Choosing the best location for a trip based on the TOPSIS method

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Abstract

Today, tourism is a vital component of the economy and a means of cultural exchange. However, the increasing number of available destinations and the vast amount of information can make it challenging to find the ideal location that suits individual preferences. Our research focuses on developing a decision support system for selecting the optimal travel destination using the TOPSIS method.

The study's objective is to analyze the decision-making process involved in choosing the best travel location through a multi-criteria evaluation. It emphasizes both the methodological and practical aspects of applying the TOPSIS method to create an effective decision support system. The goal of this study is to develop a tool that assesses various tourist destinations based on user-defined criteria, including cost, safety, climate conditions, transport accessibility, and cultural attractions.

The TOPSIS method was chosen for its ability to weigh both the positive and negative aspects of the criteria. This approach allows us to pinpoint locations that are closest to the ideal solution while being farthest from the anti-ideal one. The algorithm has been implemented as a distinct module in Python, ensuring its independence and facilitating seamless integration with other components of the system.

During the planning and development of the system, system analysis methods were employed, and UML diagrams were utilized to visualize and model various aspects of the system.

Supabase — built on a PostgreSQL database—was selected to guarantee reliable performance and scalability. The TOPSIS algorithm is hosted on a server within the AWS cloud infrastructure.

The results from utilizing the system illustrate its effectiveness in providing users with relevant and informed recommendations for selecting travel destinations. The system simplifies the planning process by assisting users in navigating a vast array of options, thereby preventing information overload.

Keywords

Decision making, Decision Support System, Multi-Criteria Decision Making, normalization, Weights of Criteria, Ranking, Tourism, Travel Planning, TOPSIS Method

1. Introduction

The abundance of information, diverse evaluation criteria, and the inherent subjectivity of human perception add complexity to the decision-making process. Traditional selection methods, often reliant on recommendations or superficial assessments, frequently overlook significant factors that can impact the quality of the travel experience. This oversight increases the risk of traveler dissatisfaction and inefficient resource allocation.

Negative experiences may arise from various issues, such as unsatisfactory accommodations, unexpected expenses, safety concerns, cultural misunderstandings, and transportation inconveniences. For instance, selecting a destination without considering climatic conditions may result in adverse weather that can negatively affect a vacation. Inadequate research into the security

MoMLeT-2025: 7th International Workshop on Modern Machine Learning Technologies, June, 14, 2025, Lviv-Shatsk, Ukraine

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situation of a region may jeopardize the traveler's safety and well-being. Furthermore, a lack of access to essential infrastructure or language barriers can present additional challenges for travelers.

Negative aspects can not only diminish the travel experience but may also have lasting repercussions, impacting an individual's psychological well-being and financial situation. In light of the increasing competition within the travel industry and rising consumer demand, it is essential to provide travelers with the tools necessary to make well-informed decisions regarding their destinations.

Addressing these challenges necessitates the systematization of information and the development of methods aimed at minimizing the risk of negative experiences. This approach enhances travel satisfaction and ensure more efficient resource utilization, a pressing concern in today's environment.

This study focuses on the decision-making process involved in selecting the optimal travel location through a multi-criteria assessment. This process entails analyzing and evaluating various tourist destinations based on an array of criteria, including cost, safety, climate, and cultural or historical attractions. The complexity of this choice arises from the vast amount of information available and the need to consider diverse factors that influence the quality of travel. Investigating this process is crucial to improving the efficiency of travel planning and addressing the needs of contemporary travelers.

2. Analysis of the current state and prospects in the field of research

2.1. Current state and trends of tourism development regarding information technologies

Tourism, as one of the most dynamic sectors of the global economy, continues to grow rapidly, stimulating social and economic development. According to the World Tourism Organization (UNWTO), in 2019, the number of international tourist arrivals reached a record 1.5 billion, which is 4% more than in the previous year [1, 2]. This demonstrates the growing interest of people in traveling and discovering new cultural and geographical spaces.

An important factor contributing to this growth is the development of information technologies. The Internet and mobile technologies have changed the way people plan and travel. According to a Phocuswright study, in 2020, more than 65% of travel bookings worldwide were made online [3]. This indicates that digital platforms have become key tools for finding information, comparing prices, and booking services.

Social media also plays an important role in shaping travel trends. Reviews and recommendations from other travelers influence potential tourists' decisions about choosing a destination. A study by Lim and colleagues found that more than 80% of tourists pay attention to online reviews before booking a hotel or tour [4]. This shows the growing importance of collective experience and opinion in the decision-making process.

Digitalization has led to a change in consumer behavior in the travel industry. Modern tourists expect quick access to information, personalized offers, and convenient booking methods. According to a study by Amadeus, 53% of travelers want to receive individualized recommendations based on their preferences [5]. This encourages companies to implement modern technologies such as artificial intelligence and machine learning to analyze customer data and create personalized services.

The development of mobile applications has also had a significant impact on the travel industry. Mobile technologies allow tourists to plan trips, book tickets, and hotels, and get real-time destination information. For example, in 2019, about 38% of all travel bookings in the UK were made via mobile devices [6]. This emphasizes the importance of mobile optimization of services to meet the needs of modern travelers.

Information technology has also contributed to the emergence of new business models in tourism. Sharing platforms such as Airbnb and Uber have changed the traditional approach to accommodation and transportation. These services provide alternative options that are often more flexible and cost-effective for consumers. The number of Airbnb users worldwide exceeded 150 million in 2018 [7], indicating these platforms' significant impact on the travel market.

However, despite positive trends, the travel industry also faces challenges. Information overload caused by the large number of available online resources can complicate the decision-making process. Tourists often have difficulty processing and analyzing a large amount of information, which can lead to stress and dissatisfaction with the choice [8]. This emphasizes the need to develop tools and systems that help consumers effectively evaluate alternatives and make informed decisions.

In addition, the rapid development of technology requires travel companies to constantly adapt and innovate. According to a Deloitte report, companies that actively use digital technologies have a competitive advantage and demonstrate higher customer satisfaction [1].

It is impossible not to mention that the coronavirus pandemic has made adjustments to global tourism, leading to an unprecedented decline in the industry [9]. According to the World Tourism Organization (UNWTO), in 2020, international tourist arrivals decreased by 74% compared to 2019, bringing the figures back to the level of the 1990s [10]. This was the largest decline in the history of modern tourism, caused by border closures, travel restrictions, and a general decline in consumer confidence. The pandemic has forced travel companies to review their business models and adapt to new realities. There is a need to develop safe and flexible offers for customers. In 2021, there was a gradual recovery in the industry, but the level of international travel was still well below pre-crisis levels [11]. According to experts, the full recovery of international tourism may take several years, depending on vaccination's success and restrictions lifting [12].

In Ukraine, the situation was further complicated by the full-scale war that began in 2022. This has led to a decrease in interest in international travel among Ukrainians due to restrictions on border crossings, as well as restrictions on other countries' acceptance of Ukrainian tourists. Ukrainians' economy and financial situation played an important role in this issue. Nevertheless, despite the difficult circumstances, domestic tourism in Ukraine has begun to gain popularity. Many Ukrainians began to discover attractive destinations within the country, which spurred a new wave of travel.

The increased interest in domestic tourism is driven not only by restrictions on foreign travel but also by the desire to support the national economy and local communities. Tourism operators and local authorities are actively working to improve infrastructure and services to meet the growing demand. Information technology plays an important role in this process by enabling travelers to easily find information about local attractions, book accommodations, and receive route recommendations.

Given these trends, the development of tools that help tourists choose the best locations for travel in the face of uncertainty and changing circumstances is particularly relevant. Decision support systems can be an important tool to improve the quality of the travel experience and help the industry grow in a challenging environment.

2.2. Analysis of existing tools and solutions for choosing tourist destinations

Today's market offers a wide range of software solutions and services that help travelers in the process of choosing tourist destinations. These tools greatly facilitate travel planning by providing users with access to a wealth of information about various locations, services, and reviews from other tourists.

One of the main categories of such services is online travel platforms that aggregate information about hotels, flights, excursions, and other services. They allow comparing prices, accommodation conditions, and availability of services in different places. For example, Booking.com [13] and Expedia [14] provide the ability to filter results by various parameters, which makes it easier to find the best option. These services rely on large databases that are constantly updated, ensuring that the information is up-to-date and reliable.

Another important category is recommender systems that help travelers choose destinations based on the experience of other users. Services such as TripAdvisor [15] provide access to a large number of reviews and ratings, which allows one to assess the popularity and quality of tourist attractions. These platforms are based on a crowdsourcing approach, where content is created by users themselves, which adds credibility and objectivity.

Social media and traveler communities also play a significant role in the choice of tourist destinations. Platforms such as Instagram and Facebook allow users to share photos and travel experiences, which influences the choices of other travelers. Many tourists use hashtags and geolocation to find interesting places and get inspiration for future trips.

The development of mobile applications has greatly simplified access to information and services in the tourism sector. Apps such as Google Maps [16] and Maps.me [17] provide the ability to plan routes, find attractions, and get recommendations for local establishments. They provide access to the necessary information anytime and anywhere, making the travel planning process more flexible and convenient.

Some services use virtual and augmented reality technologies to provide users with a preview of the location. This helps to get a more complete picture of the destination and make a more informed choice. For example, the Street View feature in Google Maps allows you to "walk" the streets of cities before you actually travel.

In general, existing software solutions and services are aimed at simplifying the process of choosing tourist destinations by providing access to a large amount of information and tools for analyzing it. They are based on modern data processing, artificial intelligence, and user experience technologies to meet the diverse needs of travelers.

In order to better understand the current state of the market and identify opportunities for improving the process of choosing tourist destinations, we conduct a comparative analysis of several popular services, namely Booking.com, TripAdvisor, Airbnb [18], Kayak [19]. The selected tools are be evaluated according to a number of criteria, such as functionality, quality and volume of information, ease of use, personalization, support for multi-criteria analysis, and others. This allow us to identify their strengths and, importantly for us, weaknesses and understand what gaps exist and how they can be used for potential opportunities (Table 1).

Table 1
Comparison of popular services for tourists

Criterion	Booking.com	TripAdvisor	Airbnb	Kayak
Functional features	Booking hotels, apartments, flights, car rental	Reviews and ratings, search for hotels, restaurants, flights	Renting a house from owners, the experience of local residents	Search and compare flights, hotels, car rental
Quality and volume of information	Extensive database around the world, detailed descriptions and photos	A wide range of reviews, ratings, user photos	Detailed descriptions of accommodation, guest reviews, photos	Compare prices from different websites, get detailed flight information
Ease of use	Intuitive interface, mobile application	Somewhat complicated interface, mobile application	User-friendly interface, mobile application	Simple interface, mobile application
Personalization and recommenda-tions	Recommenda-tions based on previous bookings	Personalized recommendations of places and services	Preference-based recommendations of accommodation and activities	Minimal personalization based on user searches

Criterion	Booking.com	TripAdvisor	Airbnb	Kayak
Support for multi-criteria analysis	Filters by price, rating, amenities	Filters and sorting by various parameters	Filters by price, type of accommodation, amenities	Filters by price, time, airlines
Integration with other services	Integration with maps, email	Integration with maps, social networks	Integration with calendars, maps	Integration with other booking sites
Cost of use	Free for users	Free for users	Free for users, commission for owners	Free for users
Multi-platform compatibility	Website, add-ons for iOS and Android	Website, add-ons for iOS and Android	Website, add-ons for iOS and Android	Website, add-ons for iOS and Android
Geographical coverage	Globally	Globally	Global, mostly in urban areas	Globally
Language support	Multilingual, including Ukrainian	Multilingual, including Ukrainian	Multilingual, partial support for Ukrainian	Multilingual, partial support for Ukrainian
Security and privacy	Secure payments, privacy policy	Secure payments, privacy policy	Secure payments, feedback, and verification system	Secure payments, privacy policy
User reviews and ratings	A large number of reviews and ratings	Focus on reviews and ratings	Guest reviews, rating system	Fewer reviews, focus on price offers

To summarize the comparison, we can say that each of the services in question offers a wide range of features that greatly facilitate various aspects of travel planning. They do an excellent job of their main tasks: booking accommodation, providing reviews and recommendations, finding favorable price offers, and providing a unique experience. Each of them has carved out its own market niche and has become an indispensable tool for millions of travelers around the world, but when it comes to choosing the best location for a trip, taking into account multiple criteria at the same time, none of these services is a perfect solution; they tend to focus on specific aspects of travel or offer limited opportunities for comprehensive analysis of destinations. For example, Booking.com and Airbnb specialize in booking lodging but do not provide a detailed comparison of destinations based on criteria such as safety, cultural features, or climate conditions. TripAdvisor offers reviews and ratings, but information overload and subjectivity of ratings can complicate the decision-making process. Kayak focuses on finding the best price offers but does not take into account other important factors that may affect the choice of travel destination.

2.3. Examples of using multicriteria decision-making in similar tasks

In today's complex landscape, decision-making increasingly requires consideration of a diverse range of criteria. This complexity is particularly evident in areas where decisions significantly affect economic, social, or environmental factors. Multi-criteria decision-making (MCDM) offers a structured and objective approach to evaluating alternatives based on multiple criteria simultaneously. This methodology enhances the decision-making process by fostering informed and transparent outcomes, thereby minimizing subjectivity and potential errors.

MCDM methods enjoy widespread application across various industries, including economics, ecology, engineering, project management, and more. They are instrumental in addressing intricate problems that necessitate a holistic view, allowing for the optimal balancing of numerous aspects. Among the widely recognized methods of multicriteria analysis are the Analytic Hierarchy Process (AHP), the Elimination and Choice Expressing Reality (ELECTRE) method, the Preference Ranking

Organization Method for Enrichment Evaluations (PROMETHEE), and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).

The TOPSIS method stands out as one of the most effective and user-friendly approaches to multi-criteria decision-making. It is predicated on identifying the alternative that is closest to the positive ideal solution while also being nearest to the negative ideal solution. This framework enables the evaluation and ranking of alternatives based on each criterion's weighted importance. To demonstrate the effectiveness of the TOPSIS method in addressing complex problems, we can reference the study conducted by Sánchez-Lozano J.M., García-Cascales M.S., and Lamata M.T. In their research titled "Evaluation of Suitable Locations for the Installation of Solar Thermoelectric Power Plants," the authors aimed to identify the optimal site for a solar thermoelectric power plant. They highlighted how the integration of geographic information systems (GIS) with multi-criteria decision-making methods, such as TOPSIS and AHP, serves as a powerful tool for solving complex siting issues.

The study focused on the coastal region of Murcia in southeastern Spain. By leveraging GIS, the researchers established a comprehensive database that formed the foundation for developing a decision support system. They applied various constraints to refine the study area and identified criteria influencing the decision-making process, which included both quantitative (numerical values) and qualitative (notations and linguistic variables) factors.

The authors utilized the Analytic Hierarchy Process (AHP) to assess the significance of each criterion, drawing on expert opinions to determine their relative importance. Following this, they employed the fuzzy TOPSIS method to evaluate potential locations, accounting for the uncertainty and fuzziness of data frequently encountered in real-world situations.

The results obtained through the TOPSIS method were compared with those derived from the ELECTRE-TRI methodology, another prominent approach in multicriteria analysis. This comparison allowed us to assess the reliability and consistency of the findings, thereby enhancing the decision-making process.

The study revealed that the integration of Geographic Information Systems (GIS) and Multi-Criteria Decision-Making (MCDM) methods serves as a robust tool for addressing complex site selection challenges. Employing the TOPSIS method facilitated an objective evaluation of the alternatives, enabling us to identify the most suitable location for a solar thermal power plant while considering various criteria and their respective weights. This methodology contributes to the more efficient and rational use of resources, which is crucial for sustainable development and environmental safety.

In the context of our broader interests, specifically in transport and tourism, these multi-criteria decision-making methods continue to demonstrate their effectiveness in tackling intricate problems related to system planning and optimization. The study "Intermodal travel planning and decision support integrated with transportation and energy systems," conducted by Weng Y., Zhang J., Yang C., and Ramzan M. [21], highlights the application of the TOPSIS method for prioritizing public transport development projects in the face of rapid urbanization in China.

The authors highlight the significance of identifying sustainable solutions that are both integrated and energy-efficient, particularly in light of the increasing economic and environmental challenges. In the context of a continuously evolving urban landscape, they recommend three initiatives to enhance public transportation: the introduction of "electric municipal buses," the establishment of a "light rail system," and the "modernization and optimization of the existing fleet." A multi-criteria approach was employed to prioritize these projects, factoring in economic, social, and environmental sub-criteria related to transportation.

To inform strategic decision-making, the authors utilized the Analytic Hierarchy Process (AHP) method to assess the relative importance of various sustainability criteria. Subsequently, they applied the fuzzy TOPSIS method to rank the alternative projects, effectively addressing the uncertainty and ambiguity often encountered in urban planning scenarios.

The study's findings indicated that adopting hybrid vehicles positively contributes to environmental sustainability, while non-hybrid vehicles tend to have an adverse effect. Notably, energy consumption in public transportation poses a significant barrier to sustainable development across three transport modes: taxis, railways, and buses. Additionally, computerized trains have demonstrated their effectiveness in promoting environmental sustainability, thereby helping to safeguard both current and future generations from environmental degradation [20, 21].

When examining specific examples within the tourism sector, it is essential to consider studies that directly tackle hotel selection using the TOPSIS method. These studies present innovative approaches to the hotel selection dilemma and utilize modified multicriteria analysis techniques [22, 23].

The research conducted by Kwok and Lau [22] highlights that while travelers typically contemplate a broad array of factors when choosing accommodations, most online booking platforms do not enable users to actively articulate their preferences for selection criteria, hindering the receipt of personalized recommendations. Consequently, tourists often expend additional effort and time comparing hotel options independently. To address this issue, the authors propose a decision support algorithm known as Vague Set TOPSIS, which assists travelers in ranking hotel choices effectively.

Their findings indicate that the structure and assumptions of traditional TOPSIS methods fall short in this context, as they fail to account for the uncertainty and subjectivity inherent in the hotel selection process. As a result, the authors recommend significant modifications to classic TOPSIS models, enhancing their applicability for hotel selection. The validity of the proposed algorithm was demonstrated through mathematical proofs, computer stochastic simulations, and a numerical example utilizing data from Hotels.com.

The study conducted by Wu and colleagues [23] examines the impact of online reviews on hotel selection, highlighting that this decision often relies on layman's judgment. Online reviews offer travelers valuable insights into hotels and destinations they have not previously visited. While many studies develop decision-making models based on these reviews using subjective criterion weights, they often overlook the objective weights derived from the assessments of opinion leaders, which can affect the reviews' overall usefulness.

This study presents a decision-making model for selecting satisfactory hotels based on online reviews. First, the RFMP model is employed to extract online reviews from opinion leaders, and the Word2Vec method is used to identify criteria from these reviews. Objective weights for the criteria are determined using the opinion leaders' reviews analyzed through Word2Vec, while subjective weights are established through the Best Worst Method (BWM). By combining these weights, the total weight of the criteria for hotel selection is established, which then informs the selection process according to the TOPSIS method. The proposed model was tested through a study involving eight alternative hotels listed on the Mafengwo.com platform, along with comparative experiments and sensitivity analysis.

Both studies aim to improve the hotel selection process using modified TOPSIS methods but approach the issue from different angles. Kwok and Lau [22] focus on adapting the TOPSIS method itself to better address the uncertainty and subjectivity inherent in travelers' preferences. They make structural changes to the classical algorithm, leading to the creation of the Vague Set TOPSIS, which more accurately reflects the decision-making process involved in hotel selection. In contrast, Wu and colleagues [23] emphasize the role of online reviews, particularly those from opinion leaders, in determining the weight of hotel selection criteria. They integrate objective weights obtained from review analyses using Word2Vec with subjective weights determined via the BWM method. This dual approach takes into account both the collective opinions of experts and individual user preferences. By employing the TOPSIS method in this context, the study aids in ranking hotels based on a defined set of criteria, ultimately facilitating a more informed choice for travelers.

Both studies illustrate the effectiveness of the TOPSIS method when combined with other techniques and technologies to address complex challenges in the tourism sector. They highlight the significance of considering multiple factors and tailoring models to the specific nuances of the issues at hand. While Kwok and Lau [22] concentrate on refining the algorithm to enhance its application, Wu et al. [23] incorporate big data analysis and machine learning to determine criteria weights that accurately reflect current trends and user preferences.

Consequently, both approaches complement one another and suggest promising possibilities for merging the TOPSIS method with contemporary technologies to enhance the decision-making process in tourism. Given that the later article builds partially on the findings of the earlier one, it is evident that research in this field is evolving actively, producing increasingly effective and innovative solutions.

These examples illustrate that the application of multi-criteria decision-making methods, such as the TOPSIS method, in conjunction with contemporary data analysis technologies, can greatly enhance the quality of services within the tourism industry. This highlights the importance and practicality of further research and development of decision support systems aimed at selecting travel locations using the TOPSIS method.

3. Developing the conceptual model

The increasing number of tourist destinations and the vast amount of available information present significant challenges for travelers when selecting the ideal trip location. Many face the dilemma of information overload while trying to evaluate numerous options based on various criteria, including cost, safety, climate, and cultural attributes, among others.

There is a pressing need to develop a system that simplifies the process of identifying and choosing the optimal travel destination, aiding individuals in making informed decisions through an objective assessment of various tourist locations. The primary goal includes creating a tool that accommodates the needs and preferences of travelers while offering a thorough and efficient evaluation of alternative destinations.

The proposed application enables travelers to easily and effectively select the best location for their journey by allowing them to customize personal preferences and criteria, receive tailored recommendations, and explore detailed options. To successfully implement this system, it is crucial to define its key components and their interactions.

The system uses the following **input data**: Destination Data – information regarding locations, encompassing geography, climate, attractions, infrastructure, safety, and more; Evaluation Criteria – a comprehensive list of factors to assess destinations, such as cost, climate, safety, cultural attributes, and others; Criteria Weights – values that indicate the importance of each criterion to the user.

Output Data. The system generates the following results: A ranked list of tourist destinations – locations organized based on their alignment with the specified criteria and user priorities; Detailed information about each destination – in-depth data regarding the location, including an analysis of its adherence to the criteria.

System Features: User Interface – a module facilitating user interaction, allowing the setup of criteria and the display of results; Data Collection and Processing Module – responsible for acquiring and updating information on tourist destinations; Multi-Criteria Analysis Module – utilizes the TOPSIS method to evaluate and rank locations effectively.

Functional Requirements. The system must provide customizable criteria, ensure the relevance and accuracy of location data, and enable swift query processing and result generation.

Non-Functional Requirements. The system should feature a user-friendly and intuitive interface, exhibit high performance and scalability, guarantee data security and confidentiality of user information, and ensure compatibility with various platforms and devices.

Database. A central repository for storing all relevant data.

By outlining these concepts and requirements, along with a clear problem statement and justification, we can better understand the purpose of developing the system, its significance for users, and the key aspects of its implementation. This foundation aid in the subsequent design and implementation of an effective decision support tool within the tourism sector.

3.1. Analysis of alternative implementation options

To identify the optimal approach for developing a decision support system aimed at selecting a trip location, it is essential to explore various alternatives and assess them through morphological analysis.

In the initial phase, it is crucial to pinpoint the primary characteristics of the system that can be adjusted, as these influence its functionality and efficiency. These parameters shape the structure and capabilities of the forthcoming application and include factors such as the platform type, user interaction method, data sources, and more.

Once the key parameters are identified, we created a morphological table that outlines the potential options for each parameter. This table acts as a valuable tool for organizing possible combinations of system characteristics and lays the groundwork for generating alternative options. By utilizing a morphological table, we created various logical and practical combinations of parameters that represent different system options (Table 2). Each alternative should form a coherent concept that outlines a feasible approach to implementing an application with a specific set of characteristics.

Table 2
Alternative system options

Parameter	Alternative 1	Alternative 2	Alternative 3
Platform type	Web application	Mobile application	Cross-platform application
Method of interaction	GUI	Chatbot	Voice assistant
Source of data	Own database	Integration with API	Crowdsourcing
Method of analysis	TOPSIS	AHP	Combination of methods
Personalization	Fixed criteria	Customizable criteria	Automatic configuration
Integration	None	With booking services	With social networks
Monetization	Advertisement	Paid subscription	Freemium

To select the best alternative, it is essential to establish evaluation criteria that reflect the system's key requirements.

- User convenience;
- Data accuracy and relevance;
- Personalization options;
- Development and support costs;
- Monetization opportunities;
- Prospects for development and scalability.

We assessed each option based on defined criteria, assigning points on a scale that enables us to compare alternatives according to their adherence to established requirements. This scale, ranging from 1, which indicates the lowest compliance with a criterion, to 5, which signifies the highest, while subjective and not entirely precise, allows us to gauge the compliance level of each option effectively (Table 3).

This method facilitates a realistic comparison of alternatives, helping to identify the best choice based on a comprehensive set of criteria. The best option is Alternative 1, which involves developing a web application with a graphical interface that utilizes its own database for obtaining up-to-date location data. By employing the TOPSIS method for multi-criteria analysis and allowing for customized criteria, the application ensures high personalization and accuracy in its recommendations. Additionally, the absence of integration streamlines the development process, making it faster and easier. Monetization through advertising allows the application to be offered for free to users, helping to attract a broader audience.

Table 3
Assessment of alternative systems

Criterion	Alternative 1	Alternative 2	Alternative 3
User convenience	5	3	4
Data accuracy	5	3	3
Personalization	4	2	5
Cost of development	3	4	2
Monetization potential	4	3	5
Development prospects	5	3	4
The sum of points	**26**	**18**	**23**

3.2. Use case diagram

Using UML diagrams in system and product planning is essential for successful software development and implementation. UML (Unified Modeling Language) is a standardized modeling language that enables the creation of visual representations of various aspects of a system, including its structure, behavior, and the interactions among its components. This fosters a deeper understanding of the system's requirements and architecture among both development team members and stakeholders.

One of the primary UML tools utilized to model user interactions with the system is the Use Case Diagram. This diagram graphically illustrates the system's functionalities available to different user categories. A use case diagram helps identify and describe the primary scenarios in which the system will be used, which is vital for defining its functional requirements Furthermore, the use case diagram serves as a foundational element for more detailed system modeling, including the development of sequence diagrams, class diagrams, and other UML diagram types, thus providing a comprehensive and integrated understanding of the system's architecture and functionality.

To gain a clearer insight into user interaction scenarios, we have created simple use cases for our application. The system features two actors: "User" and "Administrator" (Figure 1).

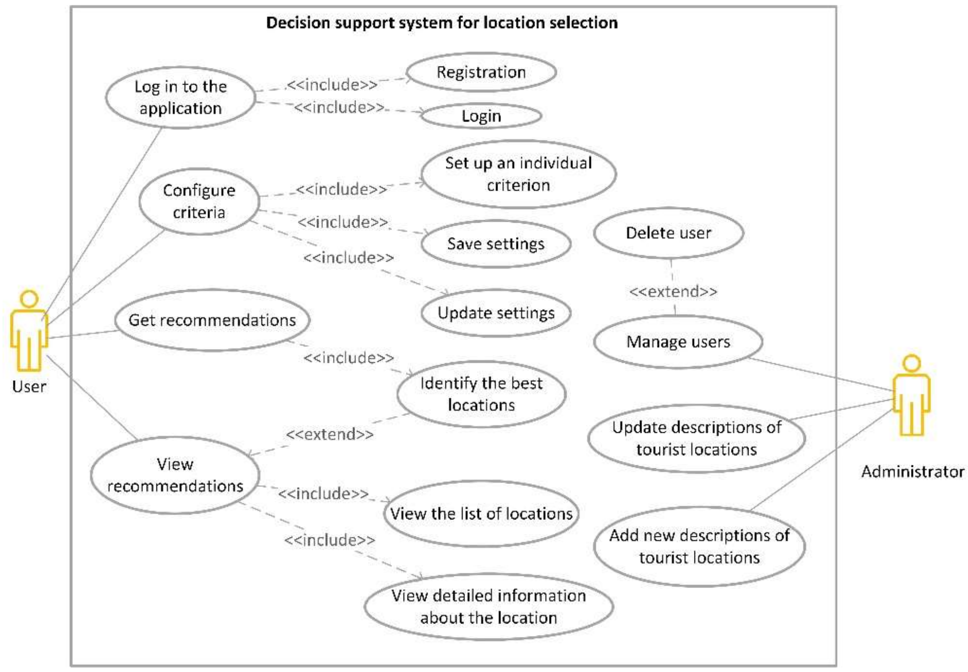

Figure 1: Use case diagram

A "User" refers to an individual who has successfully logged into the system. Upon accessing the application, they enter their credentials, including their login and password, to enter the system. This process ensures both security and personalization of the user experience, allowing them to save their preferences and interaction history. The "User" has the capability to define and customize the criteria for evaluating travel destinations. This includes creating and saving specific settings, as well as modifying them according to their current needs. The user can edit particular evaluation criteria, such as travel costs, safety, climate conditions, and more, assigning varying degrees of importance to each. Once the criteria are customized, the user can save these settings for future use, enabling a quick application for each new recommendation request. They also have the option to update already saved criteria to align with new preferences or change travel plans. Furthermore, the "User" initiates the recommendation generation process by providing their predefined settings and criteria to the system, from which they receive the results. After obtaining the recommendations, the user can view them in a well-organized format, accessing a list of suggested locations along with detailed information about each destination.

The “User” sees an orderly compilation of tourist spots that align best with their criteria and priorities, allowing them to select a specific location for further details, including descriptions, photos, and other essential information to facilitate an informed decision.

An "Administrator" is a user responsible for configuring the decision support system and managing user accounts. They ensure that the database of tourist locations remains current by updating and editing their descriptions. The administrator has the authority to add new descriptions of tourist destinations based on the relevance of specific characteristics within tourism development areas.

3.3. Activity Diagram

An activity diagram serves as a tool to model business processes or workflows within a system. It illustrates the sequence of actions, conditional transitions, and parallel processes, showcasing how different activities interact to achieve a specific objective. The activity diagram is valuable for visualizing process logic, analyzing existing workflows, identifying potential optimization opportunities, and ensuring that team members and stakeholders maintain a clear understanding of the system's operations.

In the context of our decision support system designed to determine the best trip location, the activity diagram encompasses several key processes: user authorization, establishing criteria, saving those criteria, requesting a recommendation, processing the request, and displaying the results, along with a detailed view of individual locations (Figure 2).

This diagram effectively clarifies how users engage with the system at each stage, outlines the actions performed by the system to process these interactions, and illustrates how the results are communicated back to the user.

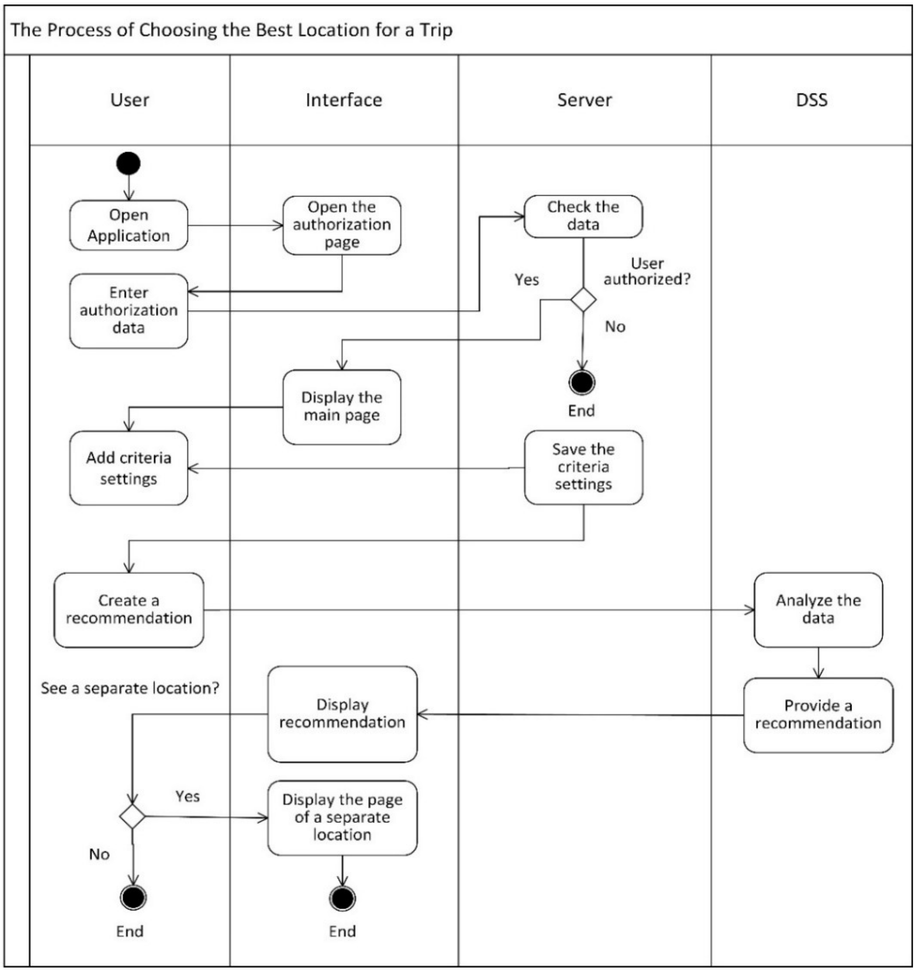

Figure 2: Activity diagram

4. Choosing and justifying methods for problem-solving

To develop an effective decision support system for selecting the ideal trip destination, it is essential to utilize methods and tools that offer an objective evaluation and ranking of tourist locations based on a predetermined set of criteria while also considering the user's individual preferences. The system should encompass key functionalities, including the collection and management of data on various tourist destinations, the ability for users to customize their evaluation criteria, multi-criteria analysis and ranking of options, as well as the presentation of results and provision of detailed information.

Multi-criteria tasks emerge as a result of a specific type of uncertainty known as goal uncertainty. In most cases, structuring this uncertainty leads to the creation of a goal tree, which facilitates the development of a set of quality criteria.

It is evident that among these criteria, some may change in one direction, while others may change in the opposite direction, or their effects may be partially similar and partially contradictory. In the absence of additional information, addressing a multi-criteria problem result in a set of non-dominated (Pareto optimal) alternatives. To narrow down this set, various rational principles of decision-making and selection are proposed, which inform the methods used to solve multi-criteria decision-making challenges.

Multicriteria decision analysis methods are utilized to choose the best option while considering various conflicting criteria. This approach is crucial in fields such as economics, finance, management, logistics, and others.

4.1. Methods without weighting factors

These methods do not necessitate the determination of criterion weights, thereby simplifying the analysis.

The **Pareto method** is based on the principle of selecting non-dominated alternatives for further consideration, known as the Edgeworth-Pareto principle [24]. According to this principle, the dominance relation among the set of admissible alternatives is formally defined as follows. Let A represent the set of potential solutions (alternatives): $x \in A,\ y \in A$. In the context of the criteria space, we consider the relation «≥». We define $Q(x) = (Q_1(x), \dots, Q_n(x))$ та $Q(y) = (Q_1(y), \dots, Q_n(y))$ as the vector evaluations of alternatives x and y, respectively. We further assume that $Q(x) \geq Q$ holds true if the following condition is met (1):

$$Q(x) \geq Q(y) \Rightarrow \forall\left(i = \overline{1,n}\right):\ \left(Q_i(x) \geq Q_i(y)\right) \wedge \exists\left(i = \overline{1,n}\right):\ \left(Q_i(x) > Q_i(y)\right), \tag{1}$$

in other words, the values of all criteria for alternative x are at least as good as those for alternative y, and furthermore, there exists at least one criterion where alternative x performs better than alternative y. In this scenario, alternative x is said to dominate alternative y according to Pareto, denoted as $x \succ_p y$.

The set of Pareto optimal (or efficient) solutions eff(A) is defined as (2)

$$P(X) = eff(A) = \{y \in A | \neg\exists(x \in A) : (x \succ_p y)\}, \tag{2}$$

an alternative y is classified as a Pareto-optimal alternative if, among all possible options, there is no other alternative that would dominate it according to the «≥» relation in the criteria space.

Only those Pareto-optimal alternatives are considered – those that cannot be improved in one criterion without causing a deterioration in another criterion. This principle serves to narrow down the set of possible solutions. However, a drawback of this method is that it often results in a large number of solutions from which a final choice still needs to be made.

The **lexicographic order method** [25] presents an approach for addressing multi-criteria problems by first ranking the criteria in descending order of importance. The most rigorous of these approaches is the lexicographic optimization method, where the criteria are ordered as $Q_1 \succ Q_2 \succ \dots \succ Q_n$. In this method, a series of optimization problems is solved, starting with Q_1. If the optimal value of the first criterion, Q_1^*, allows for the improvement of the next criterion, this improvement is implemented; otherwise, the process proceeds to the next criterion. This continues until all criteria have been evaluated. However, a notable drawback of this method is its rigidity. In many instances, achieving better values for subsequent criteria may not be possible, and there are cases where the decision-maker may accept a slight decline in the value of the current criterion if it leads to improvements in the subsequent ones.

4.2. Methods with weight factors

The **Weighted Sum Model** (WSM) is a multi-criteria decision-making method where different criteria or factors are evaluated with different weights depending on their importance for the chosen decision [26, 27]. In other words, there are several alternatives and the best alternative must be determined based on several criteria. The method involves assigning positive real values, called weights, to each alternative and then taking the weighted sum of the objectives. The weighted sum of the criteria values for each alternative is calculated:

$$S_i = \sum_{j=1}^{n} w_j \cdot x_{ij}, \tag{3}$$

where S_i represents the weighted sum of criteria values for the i-th alternative, where w_j denotes the weight, and x_{ij} indicates the criterion. The optimal alternative is the one with the highest value of S_i.

WSM helps to make a balanced decision, taking into account different aspects and the importance of each of them in a particular context, as well as adapting the weights of the criteria in accordance with changing conditions or requirements.

The main disadvantage of the method is the use only for criteria with the same scale. The choice of weights requires expert knowledge and can introduce a shift in the generated Pareto points. The method has subjectivity and complexity in determining the weight of the criteria, as well as sensitivity to changes in weight.

Weighted Product Model (WPM). In a manner similar to the previous approach, this method involves multiplying the values of the criteria [28-30] instead of adding them. The alternatives are assessed based on the product of the criteria, which helps eliminate issues related to units of measurement. For each alternative A_i, a generalized score is computed:

$$S_i = \prod_{j=1}^{n} x_{ij}^{w_j} \tag{4}$$

where S_i – alternative assessmentA_i ; x_{ij} – the value of the normalized alternative assessment A_i by the criterion C_j ; w_j – weighting coefficient of the criterion C_j ; n – total number of criteria.

A relative comparison approach eliminates the need for normalization. This method is beneficial when criteria are measured on different scales but are sensitive to shifts in weighting. If any criterion registers a value of zero, the overall score also result in zero. Additionally, the Weighted Product Model (WPM) is not suitable for scenarios involving a large number of criteria.

Multi-Objective Optimization Based on Ratio Analysis (MOORA) [31, 32] is a multi-criteria optimization method developed by Browers and Zavadskas in 2006, used to evaluate and rank alternatives based on various criteria.

A matrix is created in which: rows are alternatives $(A_1, A_2, ..., A_m)$; columns are criteria $(C_1, C_2, ..., C_n)$; elements x_{ij} – the values of alternative A_i according to criterion C_j.

A matrix is formed with alternatives $(A_1, A_2, ..., A_m)$ as rows and criteria $(C_1, C_2, ..., C_n)$ as columns. The elements x_{ij} represent the value of alternative $A_i$based on criterion C_j.

Each element is normalized by the formula (5):

$$x'_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{5}$$

where x'_{ij} – normalized value of the alternative A_i by the criterion C_j.

This is to ensure that the values of the criteria are comparable regardless of their units of measurement. The total score for each option is calculated as follows (6):

$$y_i = \sum_{j \in B} x'_{ij} - \sum_{j \in M} x'_{ij}, \tag{6}$$

where B – a set of criteria to be maximized; M – a set of criteria to be minimized.

The alternatives are arranged in descending order based on their values y_i, with the alternative that has the highest value identified as the best option. Subsequently, the adequacy of the results is evaluated. If needed, sensitivity analysis or additional methods can be employed to assess the stability of the solution. The method is deemed objective as it relies on mathematical calculations for the normalization and aggregation of criteria. MOORA is particularly versatile as it can simultaneously take into account both favorable and unfavorable criteria, making it suitable for a variety of tasks.

The **Graph Theory and Matrix Approach** (GTMA) is a method utilized to evaluate and rank alternatives based on multiple criteria [33, 34]. By representing the relationships among criteria and alternatives through directed graphs (digraphs) and corresponding matrices, GTMA offers a structured and quantitative framework for complex decision-making scenarios.

Key Components of GTMA:

- Directed Graph (Digraph): Alternatives and criteria are represented as nodes, with directed edges illustrating the relationships and influences among them.

- Adjacency Matrix: This matrix captures the connections between nodes, where each element indicates the presence and strength of a relationship between corresponding criteria or alternatives.
- Permanent Function: A mathematical function applied to the adjacency matrix to compute a single index value for each alternative, facilitating their ranking.

GTMA effectively models complex interrelationships among criteria and alternatives. Provides a clear numerical basis for ranking alternatives, enhancing objectivity. It can be integrated with other decision-making methods, such as the AHP, to improve accuracy and reliability.

4.3. Methods of distances to the reference solution

These methods evaluate how close each alternative is to the optimal (reference) solution.

The **Technique for Order of Preference by Similarity to Ideal Solution** (TOPSIS) [35-37] is a recognized method of multicriteria decision analysis that aids in selecting the best option from a set of alternatives. The alternative that is nearest to the ideal solution and farthest from the worst is chosen. In this process, there are m alternatives and n criteria. Each alternative is assessed against each criterion, resulting in a decision matrix. To ensure uniformity across the criteria, normalization is employed. Each criterion is assigned a weight, and the weighted values are subsequently calculated. In the following steps, the ideal and anti-ideal solutions are identified, and the distances to both the ideal and anti-ideal solutions are computed. The formula for determining relative proximity to the ideal solution is as follows (7):

$$C_i^* = \frac{S_i^-}{S_i^+ + S_i^-} \tag{7}$$

where C_i^* – is the relative proximity of the i-th alternative to the positive idealy; $0 \leq C_i^* \leq 1$; S_i^+ – is the distance of the i-th alternative to the positive ideal; S_i^- – is the distance of the i-th alternative to the negative ideal.

The alternatives are ranked in descending order of C_i^*, with the option showing the highest C_i^* deemed the best.

TOPSIS features a simple and straightforward implementation algorithm, taking into account both quantitative and qualitative criteria while allowing for the incorporation of weighting factors. However, the method has its drawbacks: it requires manual determination of the weights for the criteria, does not consider potential correlations between them, and is sensitive to the chosen data normalization approach.

The **Vise Kriterijumska Optimizacija I Kompromisno Rešenje** (VIKOR) [38] method is designed to identify a compromise solution that effectively balances multiple criteria. It employs a loss function for each criterion, focusing on finding the solution that is nearest to the ideal while considering conflicting criteria. To ensure comparability across different criteria, the method normalizes the results. VIKOR aims to maximize group utility (S) — representing the majority's benefit — while minimizing individual regret (R), which reflects the dissatisfaction of the least advantaged individuals. The method allows for the incorporation of various decision-making strategies by adjusting the parameter v, which signifies the decision-maker's preference for group utility over individual regret. For each alternative, the VIKOR index (Q) is calculated as a composite measure that integrates both S and R, along with the weight v. Alternatives are ranked in ascending order based on their Q values, with the alternative possessing the lowest Q value deemed the closest to the ideal solution. The highest-ranked alternative is proposed as a compromise solution if it aligns with the established preferences and sustainability criteria. If these conditions are not satisfied, a set of compromise solutions is presented, which includes the top-ranked alternative alongside other alternatives that have similar Q values.

VIKOR relies on the trade-off parameter, which can significantly influence the results based on how the criteria are weighted. Proper normalization of the criteria is essential to ensure accurate outcomes. In large-scale problems involving numerous alternatives and criteria, the calculations can become complex and time-consuming.

4.4. Methods based on pairwise comparisons

These methods utilize a pairwise comparison of alternatives.

The **Analytic Hierarchy Process** (AHP) [39-45] is a systematic approach grounded in a hierarchical representation of the elements that define the essence of the problem. This process involves decomposing the problem into simpler components, followed by an assessment of the relative degree of interaction among the elements within the resulting hierarchical structure. AHP is based on the principles of identity and decomposition, which entail organizing problems in the form of a hierarchy or network. It also includes procedures for synthesizing multiple statements, prioritizing criteria, and identifying alternative solutions. The hierarchical structure is established as follows: goal → criteria → alternatives. A matrix of pairwise comparisons is employed to evaluate the significance of criteria and the benefits of alternatives. For each row of the matrix, a geometric mean is calculated, and then all values are normalized (8):

$$W_i = \frac{\prod_{j=1}^{n} a_{ij}^{1/n}}{\sum_{k=1}^{n} \prod_{j=1}^{n} a_{kj}^{1/n}}, \tag{8}$$

where n – matrix dimension; a_{ij} – element of the pairwise comparison matrix.

This provides the weight of each criterion, indicating their relative importance.

The AHP defines priority vectors and assigns weights to various criteria. One drawback of this method is that expert opinions can be subjective. Nevertheless, AHP is a powerful tool for making complex decisions, particularly when multiple criteria need to be considered, and the selection process requires structured analysis.

Elimination and Choice Translating Reality (ELECTRE) [46-48] methods are employed to select, rank, or sort alternatives based on multiple criteria. The primary ELECTRE methods include ELECTRE I, an outranking method; ELECTRE II, a ranking method; and ELECTRE III, which incorporates fuzzy preference thresholds. These methods hinge on the concept of "preference ratio," enabling a comparison of alternatives not only in strict terms but also in the presence of uncertainty and compromise. For each of the n criteria, which are assumed to be numerical, a weight is assigned. This weight reflects the significance of each corresponding criterion, with a higher value indicating greater importance to the decision-maker. These weights can be determined by various approaches, such as ranking or utilizing the Saaty method. In its most straightforward application, each i-th criterion is assigned an integer p_i, representing the number of votes cast by a jury in favor of that specific criterion.

To evaluate whether alternative $x = (x_1, \dots, x_m)$ is superior to alternative $y = (y_1, \dots, y_m)$, with their respective representations in the criterion space being $Q(x) = (Q_1(x), \dots, Q_n(x))$and $Q(x) = (Q_1(y), \dots, Q_n(y))$, the following steps are undertaken.

The set of criteria Q is divided into three subsets: $Q^+(x,y)$, which defines the criteria by which option x is superior to y; $Q^=(x,y)$, which outlines the criteria by which x and y are equivalent; and $Q^-(x,y)$, which indicates the criteria by which y is superior to x. Corresponding to these subsets are the sets of indices $I^+(x,y)$, $I^=(x,y)$, and $I^-(x,y)$.

Subsequently, the relative importance of each of these subsets is established as $P_{xy}^+, P_{xy}^=, P_{xy}^-$. A specific threshold is determined, and option x is deemed superior to option y only if a particular function, referred to as the agreement index, meets the condition (9):

$$f\left(P_{xy}^+, P_{xy}^=, P_{xy}^-\right) \geq c. \tag{9}$$

where c – represents the agreement index.

The nature of the function f is established independently for each variation of the ELECTRE method. Condition (9) serves as a necessary, though insufficient, criterion for establishing the superiority of x over y. In the ELECTRE methods, additional criteria are formulated to consider not only the order in which x and y are assessed across the criteria but also the values of the absolute difference$|Q_i(x) - Q_i(y)|$. These criteria, referred to as the disagreement index, can be expressed in the form (10):

$$d_{xy} \leq d_1 , \tag{10}$$

where d_1 – represents the threshold value of the disagreement index d_{xy}, which is specifically defined for each variation of the ELECTRE method. By utilizing both the agreement and disagreement indices, the preference ratio R is then defined as follows (11):

$$xRy \Leftrightarrow \left(f\left(P_{xy}^{+}, P_{xy}^{=}, P_{xy}^{-}\right) \geq c\right) \wedge \left(d_{xy} \leq d_1\right). \tag{11}$$

ELECTRE I is a decision-making tool used to select the best alternatives from a set of possible solutions. Instead of creating a complete ranking, it focuses on eliminating options that are significantly worse than others. The process begins with constructing a decision matrix, where alternatives are evaluated according to specific criteria. Next, the values are normalized if the criteria have different scales. The next steps involve determining the concordance index for each pair of alternatives, followed by calculating the discordance index. Finally, alternatives are filtered, keeping only those with a high level of concordance and a low level of discordance. ELECTRE I is particularly useful when the goal is to identify the best alternatives without needing a precise ranking.

ELECTRE II is an extended version of ELECTRE I that allows for the construction of a partial or full ranking of alternatives. It follows all the steps of ELECTRE I, including creating the decision matrix, normalization, and checking for consistency or inconsistency. This method involves two consecutive rankings: the first ranks alternatives from best to worst, and the second does so in the reverse order (from worst to best). The two rankings are then combined to create a final order. ELECTRE II is beneficial when it's necessary to rank alternatives from best to worst rather than just eliminating the less suitable options.

ELECTRE III acknowledges the inherent vagueness and potential inaccuracies in defining criteria and their associated values. A key feature of this method is the incorporation of thresholds for indistinguishability, superiority, and strong preference: q (indifference) – if the difference between alternatives is less than q, they are regarded as nearly identical; p (superiority threshold) – if the difference exceeds p, one alternative is significantly preferable to the other; v (strong preference threshold) – this represents an even higher level of dominance. The method constructs a preference relation among alternatives based on these fuzzy thresholds. Consequently, a relational graph is generated, facilitating informed decision-making. ELECTRE III is particularly effective in complex scenarios where criteria may be obscure or where expert assessments are not precise.

4.5. Methods of fuzzy logic and artificial intelligence

These methods are employed when criteria are not clearly defined or involve subjective evaluations. Examples include Fuzzy AHP, Fuzzy TOPSIS, and neural networks. A common drawback of these approaches is the complexity involved in their implementation and the interpretation of the results.

Fuzzy AHP, or fuzzy hierarchy analysis, is an extension of the classical AHP that incorporates fuzzy set theory to address uncertainties and imprecision in decision-making. This approach enables a more flexible and accurate representation of experts' subjective judgments, particularly in situations where information is ambiguous or fuzzy [49, 50].

First, it is essential to identify the objectives, criteria, and alternatives that can be evaluated [51]. The process involves forming fuzzy pairwise comparisons, where experts conduct comparisons of criteria and alternatives using fuzzy numbers, typically triangular or trapezoidal, to account for uncertainty in their judgments. From these pairwise comparison matrices, fuzzy weights are derived for each criterion and alternative. These fuzzy weights are then aggregated to calculate overall scores for the alternatives based on the established criteria. Next, defuzzification occurs, wherein the fuzzy scores are converted into clear, precise values to facilitate interpretation and support final decision-making. The Fuzzy AHP method effectively addresses the inaccuracies and uncertainties inherent in expert opinions, thereby enhancing the reliability of the results. This approach can be applied across various domains where subjective judgments play a crucial role, such as strategic planning, risk management, and supplier selection. By incorporating fuzzy logic, the method helps mitigate the impact of subjectivity, enabling more informed decisions.

However, the use of fuzzy numbers can complicate mathematical computations and necessitates a solid understanding of fuzzy logic. Similar to classical AHP, the Fuzzy AHP method heavily relies on the quality and precision of expert judgments.

The **Fuzzy TOPSIS** method is an extension of the classical TOPSIS method that incorporates fuzzy logic to address uncertainties and inaccuracies in multi-criteria decision-making [52-54]. It is particularly useful in situations where expert opinions may be subjective and vague. The advantages of Fuzzy TOPSIS include its ability to account for uncertainty in expert opinions, the flexibility in selecting membership functions, and its relatively straightforward implementation compared to other fuzzy methods for multi-criteria decision-making. However, Fuzzy TOPSIS is highly dependent on the choice of membership functions and defuzzification methods, and it is also sensitive to the weighting coefficients.

A comparative analysis of various multi-criteria decision-making methods is provided in Table 4.

Table 4
Comparison of methods for multi-criteria decision making

Method	Simplicity	Use of scales	Scale sensitivity	Type of problem
Pareto	+++	-	-	Filtering solutions
Lexicographic	++	-	-	Clear prioritization
WSM	+++	+	+	Quantitative criteria
TOPSIS	++	+	+	Distance to the ideal
AHP	+	+++	+	Hierarchical solutions
ELECTRE	-	+	+	Pairwise comparisons

The analysis of problem-solving methods for selecting the optimal option while considering multiple conflicting criteria has allowed us to categorize these methods based on the complexity of the problem:

- for simple problems: use weighted sum or Pareto methods.
- for compromise choices: consider TOPSIS or VIKOR methods.
- for decisions based on expert opinions: apply AHP or ELECTRE methods.
- for problems involving fuzzy criteria: utilize Fuzzy AHP or neural networks.

4.6. TOPSIS method for selecting the optimal trip

To conduct an objective assessment and effective ranking of tourist destinations, we chose the TOPSIS multi-criteria decision-making method. This method was selected for its simplicity and clarity, its effectiveness with numerous criteria and alternatives, and its capacity to incorporate weighting factors. Additionally, TOPSIS has widespread applications in various fields, including tourism, which enhances the reliability and efficiency of our system. The system organizes knowledge about tourist destinations and evaluation criteria in structured data stored within a database. We utilize numerical values to represent weighting factors and criteria values, facilitating mathematical calculations. The logical conclusions are drawn through a sequential application of the TOPSIS algorithm, which involves steps such as normalizing the decision matrix, weighting the normalized data, identifying ideal and anti-ideal solutions, calculating distances to these solutions, determining relative proximity to the ideal solution, and finally ranking the alternatives.

The TOPSIS method allows for an objective evaluation and ranking of tourist destinations based on a specified set of criteria, incorporating individual user priorities. Let's explore how the TOPSIS method operates.

First, a decision matrix is created, where the rows represent the alternatives, and the columns denote the evaluation criteria.

Let us denote $A = \{A_1, A_2, \cdots, A_m\}$ as the set of alternatives, and $C = \{C_1, C_2, \cdots, C_n\}$, as the set of criteria. Let x_{ij} represent the value of the *j*-th criterion for the *i*-th alternative.

Thus, the decision matrix is illustrated as follows (12):

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{12}$$

Normalization is done to adjust different units of measurement to a single scale. The formula for normalization using the Euclidean metric is (13):

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \tag{13}$$

where r_{ij} – normalized value; x_{ij} – initial value of the criterion.

Each normalized value is multiplied by the corresponding criterion weight. w_j:

Each normalized value is multiplied by the corresponding weight of its criterion, denoted as w_j (14):

$$v_{ij} = w_j \cdot r_{ij}, \tag{14}$$

where v_{ij} – зважене нормалізоване значення; w_j – вага j-го критерію, $\sum_{j=1}^{n} w_j = 1$.

A positive ideal solution (PIS) (15):

$$V^+ = \{v_1^+, v_2^+, \cdots v_n^+\}, \tag{15}$$

where:

$$v_j^+ = \begin{cases} \max_i v_{ij}, & \text{if criterion } j \text{ is desirable (benefits);} \\ \min_i v_{ij}, & \text{if criterion } j \text{ is undesirable (costs).} \end{cases}$$

Negative ideal solution (NIS) (16):

$$V^- = \{v_1^-, v_2^-, \cdots v_n^-\}, \tag{16}$$

where:

$$v_j^- = \begin{cases} \min_i v_{ij}, & \text{if criterion } j \text{ is desirable (benefits);} \\ \max_i v_{ij}, & \text{if criterion } j \text{ is undesirable (costs).} \end{cases}$$

Distance to the positive ideal (17):

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2}, \tag{17}$$

distance to the negative ideal (18):

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2}, \tag{18}$$

where S_i^+ – is the distance of the i-th alternative to the positive ideal; S_i^- – is the distance of the i-th alternative to the negative ideal.

Calculating the relative proximity to a positive ideal (19):

$$C_i^* = \frac{S_i^-}{S_i^+ + S_i^-} \quad (19)$$

where C_i^* – the relative proximity of the i[th] alternative to the positive ideal; $0 \le C_i^* \le 1$.

The alternatives are ordered in descending order of importance C_i^*. The higher the value of C_i^*, the better the alternative.

In our decision support system for selecting the optimal location for a trip, we utilize the TOPSIS method to evaluate tourist destinations based on individual user preferences. The TOPSIS algorithm comprises seven steps.

Step 1. Formation of a decision matrix:

- The decision matrix is formed from the criteria and weights based on the user's settings.
- The system collects data x_{ij} for each alternative A_i according to the selected criteria.

Step 2. Normalization of the decision matrix using formula 2.

Step 3. Weighting of normalized values according to the formula 3.

Step 4. Identification of ideal solutions. The system determines the positive and negative ideal solutions V^+ and V^- based on the type of criteria (benefits or costs).

Step 5. Calculating distances to ideals: For each alternative, we calculate S_i^+ and S_i^- using formula 6 and 7, respectively.

Step 6. Calculating relative proximity: C_i^* is calculated using formula 8.

Step 7. Ranking and display of results. The system ranks the alternatives by C_i^* values and returns them to the user as a list of recommendations.

4.7. Example of TOPSIS method application

There are three criteria for evaluating tourist destinations: C_1 – travel cost (cost criterion); C_2 – safety (benefit criterion); C_3 – climatic conditions (benefit criterion).

Based on the «User's» preferences, the following weighting factors have been determined: $w_1 = 0.4$; $w_2 = 0.35$; $w_3 = 0.25$.

The system collects data for three alternatives: A_1 – Location 1; A_2 – Location 2; A_3 – Location 3.

The calculations are as follows:

1. Decision matrix: $\begin{bmatrix} x_{11} & x_{12} & x_{13} \\ x_{21} & x_{22} & x_{23} \\ x_{31} & x_{32} & x_{33} \end{bmatrix}$.
2. Normalization: $r_{ij} = \frac{x_{ij}}{\sqrt{x_{1j}^2 + x_{2j}^2 + x_{3j}^2}}$.
3. Weighted normalized values: $v_{ij} = w_j \cdot r_{ij}$.
4. Calculating V^+ and V^-:

- for the cost criterion (C_1): $v_1^+ = \min_i v_{i1}$, $v_1^- = \max_i v_{i1}$;
- for the benefit criterion (C_2, C_3:): $v_j^+ = \max_i v_{ij}$, $v_j^- = \min_i v_{ij}$.

5. Calculation S_i^+ and S_i^-: $S_i^+ = \sqrt{\sum_{j=1}^{3} (v_{ij} - v_j^+)^2}$, $S_i^- = \sqrt{\sum_{j=1}^{3} (v_{ij} - v_j^-)^2}$.
6. Calculation C_i^*: $C_i^* = \frac{S_i^-}{S_i^+ + S_i^-}$.
7. Ranking.

5. Overview of the prototype implementation for the information system

Now we can illustrate how we integrated the selected methods and tools to develop a functional application that meets user requirements and effectively operates the TOPSIS algorithm in a real-world environment. Our discussion covers technical aspects of the implementation [55, 56], such as the database structure, the features of working with the Supabase platform, the integration of the TOPSIS algorithm using Python and AWS, and the creation of an intuitive interface using React and TypeScript.

5.1. Database structure

Supabase was utilized for backend and database management. It is an open-source Backend-as-a-Service (BaaS) platform that provides instant APIs and real-time functionalities, built on PostgreSQL. Supabase simplifies database management by offering an intuitive interface that seamlessly integrates with front-end applications. It was selected for its ability to deliver a scalable and secure database solution without requiring extensive infrastructure management. Since Supabase is built on PostgreSQL, it benefits from PostgreSQL's reliability and advanced features, including support for complex queries and transactions.

The database structure is a crucial system component, as it dictates how data is stored, organized, and accessed for processing. A well-designed database ensures efficient application performance, quick information retrieval, and support for the complex operations required to implement the TOPSIS algorithm, which ultimately provides users with accurate and personalized recommendations. The database architecture is designed to facilitate efficient storage and rapid access to data related to users, their preferences, evaluation criteria, and information about tourist locations (Figure 3).

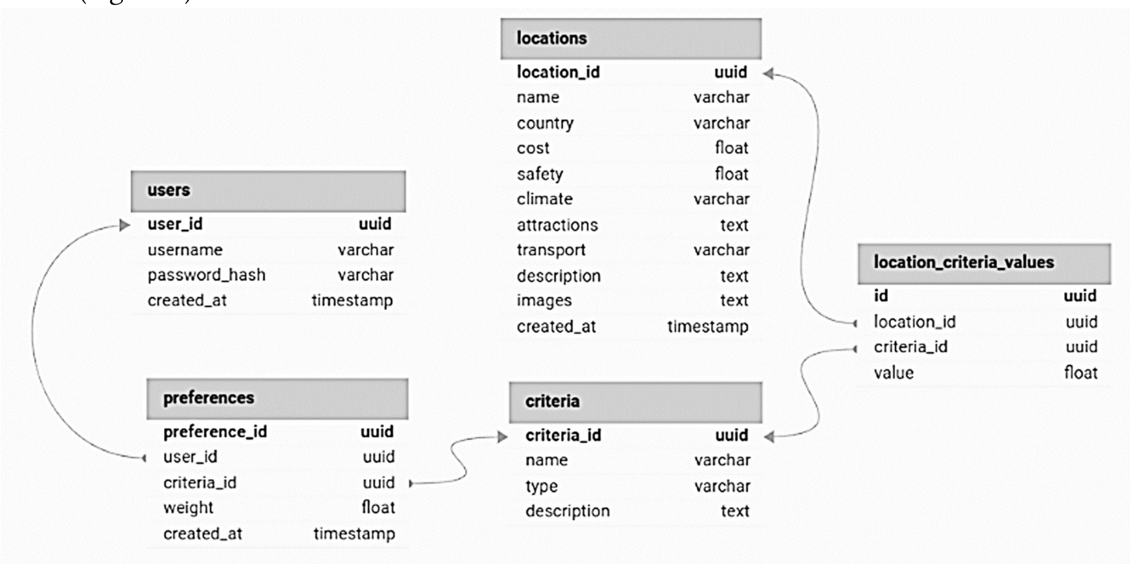

Figure 3: Database structure

Users Table: stores information about system users. Columns include: user_id (PRIMARY KEY) – a unique user identifier (UUID); username – a unique user login (VARCHAR); password_hash – a hash for secure password storage (VARCHAR); created_at – the date and time of account creation (TIMESTAMP).

Preferences Table: This table stores the criteria settings for each user. Columns: preference_id (PRIMARY KEY) – a unique identifier for each preference (UUID); user_id (FOREIGN KEY) – a reference to the user in the users table; criteria_id (FOREIGN KEY) – a reference to the criterion in the criteria table; weight – the weight of the criterion as set by the user (FLOAT); created_at – the date and time when the preference was created (TIMESTAMP).

Criteria Table (contains a list of possible criteria for evaluating locations): criteria_id (PRIMARY KEY) – a unique identifier for the criterion (UUID type); name – the name of the criterion (VARCHAR type); type – the type of criterion, which can be either "benefit" or "cost" (VARCHAR type); Description – a detailed description of the criterion (TEXT type).

Locations Table (stores information about tourist locations): location_id (PRIMARY KEY)– aunique identifier for the location (UUID type); name – the name of the location (VARCHAR type); country – the country where the location is situated (VARCHAR type); cost – the cost of traveling to the location (FLOAT type); safety – the safety level of the location (FLOAT type); climate – the climatic conditions at the location (VARCHAR type); attractions – adescription of cultural attractions available at the location (TEXT type); transport: An evaluation of transportation infrastructure (VARCHAR type); description – acomprehensive description of the location (TEXT type); images: URLs of images depicting the location (TEXT[] type); created_at – the date and time when the location was added (TIMESTAMP type).

Location_Criteria_Values Table (stores the criterion values for each location): id (PRIMARY KEY) – aunique record identifier (UUID type); location_id (FOREIGN KEY) – a reference to the corresponding location in the locations table; criteria_id (FOREIGN KEY) – a reference to the corresponding criterion in the criteria table; value – the value of the criterion for this location (FLOAT type).

The choice of this database structure was motivated by the need for efficient data storage and access to support the TOPSIS algorithm and deliver a personalized user experience. The PostgreSQL relational database, which underpins Supabase, offers the necessary reliability, scalability, and support for complex queries essential for processing multi-criteria data.

The tables are designed to minimize data duplication and ensure database integrity. By using foreign keys and establishing well-defined relationships between tables, we maintain data consistency and simplify the processes for selecting and updating information.

5.2. TOPSIS algorithm

The TOPSIS algorithm was implemented using the Python programming language, which offers flexibility and ease of integration with other web application components. The implementation is organized within the TOPSIS class that includes methods corresponding to various stages of the algorithm. These stages involve normalizing the decision matrix, determining weights, identifying the ideal and negative ideal solutions, calculating distances to these ideal solutions, and ranking the alternatives.

To ensure high availability and scalability, the TOPSIS algorithm was deployed separately on a server hosted in the Amazon Web Services (AWS) cloud infrastructure. This approach has several significant advantages. First, AWS cloud services make it easy to scale computing resources depending on the load, which ensures stable operation of the application as the number of users increases. Secondly, the use of cloud infrastructure guarantees high service availability and minimal downtime due to the distributed architecture and automatic disaster recovery. In addition, AWS offers a wide range of tools to ensure data security, including encryption, access control, and security monitoring. Placing the algorithm on a separate server also makes it easy to integrate it with other components of the web application via APIs, which simplifies system development and maintenance. Finally, the use of cloud services allows you to optimize the cost of maintaining and updating server hardware, as AWS takes care of most operational tasks.

5.3. Web application

The web application plays a key role in ensuring that the decision support system is accessible and easy to use for a wide range of users. An intuitive and efficient user interface makes it easy to interact with the application, customize selection criteria, receive recommendations, and view detailed location information. High-quality UI design improves user experience, increases user satisfaction, and promotes more active use of the application, which ultimately leads to the achievement of system goals and satisfaction of users' travel planning needs.

The web application was developed using the React front-end framework and the TypeScript programming language, with Supabase and AWS integration to provide back-end functionality. Supabase is used for user authentication and database management based on PostgreSQL. It stores user data, their criteria settings, and location information. The TOPSIS algorithm, implemented in Python, was hosted on a server in the AWS infrastructure. The interaction between the application, Supabase, and AWS is as follows: the front-end application accesses Supabase for authentication and access to the database, while the TOPSIS algorithm is used to receive recommendations via an HTTP request to AWS. This ensures load balancing and improves system performance, as the algorithm's computational tasks are performed separately from the main application.

The following main libraries were used to implement the application functionality:

- **Axios** is a library for executing HTTP requests used to communicate with Supabase and AWS backend servers. It simplifies data exchange between the front-end and server components by providing asynchronous request and response processing.
- **Material-UI** (MUI) is a set of components for React that simplifies user interface development. MUI offers ready-made stylized components and themes that enable you to quickly create a modern and intuitive UI quickly without having to write your styles from scratch.
- **React Router DOM** is a library for routing in React applications that facilitates navigation between different pages of an application.ion.

5.4. Application functionality

The application's functionality includes the ability to log in using user credentials provided through integration with Supabase. Users can customize and save their criteria for selecting locations with an interactive slider that features multiple components. This slider allows setting weights for different criteria such as cost, safety, climate, transportation, and cultural attractions. Above the slider is a pie chart that visually displays the ratio of the set weights, helping users better understand and customize their priorities. After adjusting the criteria, users can save their settings for future use. Once the user has established the desired criteria, the app sends a request to the TOPSIS algorithm on AWS, passing the user's settings. The algorithm processes the data and returns a list of recommended locations ranked by their degree of compliance with the specified criteria. The results are displayed in a convenient format, where each location includes basic information such as name, image, and similarity to the user's preferences.

Users can view detailed information about each location by clicking on it from the list of recommendations. The detailed information page provides advanced data, including a detailed description, photo, and other relevant information. This helps users to make more informed decisions about choosing a travel destination.

As a result, the developed application provides a full cycle of interaction from setting personal priorities to receiving personalized recommendations and getting to know the selected locations in detail. Integration with Supabase and AWS provides a reliable and scalable platform for storing data and processing complex computations, and the use of modern libraries contributes to the creation of a convenient and attractive user interface.

5.5. Analysis of the results obtained

The analysis of the web application performance is based on the example of key screens that demonstrate the main functionalities and user interaction with the system. To access the application, users can enter their credentials (login and password). If an incorrect password is entered, an error message is displayed, informing the user of the need to verify the entered data. For a new user, the first step in using the application is to configure the criteria. For an ordinary user, it is possible to change the criteria settings or start the algorithm execution.

The screenshot of the criteria setting screen shows an interactive slider and a pie chart that allow users to set and visualize the weights of different location selection criteria (Figure 4a).

A screenshot of the results screen shows a list of recommended locations organized by the degree of compliance with the established criteria (Figure 4b).

Finally, a screenshot of the individual location screen shows detailed information about the selected location, including a description, photos, and ratings (Figure 4c).

A step-by-step control example of using the application from the user's point of view confirmed the effectiveness and functionality of the developed system. The user was able to seamlessly log in to the application, set up criteria, receive personalized recommendations, and view detailed information about the selected locations.

This shows that the system not only meets the requirements but also really helps users in the process of travel planning. The system provides an effective solution to the problem of choosing the best location for a trip, combining modern technologies with innovative methods of multi-criteria analysis.

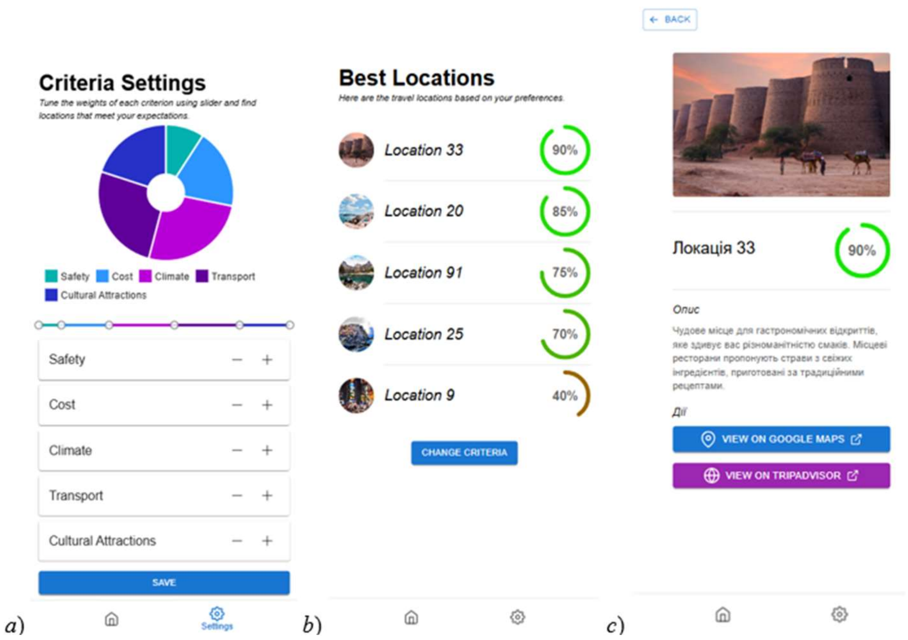

Figure 4: The screenshot of the criteria setting screen: a) setting up criteria, b) search results, c) description of an individual location

6. Conclusions

This article presents a decision support system for choosing the optimal location for travel based on the TOPSIS method. The aim of the study was to create a tool that enables users to make informed decisions based on their individual preferences and a set of criteria.

An important component of the development process was the use of system analysis tools. An in-depth analysis of the subject area allowed us to study in detail the requirements of users and the specifics of the travel industry. Using UML diagrams, such as use case and activity diagrams, the system structure and interaction between its components were modeled.

This ensured a clear understanding of the application architecture, the identification of key modules and their functions, as well as the identification of potential risks and bottlenecks in the development process. Using these tools contributed to the effective planning and implementation of the project, ensuring consistency between the requirements and the final product.

The developed system allows users to customize the criteria for selecting tourist locations, set weighting factors, and receive personalized recommendations based on multi-criteria analysis. The integration of the TOPSIS algorithm ensured the objectivity and accuracy of the assessment of alternatives, which is confirmed by a benchmark example of the application. Users can quickly and conveniently receive relevant recommendations, which increases the efficiency of travel planning.

The use of modern technologies, such as React and TypeScript for front-end development and Supabase for database management, contributed to the creation of a productive and scalable application. Implementation of the TOPSIS algorithm on the server side using Python and its deployment on AWS allowed for powerful data processing, reducing the load on client devices and improving the user experience. The intuitive interface simplifies interaction with the system, making the process of setting up and receiving recommendations as comfortable as possible for the user.

The results of using the system demonstrate its effectiveness in providing users with relevant and informed recommendations on choosing a travel destination. The system simplifies the planning process by helping users navigate the large number of available options and avoid information overload.

The system is only an initial and basic implementation. Prospects for further development of the application include expanding the database of tourist locations and criteria and integration with external services to obtain up-to-date information such as weather, ticket prices, and user reviews. Additional data analysis methods, including machine learning, are planned to be introduced to improve the accuracy and relevance of recommendations. A possible direction is to develop a mobile version of the app and add social features allowing users to share experiences and recommendations, creating a community around the service.

Declaration on Generative AI

The authors have not employed any Generative AI tools.

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