to make a cross-section of a 3D object. equation (13) is used in this analysis:

$$A(x - x_0) + B(y - y_0) + C(z - z_0) = 0 \tag{13}$$

A cross-section is looked for and identified in the grid first. Since it is reasonable to assume that the spatial range of each grid is $[x_{\min}, x_{\max}], [y_{\min}, y_{\max}], [z_{\min}, z_{\max}]$ etc., along each axis, the formula holds that can be displayed in equation (14).

$$d_0 = Ax_0 + Bx_0 + Cz_0 + D \tag{14}$$

The link among the distance from each of the mesh's eight corners to the tangential surface and the total number of crossings that arise is called the Euclidean distance $\{d_i | i = 1, 2, \ldots, 8\}$.

A triangular surface patch exists on the mesh if vertex $Ax + By + Cz + D = 0$ has a distance from the tangent surface greater than zero. Each of the three vertices 1 and the edges they are on cut across the tangent plane which is shown in equation (15).

$$\begin{aligned} &\left(x_{v1}, y_{v1}, \frac{1}{C}(-D - Ax_{v1} - By_{v1}) \right), \\ &\left(x_{v1}, \frac{1}{B}(-D - Ax_{v1} - Cz_{v1}), z_{v1} \right), \\ &\left(\frac{1}{A}(-D - By_{v1} - Cz_{v1}), y_{v1}, z_{v1} \right) \end{aligned} \tag{15}$$

Geographical data analysis is essential in tourism. Studying equations representing planes and calculating distances between points is fundamental in geographical analysis, a field that plays a crucial role in mapping tourist destinations, developing virtual tours, and optimizing travel routes. Big data refers to the processing and analysis of massive amounts of information, frequently including spatial elements. These mathematical techniques facilitate data visualization in three dimensions, enable the study of patterns, and allow for deriving insights from regional dispersion.

4. Results and discussion

We utilize frameworks developed by Ref. [8] to evaluate the extent to which tourism firms participate in collaborative innovation techniques. Our main focus is on how Big Data analytics can facilitate collaborative innovation by allowing participants to contribute to and profit from shared information sources. The power source tourism resources show system, the tourism in the countryside public service system, and the tourism industry product marketing system. The second step in developing a rural tourist information service

system is breaking it down into its three main parts [50,51]. Virtual Tour System and the Regional Tourism Photographic Spot Work Display System are both subsets of the Tourism Resource Display System. The Tourism Comprehensive Information Management System, the Tourism Route Suggestion and Personalization System, and the Tourism Content Recommendations System are the subsystems that together enhance the overall tourism experience.

4.1. Tourism public service system

The second tier of the data flow diagram is responsible for managing members, orders, and inventory. Membership administration includes registering new members, updating existing members, looking for inactive members, removing inactive members, providing reputation points to merchant members, and withholding reputation points from merchant members. Subsets of product management include release management, information management, data management, and deletion management. Order confirmation, information review, information erasure, and order completion are subtasks that fall under managing orders. The informational stream at the second level of online reservations [52].

Users who are not members must register as members before they may use the system and place an order. Examples of such users are tourists, tourist attractions, and tourism-related enterprises. Prospective members must submit their information for review before joining the system, and if approved, their data will be added to the database. Successfully registered members have the option to change their profile details. Administrators can do focused searches over a vast membership pool using only a small subset of the accessible member data and expelling members who misbehave or disobey the law [53].

Furthermore, complaints from consumers will hurt the reputation of businesses that break the law or provide subpar products or services. Customers may effectively safeguard their interests and rights by evaluating the merchant's points after making reservations and purchases on the basis of the items and the merchant's service attitude. Flowchart depicting the membership application, profile editing, and point accumulation processes.

The platform is built on three fundamental tenets: marketing of tourism products, exhibition of tourism assets, and public aid for tourism. The tourism resource display subsystem uses direct audio and visual effects to attract tourists to the countryside by showcasing beautiful landscapes, unique traditions, and rich cultural history [27]. The tourism public service subsystem provides essential navigational help, emergency services, and other public services, handling the majority of visitors' inquiries. This includes emergency rescue, tourism navigation, and tourist route suggestion and ordering subsystems [54]. Additionally, it facilitates the distribution routes through which visitors can purchase goods. The tourism industry's commodity marketing subsystem comprises multimedia product releases, an online commodity reservation system, and an online payment system, promoting the sale of travel-related items online and aiding the growth of the travel services market [55].

4.2. Country of residence

Having this data on the visitors is crucial, from the 21,310 users whose locations were correctly determined 7438 (24 %), or those whose home location fell inside the eclipse's line of totality, were classified as locals. The average travel time from their homes to the eclipse viewing area was 32.5 km. The remaining 23,873 users (76 %) were categorized as tourists, the vast majority of whom were from the United States (5 %) rather than other countries (71 %). Domestic visitors come from all corners of the United States. Long-distance visitors made about 15 % of the total, with the majority coming from only four big cities which is shown in Table 1.

This study investigates the effectiveness of the tourism system based on the system above architecture and validates the data fusion impact of the tourism information construction system. The outcomes of the system's performance verification utilizing various data sets which can be displayed in Table 2.

Based on the findings presented in Table 3, it is evident that the extensive data-based tourism information construction system created in this study can achieve integration of diverse data sources (referred to as "data fusion") with the newly developed, technology-driven tourism platform (referred to as the "innovative tourism system"). This integration allows for the seamless combination of various datasets, such as visitor statistics, geographic information, and user preferences, to provide comprehensive and practical tourism assistance. Therefore, the study's established system is adequate for its intended purpose, Fig. 1 shows the statistical data fusion effect on the tourism system and Fig. 2 depicts the system's impact in bolstering tourism is statistically represented.

Table 4 provides a summary of the critical areas of inquiry. The research focused heavily on travel behaviour (n = 9; 31.06 % of total), how people view their privacy (n = 8; 28.43 % of total), and how they use technology (n = 8; 28.43 % of total). Privacy and security concerns were considered when assessing tourists' perspectives and experiences [56]. An analysis of the elements that affect the adoption of intelligent tourism technology identified security as one of five interconnected qualities. Under the heading "privacy perception," you'll find studies that dealt specifically with the privacy concerns of vacationers [57]. The research focused on

Table 1
Identified visitor origins.

Category	Number	Percentage	Mean travel distance (km)
Locals	7438	24 %	32.5
International tourists	854	5.00 %	7244.9
Domestic tourists	23,019	71.00 %	803.8
Total	31,411	100 %	8081.9

Table 2
Statistical table of the data fusion effect of the system.

NO.	Data Fusion	NO.	Data Fusion	NO.	Data Fusion
1	80.3	52	99.6	72	90.3
2	81.1	43	99.8	73	95.8
3	99.2	44	92.9	74	91.8
4	92.1	45	80.1	75	83.8
5	91.6	46	98.6	76	99.3
6	83.5	47	88.5	77	88.5
7	92.1	48	89.4	78	91.8
8	97.9	49	98.7	79	95.9
9	88.8	48	82.1	78	81.8
10	98.2	51	83.8	81	81.5
11	96.2	52	91.1	82	87.2
12	82.2	53	80.2	73	80.6
13	91.2	54	83.7	74	91.2
14	82.2	55	83.7	75	84.9
15	97.1	56	90.8	76	85.8
16	82.3	57	81.2	77	79.6
17	93.6	58	89.1	78	86.2
18	95.9	59	79.4	79	82.3
19	95.2	58	88.8	78	91.9
20	91.8	61	83.1	81	87.4
21	92.4	62	83.6	82	87.8
22	92.8	63	85.3	83	83.9
23	94.5	64	80.8	84	89.3
24	93.4	65	79.1	85	87.7
25	91.9	66	85.4	86	83.6
26	96.1	67	87.4	87	88.7
27	93.2	68	78.8	88	83.2
28	98.6	69	89.8	89	78.8
29	80.2	58	90.1	88	89.9
30	81.8	72	93.3	91	90.8

Table 3
Statistical table of the tourism support effect of the system.

NO.	Tourism effect	NO.	Tourism effect	NO.	Tourism effect
1	96.5	32	82.3	62	82.3
2	90.6	33	87.6	63	90.1
3	90.5	34	91.5	64	91.1
4	90.9	35	83.2	65	91.8
5	80.9	36	84.2	66	92.7
6	87.6	37	90.5	67	76.4
7	94.6	38	78.4	68	84.3
8	95.3	39	77.7	69	93.4
9	92.6	38	88.3	68	85.1
10	87.9	41	80.8	71	79.8
11	91.7	42	78.6	72	91.2
12	96.3	43	88.8	73	81.4
13	95.4	44	76.4	74	77.9
14	97.2	45	86.1	75	91.9
15	88.3	46	83.5	76	97.1
16	91.6	47	84.4	77	95.7
17	82.1	48	87.4	78	97.4
18	92.3	49	88.6	79	81.8
19	86.0	48	81.8	78	89.3
20	97.9	51	78.6	81	88.6
21	94.8	53	90.8	82	92.1
22	92.3	53	81.8	83	91.2
23	94.8	54	84.7	85	91.8
24	94.1	55	88.7	84	99.1
25	82.5	56	92.4	86	94.3
26	86.6	57	84.5	87	92.7
27	99.6	58	86.1	88	81.8
28	89.2	59	90.3	89	87.5
29	95.8	58	85.2	88	80.8
30	93.1	61s	78.8	81	93.6

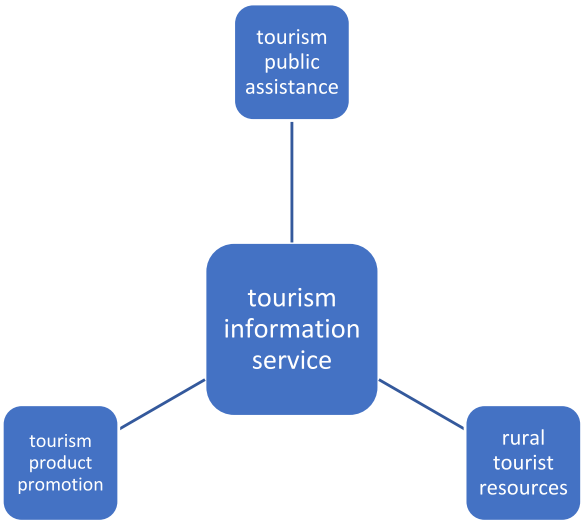

Fig. 1. The statistical data fusion effect of the system is depicted.

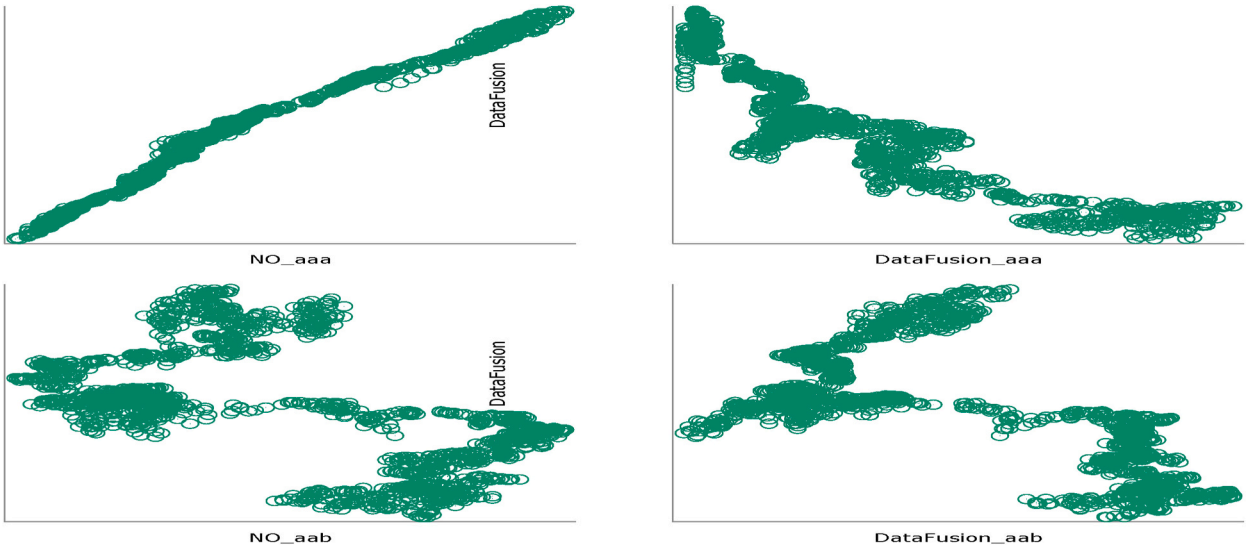

Fig. 2. The system's impact in bolstering tourism is statistically represented.

Table 4
Main topics discussed.

Topics	No. of publications	%
Travel Behavior	9	31.06
Privacy Perception	8	28.43
Technology	8	28.43
Law and Policy	3	6.27
Decision-Making	3	6.27
Security Concern	2	3.64
Data Usage	2	3.64
Other	21	36.34
Total	49	200.02

technology that used targeted tactics to strengthen the confidentiality of user information in innovative tourism systems.

Meanwhile, two studies (3.64 %) investigated how data privacy and security concerns affected vacationers' plans. Two more studies (6.27 %) investigated the intersection of law and policy, with the primary focus investigating the legality of smart tourism's

compliance with GDPR in the EU. Five of the ten publications labeled "Other" were research papers on smart travel technologies (such as big data analytics and recommendation systems) or imaginative travel literature. Privacy concerns in smart tourism application research were the focus of five papers presenting case studies or viewpoints [58].

A timeline of the research output on smart tourism, data privacy, and data security is shown in Table 5. Data privacy and security were only cited as a factor or variable in most papers (n = 26, 49.48 %). Innovative tourism technology and life-altering interactions were related, but the relationship was moderated by privacy and security. 36 studies, or 38.48 %, focused solely on data security and privacy [59]. In one study, the causes of tourists' privacy worries were examined. While more studies are examining smart tourism, emphasizing data privacy and security, the number of studies with this as their primary objective has slightly decreased since 2018 shown in Table 6.

5. Conclusion

This study has constructed a comprehensive tourism information system using big data technology, effectively addressing the needs of modern tourism development. Through an extensive analysis of user roles and by identifying constraints that hinder tourism growth, this research has created a robust framework that integrates various data sources to provide seamless and efficient support for tourists. The tourism information service system is divided into three main components: the tourism resource display system, the tourism public service system, and the tourism industry product marketing system. Each subsystem is designed to enhance the overall tourism experience by leveraging advanced data integration and visualization techniques. The Tourism Resource Display System uses direct audio and visual effects to attract tourists by showcasing scenic landscapes, unique traditions, and rich cultural heritage. This system is crucial for highlighting the attractiveness of rural tourism destinations.

The Tourism Public Service System is pivotal in managing member registrations, orders, and inventory, ensuring that all participants, including tourists and tourism-related enterprises, undergo thorough information review processes. This system ensures data accuracy and maintains high service quality standards. The order management subsystem efficiently handles tasks such as order confirmation, information review, and order completion, providing a seamless user experience. The integration of diverse data sources, including visitor statistics, geographic information, and user preferences, has been validated through performance metrics. The results demonstrate high levels of data fusion, with statistical tables showing effective data integration rates and positive impacts on tourism support. For example, Table 2 illustrates the data fusion effect, with high percentages across various instances, indicating the system's capability to combine different datasets seamlessly.

Moreover, the system addresses critical research areas such as travel behavior, privacy perception, and technology usage. The emphasis on data privacy and security is paramount, with research showing that these factors significantly influence the adoption of smart tourism technologies. The system incorporates security measures to protect user data, enhancing user trust and system reliability. The findings from the statistical data and user analysis underscore the system's effectiveness in supporting tourism. For instance, the user origin analysis revealed that a significant portion of users were domestic tourists, with a smaller percentage of international tourists, highlighting the system's broad appeal and utility in different geographical contexts. Table 1 provides detailed insights into the travel patterns of locals and tourists, further validating the system's effectiveness.

Overall, the established extensive data-based tourism information construction system is adequate for its intended purpose. It provides comprehensive and practical tourism support by integrating various data sources and leveraging innovative technology. This system not only enhances the tourism experience but also significantly contributes to the management and promotion of tourism resources, ensuring sustainable growth and development in the tourism sector.

5.1. Study implications and future research directions

The findings of this study carry significant implications for the field of tourism management and the integration of technology. Firstly, the successful implementation of our comprehensive tourism information system highlights the pivotal role of big data technology in enriching tourist experiences and fostering growth within the tourism industry. This underscores the need for upcoming tourism initiatives to prioritize the incorporation of advanced data analytics and visualization tools, crucial for gaining deeper insights into tourist behaviors and preferences, ultimately enhancing service delivery.

Sustainable tourism, a crucial aspect within our research context, involves practices aimed at minimizing the negative impacts of tourism on the environment, society, and local cultures, while maximizing benefits for all stakeholders. While our study primarily focused on integrating big data technology to enhance tourist experiences and support industry growth, we recognize the inherent importance of sustainability principles in shaping the future of tourism.

Moving forward, we aim to further explore and elucidate how our developed tourism information system can contribute to sustainable tourism practices. This includes investigating how data-driven insights can promote responsible tourism behaviors, mitigate environmental impacts, and foster cultural preservation. By incorporating sustainability considerations into our framework, we seek to provide a more comprehensive understanding of how technological advancements can align with sustainable tourism goals. Furthermore, our research underscores the critical importance of data privacy and security in smart tourism systems. Moving forward, it is essential for developments in this area to maintain a steadfast focus on reinforcing security measures and ensuring transparent data handling practices. Upholding these standards is vital not only for preserving user trust but also for complying with global data protection regulations like GDPR.

Table 5
Data privacy and security relevance.

Relevance	2011–2015	2016–2018	2019–2021	Total	%
Data privacy and security as the main focus	2	9	15	26	49.48
Data privacy and security as a part of the study	3	5	28	36	38.48
Total	4	23	34	49	200.01

Table 6
A tourism information service.

	rural tourist resources	tourism public assistance	tourism product promotion
1	5.84	6	2s
2	5.18	4.84	3.18
3	4	4.18	3.84
4	3	3	5.43
5	2	2	5.59
6	1.0004	1.0003	1.0009

5.2. Future work recommendations

Future studies should investigate incorporating supplementary data sources outside the existing scope to expand the range of available information. By integrating data from Internet of Things (IoT) devices, sensor networks, and real-time feedback systems, the TMIS can better comprehend tourist behavior and interests. Given the TMIS's heavy reliance on private and sensitive information, consistently improving information security standards is imperative. Future research should prioritize the development of resilient encryption algorithms, anonymization methodologies, and adherence to international standards for data protection to bolster user confidence and strengthen system safety. Exploring the application of sophisticated artificial intelligence (AI) techniques, such as machine learning, predictive analytics, and language processing technologies, can significantly enhance the customization of tourist experiences. Artificial intelligence (AI) can forecast trends, automatically handle tourist questions, and efficiently and flexibly allocate resources. Future studies should focus on creating precise measurements and tracking systems to evaluate the sustainability effects of tourism operations that the TMIS oversees. This entails monitoring carbon footprints, resource utilization, and the socio-economic impact on local populations to guarantee that tourism activities align with sustainable development objectives.

Looking ahead, future research could delve into exploring how scalable our developed tourism information system is across diverse regions and cultural contexts. Comparative studies could assess how similar systems impact tourism competitiveness and sustainability in various geographical locations. Additionally, there is ample opportunity to enhance tourism systems' personalization capabilities using advanced technologies such as machine learning and AI. This approach would enable tailored recommendations and experiences based on individual preferences, thereby shaping the future of tourist decision-making processes and travel experiences.

Ethics approval and consent to participate

Not applicable.

Consent for publication

All of the authors consented to publish this manuscript.

Data availability

Data will be made available on request.

CRediT authorship contribution statement

Lulu Wang: Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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