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A Multi-Criteria Decision Framework for Sustainable Mountain Tourism Development Under Climate Change: Case Study Central Serbia

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Abstract

Mountain tourism destinations are increasingly challenged by climate change, environmental degradation, and the need to balance economic development with the long-term conservation of natural resources. This study evaluates alternative pathways for the sustainable development of mountain tourism in Central Serbia by applying an integrated multi-criteria decision-making framework that combines conventional and fuzzy approaches to account for uncertainty in expert judgments. A set of economic, environmental, social, developmental, and governance-related criteria was used to assess different tourism development models and identify those with the greatest potential to support long-term sustainability. The findings indicate that development strategies emphasizing climate adaptation, environmental protection, tourism diversification, and active participation of local communities provide the most promising basis for sustainable mountain tourism development. The study also highlights the importance of diversifying tourism products beyond winter-based activities through nature-based forms of tourism, including geotourism, which builds upon the region's rich geoheritage, geomorphological diversity, and cultural landscapes while strengthening destination resilience to climate change. The proposed evaluation framework provides a practical decision-support tool that can be adapted to other mountain regions facing similar environmental and developmental challenges.

Keywords: sustainable tourism; mountain regions; TOPSIS method; Fuzzy TOPSIS; Central Serbia



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1. Introduction

Mountain ecosystems play a significant role in sustainable development due to the wide range of ecosystem services they provide, including water supply, energy resources, food production, biodiversity conservation, and related regulating and cultural services. They are home to a substantial portion of the world's population, including indigenous peoples and local communities whose knowledge and traditional practices contribute to ecosystem preservation; consequently, a large number of people depend indirectly on these ecosystems [1]. Owing to their rich geological and other natural values, mountain regions possess considerable tourism potential, serving as an important driver of economic development in these areas.

As a form of tourism activity, mountain tourism represents one of the most dynamic, yet simultaneously one of the most vulnerable, forms of tourism activity. Mountain regions are highly attractive due to their natural landscapes, geodiversity, biodiversity, recreational opportunities, and cultural heritage; however, intensive tourism development, climate change, and accelerated urbanization generate serious sustainability challenges. Climate change constitutes one of the greatest constraints on the tourism sector and its capacity to contribute to sustainable development goals [2]. These challenges are even more pronounced in developing and transition economies [2], where tourism development is considered an important mechanism for poverty reduction and sustainable development [3–5]. Over the past decade, the tourism sector has experienced substantial growth, with the largest contribution originating from developed and emerging economies, particularly China, which accounted for 23% of global aircraft deliveries in 2018, reflecting the considerably higher demand for travel in these regions [6]. In this context, sustainability in tourism is increasingly viewed through the ability of destinations to adapt, recover, and continue functioning effectively after crises, including economic recessions, pandemics, and political or security-related disruptions [6].

Mountain destinations are recognized as climate-sensitive systems, as their competitiveness largely depends on the stability of snow cover, the availability of natural resources, and the preservation of landscapes [7]. Climate change projections for Europe indicate a shortening of the winter season and increasing costs of artificial snowmaking, thereby questioning the long-term sustainability of the traditional winter tourism model [8]. Tourism in Europe is facing numerous challenges related to the impacts of climate change, as well as the need for adaptation and mitigation measures [9,10], making the strategic transformation toward diversified, year-round, and low-carbon development models a necessity. Previous research indicates that destinations effectively incorporating sustainability principles, climate adaptation strategies, and participatory governance mechanisms exhibit higher resilience to external disturbances and greater long-term economic stability [11–13].

The concept of destination resilience, understood as the capacity of a tourism system to absorb disturbances, adapt to change, and maintain its essential functions, has become a central analytical framework in contemporary tourism research [14]. This is particularly relevant for mountain regions in Central Serbia, where tourism development is closely linked to ski tourism potential, infrastructure expansion, accommodation growth, and increasing investment in tourism facilities [15–17]. However, such development has often been accompanied by spatial concentration, pressure on natural resources, pronounced seasonality, and insufficiently coordinated planning, especially in major mountain centers such as Kopaonik, Zlatibor, and Stara Planina. These challenges are further intensified by the climate vulnerability of winter tourism, as rising temperatures and reduced snow reliability directly affect the competitiveness of ski resorts in Southeastern Europe [2,18,19]. Under such circumstances, strategic planning must move beyond conventional growth-oriented models and incorporate climate adaptation, diversification, environmental protection, and governance capacity as core sustainability dimensions. Multi-criteria decision-making methods are increasingly used in this context as analytical tools for evaluating development alternatives and identifying strategic priorities under complex and uncertain conditions [20–23]. This approach is also consistent with contemporary international policy frameworks, including the Agenda 2030 [24,25], the European Green Deal, and sustainable tourism strategies promoted by international tourism organizations [26,27], which emphasize the transition toward climate-responsible, resilient, and socially inclusive tourism systems.

Despite the growing body of research on sustainable mountain tourism, climate adaptation, and destination resilience, relatively limited attention has been devoted to the systematic evaluation and comparison of alternative mountain tourism development

models using integrated multi-criteria decision-making approaches. Existing studies have primarily focused on individual sustainability dimensions, such as environmental impacts, climate vulnerability, or economic performance, while comprehensive frameworks that simultaneously incorporate economic, environmental, social, developmental, and governance-related criteria remain scarce. Furthermore, few studies have examined these issues in the context of mountain destinations in Central Serbia, despite their high environmental sensitivity, rich geoheritage, and increasing exposure to climate change. This research therefore addresses an important gap by providing an integrated assessment of alternative sustainable tourism development pathways under conditions of uncertainty.

Accordingly, the main objective of this study is to identify and evaluate the most appropriate model for the sustainable development of mountain tourism in Central Serbia. To achieve this objective, the study addresses the following research questions:

RQ1: Which mountain tourism development model provides the highest overall potential for achieving long-term sustainability in Central Serbia?

RQ2: Which sustainability criteria exert the greatest influence on the evaluation and ranking of alternative mountain tourism development models?

RQ3: To what extent can an integrated multi-criteria decision-making framework support strategic planning and decision making for sustainable mountain tourism development under conditions of uncertainty and climate change?

By answering these research questions, the study contributes to both the theoretical and practical understanding of sustainable mountain tourism planning. It provides a comprehensive decision-support framework that can assist policymakers and destination managers in selecting development strategies that enhance climate resilience, environmental conservation, tourism diversification—including geotourism—and the long-term sustainability of mountain destinations.

2. Theoretical Framework and Literature Review

Mountain tourism refers to a distinct type of tourism conducted in mountainous regions, relying on the use of natural, landscape, climatic, and cultural resources of mountain ecosystems for recreation, leisure, sports activities, and nature-oriented experiences. It includes winter activities, such as skiing and snowboarding, summer activities, such as hiking, mountaineering, and cycling, as well as rural, ecotourism, health, and adventure-based activities [28]. It implies the sustainable use of mountain resources while ensuring the preservation of biodiversity, cultural identity, and traditional livelihoods of local communities, and it can also be understood as an integrated socio-ecological system in which tourism activities are strongly influenced by climatic conditions, the availability of natural resources, and institutional governance structures [2,29,30]. In the context of climate change, mountain tourism is increasingly viewed through the lens of vulnerability and adaptive capacity, as it depends on the stability of key environmental factors such as snow cover, water resources, and ecosystem integrity [19,31]. In line with the principles of sustainable development and the Agenda 2030 framework, mountain tourism can be defined as a complex socio-ecological system of tourism activities in mountain regions that, through the sustainable management of natural and social resources, contributes to economic development, environmental protection, social inclusion, and the capacity to adapt to climate change [24]. Strategic priorities for the sustainable development of tourism in mountain regions are therefore commonly conceptualized through an integrated model encompassing economic, environmental, and social sustainability, as well as institutional and governance capacity [32–35].

Economic sustainability in mountain tourism areas refers to the ability of a destination to generate stable and long-term economic benefits without compromising natural

resources. It implies a balance between competitiveness, resilience to external shocks, and the equitable distribution of benefits at the local level [36]. In contrast to short-term growth models based on capacity expansion and intensive construction, economic sustainability in mountain regions focuses on long-term income stability, diversification of tourism products, reduction in seasonality, strengthening of local value creation, and increased resilience to both climate and market changes. The Organisation for Economic Co-operation and Development [37] highlights that mountain regions are characterized by specific structural weaknesses, including peripheral location, small markets, and infrastructural constraints. To ensure economic sustainability, it is necessary to promote year-round tourism activities, including hiking, cycling, wellness, and rural tourism, while integrating gastronomy, cultural heritage, and local products into the tourism portfolio, together with specialized forms of tourism such as adventure, ecotourism, and health tourism. Destinations with multi-seasonal tourism services achieve more stable revenues and greater resilience to climate change [2], while seasonality remains one of the key economic challenges for mountain destinations, leading to unstable employment, low infrastructure utilization during the off-season, and increased financial risk for investors. Strategies aimed at reducing seasonality include organizing events outside the peak season, developing congress and sports tourism, and promoting natural and cultural resources throughout the entire year. In this way, a greater share of tourism revenue remains within the local community, contributing to multiplier effects through local entrepreneurship, integration of agriculture and tourism, and support for small and medium-sized enterprises. Economic sustainability can therefore be assessed through indicators such as GDP contribution, employment, consumption patterns, local supply chains, and investment flows, and it represents a key criterion in tourism development.

Ecological priority in sustainable mountain development implies assigning primary importance to the protection and preservation of mountain ecosystems within development strategies and policies. It is based on the principle that the long-term economic and social sustainability of mountain regions is possible only if the natural resources and ecosystem services provided by these areas are preserved [38]. Mountain ecosystems are among the most vulnerable to global changes, including climate change, environmental degradation, and deforestation [39]. Consequently, an increasing number of studies emphasize the need for “ecological primacy,” meaning the integration of ecological constraints into development decision-making processes [6]. Ecological priority includes the protection of designated natural areas, such as national parks and biosphere reserves; the preservation of habitats and wildlife migration corridors; the prevention of landscape fragmentation caused by infrastructure development and urbanization; integrated watershed management and sustainable water use, particularly in activities such as artificial snowmaking; the reduction in greenhouse gas emissions; the transition to renewable energy sources; the application of nature-based solutions; and the restriction of infrastructure expansion in environmentally sensitive areas [24,40]. Multi-criteria decision-making methods enable environmental criteria to be explicitly weighted and evaluated in relation to economic and social objectives.

Social sustainability in mountain regions refers to the preservation of social cohesion, cultural identity, and the quality of life of local populations, alongside the equitable distribution of benefits derived from tourism and other development activities. In the context of mountain destinations, it encompasses participatory governance, the empowerment of local communities, the prevention of depopulation, the safeguarding of traditional knowledge and practices, and access to public services and infrastructure. Contemporary research emphasizes that the long-term sustainability of mountain tourism depends on the involvement of local stakeholders in decision-making processes and on maintaining a balance between tourism expansion and social stability [41,42]. Furthermore, the Organisation for Economic

Co-operation and Development [37] highlights that inclusive development models enhance the resilience of mountain regions to both economic and climate-related shocks, whereas social inequality and the marginalization of local populations can undermine destination sustainability over time. Accordingly, social sustainability represents an essential criterion in the evaluation of strategic priorities for tourism development. Institutional and governance capacity represents a strategic priority for the sustainable development of mountain regions, as it encompasses the quality of public policies, coordination across levels of government, transparency in decision-making processes, and the involvement of relevant stakeholders in development planning and implementation. Effective institutions enable the integration of environmental, economic, and social objectives, reduce land-use conflicts, and ensure long-term stability of the investment and regulatory framework. In mountain tourism destinations, adaptive and participatory governance enhances resilience to climate change, market fluctuations, and demographic challenges, whereas insufficient coordination often leads to uncontrolled urbanization and resource degradation [43–46]. The Organisation for Economic Co-operation and Development [36] emphasizes that multi-level governance and horizontal cooperation among public, private, and civil sectors constitute a foundation for the competitiveness and long-term sustainability of mountain regions, while the United Nations [24] highlights the need for institutional strengthening to support the implementation of Agenda 2030 in mountain regions.

The integration of these dimensions provides the conceptual basis for evaluating sustainable mountain tourism development in Central Serbia. In this study, the theoretical framework directly supports the selection of five evaluation criteria: economic effects, protection of natural resources, social sustainability and local community, long-term development stability, and institutional and governance sustainability. These criteria reflect the need to assess development alternatives not only according to their economic potential, but also according to their environmental compatibility, social acceptability, long-term resilience, and governance feasibility.

3. Study Area, Materials and Methods

3.1. Study Area: Mountain Regions of Central Serbia

The study area was defined according to the spatial distribution of mountain tourism centers in Central Serbia and their relevance for evaluating alternative tourism development pathways under climate change conditions. Serbia is predominantly located on the Balkan Peninsula, which encompasses approximately 75.6% of its territory, while the northern region of the country, situated north of the Sava and Danube rivers, geographically belongs to Central Europe and accounts for the remaining 24.4% of the national territory. The Pannonian Plain occupies approximately 27.5% of the territory of Serbia, thereby positioning the country within the group of Pannonian states. Moreover, the Danube River, one of the most significant international navigable waterways in Europe, traverses Serbia and represents an important geographic, economic, and transport corridor [47]. Due to its favorable geographical position, Serbia represents an important international crossroads of major transportation and communication corridors, which significantly contributes to its tourism attractiveness and accessibility. The country's tourism potential is also reflected in its geomorphological diversity. The geomorphological diversity and geodiversity of mountain systems represent foundational assets for contemporary regional tourism, heavily influencing the overall attractiveness of specific territories. This directly aligns with the core principles of geotourism, which is conceptually defined as a distinct form of tourism focusing explicitly on geology, landforms, and landscape enhancement to foster sustainable regional development [48]. Within a broader European perspective, managing these geological assets requires a comprehensive framework where geoheritage is viewed not

only as an essential component of the natural world but also as a driving force for targeted geotouristic promotion and protection [49]. Consequently, integrating these theoretical foundations and practical principles of geotourism allows for a more effective valorization of specific mountain environments, ensuring that geoconservation and strategic tourism planning operate in synergy [50]. The southern margins and floor of the Pannonian Basin occupy the northern part of Serbia, while a composite system of valleys and basins extends across the central, southern, eastern, and southeastern parts of the country. Such a diverse and complex spatial composition includes virtually all major landform types. Among the most significant geomorphological tourism assets in Serbia are mountains, gorges and canyons, valleys, caves, natural stone arches, and earth pyramids. Mountains constitute the dominant relief form, covering approximately 38.5% of the national territory, whereas areas above 2000 m above sea level account for only 0.23% of Serbia's total area. The mountainous region (Figure 1, Table 1) is composed of three major mountain zones: the western zone of younger fold mountains, the eastern zone of younger fold mountains, and the central zone of block mountains and basins [47]. The spatial visualization presented in Figure 1 was created using QGIS (v4.0.2; QGIS Development Team, 2026), available at <https://www.qgis.org/> (accessed on 5 May 2026).

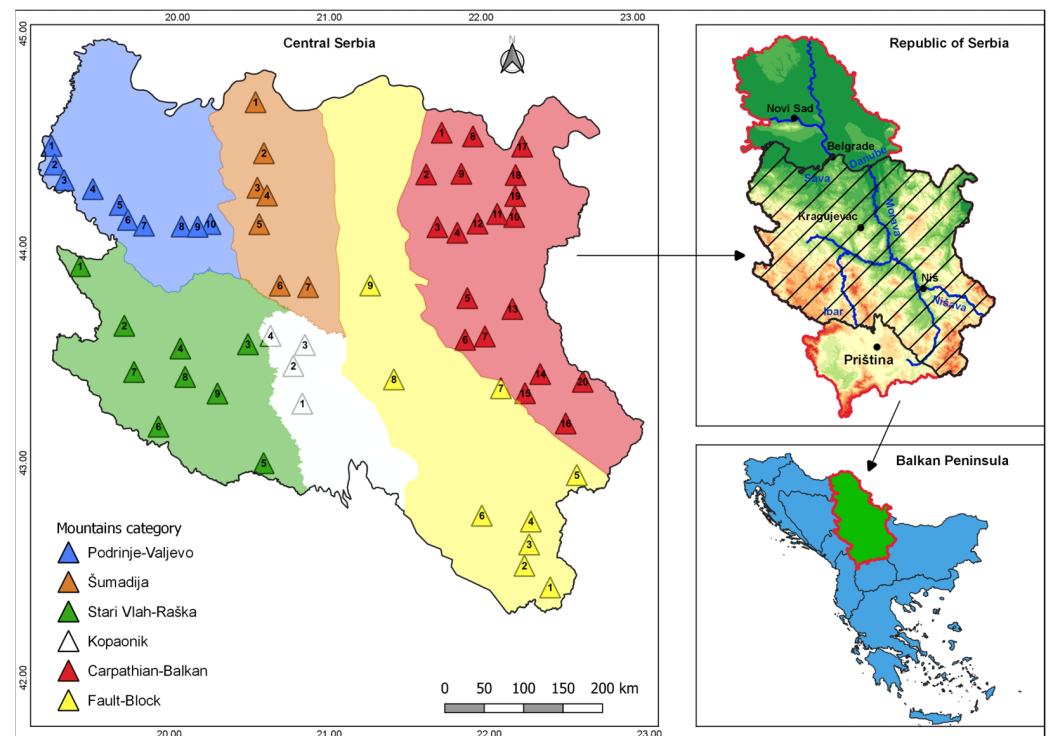


Figure 1. Location of mountain tourism centers in Central Serbia. Source: Created by the authors using QGIS v4.0.2.

The data presented in Table 1 complement Figure 1 by identifying the main mountain tourism centers in Central Serbia, their geomorphological grouping, highest peaks, and altitudinal characteristics. Together, Figure 1 and Table 1 provide the spatial basis for the subsequent evaluation of alternative mountain tourism development models.

The western zone of young fold mountains extends across the western and southwestern regions of Serbia. Geomorphologically, it forms part of the Dinaric Alps, characterized by a highly dissected and morphologically complex relief structure. This mountain zone comprises several distinct geomorphological units, including the Podrinje–Valjevo Mountains, the Šumadija Mountains, the Stari Vlah–Raška Mountains and plateaus, the Kopaonik

Mountains, and the Prokletije–Šar Mountains, which are situated outside Central Serbia, within the territory of Kosovo and Metohija [47].

The Podrinje–Valjevo mountain group comprises a series of low and medium-altitude mountains extending from north to south. The Podrinje Mountains gravitate toward the valley of the Drina and range in elevation from 700 to 1000 m above sea level, including Gučevo, Boranja, and Jagodnja–Sokolska Planina. The Valjevo Mountains reach elevations between 700 and 1347 m and include Medvednik, Jablanik, Povlen, Maljen, Ravna Gora, and Suvobor. This area is characterized by a well-developed hydrographic network consisting of rivers, springs, and streams. The highly dissected relief and favorable hydrological conditions have contributed to rich biodiversity and the exceptional attractiveness of the landscape [47]. Among the mountains of this region, Maljen stands out due to the tourist center of Divčibare, where tourism activities can be organized throughout the entire year, including hiking and ski trails, sports and recreational facilities, and a panoramic cable car operating year-round [51].

Table 1. Overview of basic information on mountain tourism centers in Central Serbia (source: created by the authors).

Mountain Zones	Mountain Groups	Code	Mountains	Highest Peak	Elevation (m)
Western Zone of Young Fold Mountains	Podrinje–Valjevo Mountains	1.	Gučevo	Crni Vrh	779
		2.	Boranja	Crni Vrh	856
		3.	Jagodnja	Košutnja stopa	939
		4.	Sokolska	Rožanj	973
		5.	Medvednik	Medvednik	1.247
		6.	Jablanik	Jablanik	1.275
		7.	Povlen	Mali Povlen	1.347
		8.	Maljen	Kraljev Sto	1.104
		9.	Ravna Gora	Babina Glava	1.034
		10.	Suvobor	Suvobor	864
	The Šumadija Mountain Range	1.	Avala	Žrnov	511
		2.	Kosmaj	Kosmaj	626
		3.	Bukulja	Bukulja	696
		4.	Venčac	Venčac	659
		5.	Rudnik	Cvijičev Vrh	1.132
		6.	Kotlenik	Veliki Vrh	749
		7.	Gledičke Planine	Samar	922
	Stari Vlah–Raška Mountains	1.	Tara	Kozji Rid	1.591
		2.	Zlatibor	Tornik	1.496
		3.	Čemerno	Smrdljuč	1.579
		4.	Mučanj	Jerinin Grad	1.534
		5.	Rogozna	Crni Vrh	1.504
		6.	Giljeva	Jelenak	1.617
		7.	Zlatar	Golo Brdo	1.627
		8.	Javor	Vasilijin Vrh	1.519
		9.	Golija	Jankov Kamen	1.833
	Kopaonik Mountains	1.	Kopaonik	Pančić's Peak	2.017
		2.	Željin	Željin	1.785
		3.	Goč	Ljukten	1.216
		4.	Stolovi	Usovica	1.375

Table 1. Cont.

Mountain Zones	Mountain Groups	Code	Mountains	Highest Peak	Elevation (m)
Eastern Zone of Young Fold Mountains and Basins	Carpathian–Balkan Mountains	1.	Zviške planine	Mikulj	890
		2.	Homoljske planine	Oman	962
		3.	Beljanica	Beljanica	1.339
		4.	Kučaj	Velika Tresta	1.284
		5.	Rtanj	Šiljak	1.565
		6.	Ozren	Leskovik	1.174
		7.	Devica	Čapljina	1.187
		8.	Šomrda	Šomrda	803
		9.	Majdanpečke planine	Glavica	650
		10.	Stol	Goli krš	1.156
		11.	Veliki krš	Veliki krš	1.148
		12.	Crni Vrh	Crni Vrh	1.043
		13.	Tupižnica	Bučji kamen	1.162
		14.	Tresibaba	Tresibaba	787
		15.	Svrljiške planine	Zeleni vrh	1.334
		16.	Belava	Kardašica	946
		17.	Miroč	Štrbac	768
		18.	Veliki Greben	Crni Vrh	656
		19.	Deli Jovan	Crni Vrh	1.141
		20.	Stara planina	Midžor	2.169
The Central Zone of Fault-Block Mountains and Basins	Fault-Block Mountains	1.	Dukat	Crnook	1.881
		2.	Besna Kobila	Besna Kobila	1.923
		3.	Vardenik	Veliki Strešer	1.876
		4.	Čemernik	Veliki Čemernik	1.638
		5.	Ruj	Ruj	1.706
		6.	Kukavica	Vlajna	1.442
		7.	Pasjača	Pasjački Vis	971
		8.	Jastrebac	Veliki Đulica	1.491
		9.	Juhor	Veliki Vetren	774

*** The data presented in Table 1 accompany Figure 1 and provide its corresponding legend.

The Šumadija Mountains, including Avala, Kosmaj, Bukulja, Venčac, Rudnik, Kotlenik, and the Gledić Mountains, are located in the central part of Serbia, with elevations ranging from 500 to 1132 m above sea level. The highest of these mountains is Rudnik, which constitutes the hydrographic center of the Šumadija region, with its waters draining into the basins of the Velika Morava, Zapadna Morava, and Kolubara rivers. These mountains are predominantly covered by vegetation, while numerous thermo-mineral springs are situated along fault lines within the Šumadija region, where modern spa settlements have developed [47]. Although these mountains possess relatively modest tourism attractiveness compared to Serbia's major mountain destinations, they are integrated into the broader regional tourism framework through secondary residences, rural tourism, children's and youth tourism, sports and event tourism, health and spa tourism, excursion tourism, and related recreational activities.

The Stari Vlah–Raška Mountains and plateaus encompass the western and southwestern parts of Serbia and are characterized by extensive highlands and prominent mountain peaks ranging from 1300 to 1800 m above sea level. These plateaus are deeply incised by narrow river valleys, from which mountains such as Tara Mountain, Zlatibor, Čemerno, and

Mučanj prominently rise [47]. Within the meander of the Ibar lies Rogozna [52], while to its west extends the Novi Pazar Basin, connected through the Pometenik Pass with the Pešter Plateau and the Sjenica Basin. The region is distinguished by densely forested mountains, including Giljeva, Zlatar, Javor, and Golija [53]. The mountains of Zlatibor, Zlatar, Tara, and Golija represent important tourism centers with a long tradition in winter tourism, while the area supports diverse forms of tourism activity, including rural, cultural-event, sports-event, and excursion tourism. Zlatibor, Zlatar, Tara Mountain, and Golija are among the most important mountain tourism destinations in Western Serbia, featuring developed or prospective ski resort capacities and considerable potential for year-round tourism development [54–59]. They are characterized by favorable natural and climatic conditions, although they differ in terms of infrastructural development and the seasonal diversification of tourism services [54–59]. The Sjenica–Pešter Plateau is additionally distinguished as an area with significant winter tourism potential due to its long-lasting snow cover and low temperatures, which create favorable conditions for the development of winter tourism and Nordic skiing disciplines [19,60].

The Kopaonik mountain group comprises the Kopaonik Mountains, Željin, Goč, and Stolovi. Kopaonik Mountains belong to the Dinaric mountain system, with Pančić's Peak representing the highest summit at 2017 m above sea level. The majority of the mountain area lies between 500 and 1000 m in elevation, while significant portions are situated between 1000 and 1500 m [61]. Such altitudinal characteristics provide favorable conditions for multiple forms of tourism activity during both summer and winter seasons. Due to its central geographical position within Serbia and its considerable elevation, Kopaonik Mountains represent an important climatic modifier. Among all climatic elements relevant to winter tourism, sports, and recreation on Kopaonik, snow cover is the most significant. With an average of 155 days of snow cover annually, Kopaonik Mountains represent the largest and most significant winter tourism destination in Serbia, providing conditions for skiing and other winter sports activities for at least four months each year [62,63]. Tourism infrastructure on the mountain is highly developed, comprising approximately 47.74 km of ski slopes, including sections certified according to FIS standards [55,64]. At the foothills of Kopaonik are located several spa centers, including Jošanička Spa, Lukovska Spa, Kuršumlijska Spa, and Bruska Spa [65]. Toward the northwest, Kopaonik Mountains extend into the mountain ranges of Željin, Goč, and Stolovi. The entire area is characterized by a highly dissected relief, shaped by numerous river valleys and intermontane basins.

The eastern zone of fold mountains extends from the Đerdap Gorge in the north to Mount Ruj and the Zaplanje–Lužnica Basin in the south, and from the central zone of block mountains in the west to the Vlach–Pontic Basin in the east. The segment of this mountain arc within Serbia is referred to as the Carpathian–Balkan Mountains. Mountains in this zone are predominantly composed of limestone and include Zviške, Homoljske, Beljanica, Kučaj, Rtanj, Ozren, Devica, Severni Kučaj, Šomrda, Majdanpek Mountains, Stol, Veliki Krš, Crni Vrh, Tupižnica, Tresibaba, Svrlijig Mountains, Miroč, Veliki Greben, Deli Jovan, and Stara Planina. The relief of this belt is characterized by karst landforms and is deeply dissected by river valleys, including those of the Porečka River, Timok, Nišava, Mlava, and Pek, making it more accessible than the western mountain zone. Among the caves, notable examples include Lazareva, Resavska, Rajkova, Ceremošnja, Ravanička, and Bogovinska. The karst region of Eastern Serbia is also rich in natural stone bridges, while karst fields represent additional tourism resources [47]. Crni Vrh in Eastern Serbia is characterized by a moderately mountainous climate and a local ski resort with three ski slopes, two of which are currently operational [66,67]. Due to the short duration of snow cover, the area has limited potential for large-scale winter tourism investments. In contrast, Stara Planina represents one of the most important ski resorts in Serbia, offering conditions suitable for

both alpine and Nordic skiing, with long-lasting snow cover and infrastructure adapted to modern tourism requirements [68]. According to data from Ski Resorts of Serbia, it features nine ski runs with a total length of 12 km, six ski lifts, and an artificial snowmaking system [69,70]. In addition to winter tourism, the area also has significant potential for summer recreational activities [68–70].

The central zone of block mountains and basins encompasses the region of Serbia surrounding the Južna Morava and Velika Morava river systems. To the east, it borders the eastern zone of young fold mountains, while to the west it transitions toward the Dinarides. This zone belongs to the Serbo-Macedonian Massif, the oldest geological part of the Balkan Peninsula. Mountains with significant tourism development potential within this zone include Dukat, Besna Kobila, Vardenik, Čemernik, Ruj, Kukavica, Pasjača, Jastrebac, and Juhor. Between these mountain systems lie the Jablanička, Toplička, and Kruševac basins [47]. Besna Kobila is part of the Rhodope mountain massif, with its peaks covered by snow for most of the year. The massif offers opportunities for year-round sports and recreational activities, including winter sports, hiking excursions, cycling, and off-road jeep tours along designated trails. In 2008, the public enterprise “Ski Resort Besna Kobila” was established with the aim of developing infrastructure and creating conditions for ski tourism development. Skiers currently have access to two prepared ski slopes, 480 m and 250 m in length, as well as a ski lift with a capacity of 500 skiers per hour. One of the slopes is also equipped for night skiing [71]. The mountain lodge “Besna Kobila,” with a capacity of 80 beds, is located at an elevation of 1480 m [71].

Mountain regions in Serbia are characterized by pleasant temperatures during the summer months, which support the development of the summer tourism season, as well as significantly higher levels of precipitation. For winter tourism movements, snowfall is of particular importance, especially the duration and thickness of snow cover, as well as solar radiation. The highest precipitation levels occur in the western zone of young fold mountains, particularly in areas such as Zlatibor and Kopaonik Mountains [18]. Due to the number of days with sub-zero temperatures, snow cover in Serbian mountain regions persists for approximately three to six months. Insolation levels in Serbia’s mountain regions range between 1800 and 2000 h annually [62]. These geomorphological, climatic, infrastructural, and tourism-development differences among the analyzed mountain regions justify the use of a multi-criteria decision-making approach. They provide the spatial and developmental basis for defining alternative tourism development models and evaluation criteria in the following section.

3.2. Selection of Alternatives and Decision-Making Criteria

The identification of the most effective development strategies for mountain tourism in the central part of Serbia required a methodologically rigorous approach, particularly given the high sensitivity of ski tourism to climate change. The selection of alternatives and evaluation criteria was based on a multi-stage process incorporating previous research findings, expert consultations, and relevant statistical data.

Existing studies on climate change and mountain tourism in Europe provide an essential foundation for defining development alternatives oriented toward the sustainable transformation of mountain tourism in Central Serbia. In particular, mountain tourism is increasingly required to adapt to rising temperatures and the reduction in snow cover, which underscores the necessity of developing a year-round tourism model, including initiatives such as the “321 Serbia” project [72]. A fundamental strategic priority is the reduction in dependence on natural snowfall and artificial snowmaking, drawing on valuable experiences from countries with comparable geographical and climatic conditions. Development strategies must therefore be grounded in infrastructure and tourism products that ensure

long-term viability, while approaches that generate short-term economic benefits but remain highly vulnerable to climate variability cannot be considered sustainable. In this context, the existing literature offers significant insights into best practices and common challenges in the development of climate-resilient mountain tourism systems [10,18,29,54,73–75].

Tourism development must be aligned with the carrying capacity of mountain ecosystems. Sustainability is based on the regulation of tourism activities, the protection of biodiversity, and the minimization of degradation of land, forest, and water resources. Spatial coherence is a fundamental precondition for sustainability [76–79]. In this context, mountain tourism in Serbia should be developed as part of a broader spatial and regional system rather than as an isolated activity. This implies full alignment with spatial and development planning frameworks. Effective management requires the coordination of multiple sectors, including tourism, nature conservation, transport, and energy, as well as the control of urban expansion and spatial fragmentation.

Local communities play a significant role in the development of sustainable tourism [80,81]. The local population should be an active stakeholder in the areas where they live, work, and generate income. Their involvement includes participatory planning and decision making, support for local entrepreneurship, and the preservation of traditional knowledge and ways of life. Social sustainability is also crucial for the long-term development of tourism, particularly in terms of socio-economic equity [82]. It helps reduce social inequalities and ensures that benefits are distributed across different social groups. In addition, it contributes to the creation and maintenance of stable employment and income opportunities for local communities.

“Quality over quantity” is a fundamental requirement for long-term sustainable development, as it is based on high value added rather than mass tourism [83]. This principle implies limiting the number of visitors in environmentally sensitive and legally protected areas, while focusing on authentic tourism experiences and increasing tourist expenditure per visitor rather than maximizing the total number of tourists. The preservation of landscape integrity and the identity of mountain regions represents a key development resource. This can be achieved through the regulation of infrastructure development and its visual impact on the environment, the protection of natural and cultural identity, and the harmonization of new construction with traditional architectural forms and spatial patterns.

Sustainability is an adaptive and responsible management process. Tourism management must be flexible and evidence-based, relying on continuous monitoring of impacts, policy and measure adjustment, as well as a clear allocation of responsibilities among stakeholders. Planned development must also be realistically implementable, as solutions that are not feasible in practice cannot be considered sustainable. Tourism development should minimize spatial, environmental, and social conflicts, since sustainability also implies social stability.

In line with the above considerations, the selected alternatives for mountain tourism development represent macro-level strategic pathways designed to address climate vulnerability, seasonality, environmental protection, local community involvement, and long-term governance capacity. These alternatives provide the basis for the comparative Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Fuzzy Technique for Order Preference by Similarity to Ideal Solution (Fuzzy TOPSIS) evaluation presented in the following sections.

Five core alternatives (Figure 2) were identified as potential pathways toward the long-term sustainability of mountain tourism in Central Serbia, in response to marked warming trends. These alternatives represent distinct development scenarios that regional authorities and local communities may implement individually or in combination.

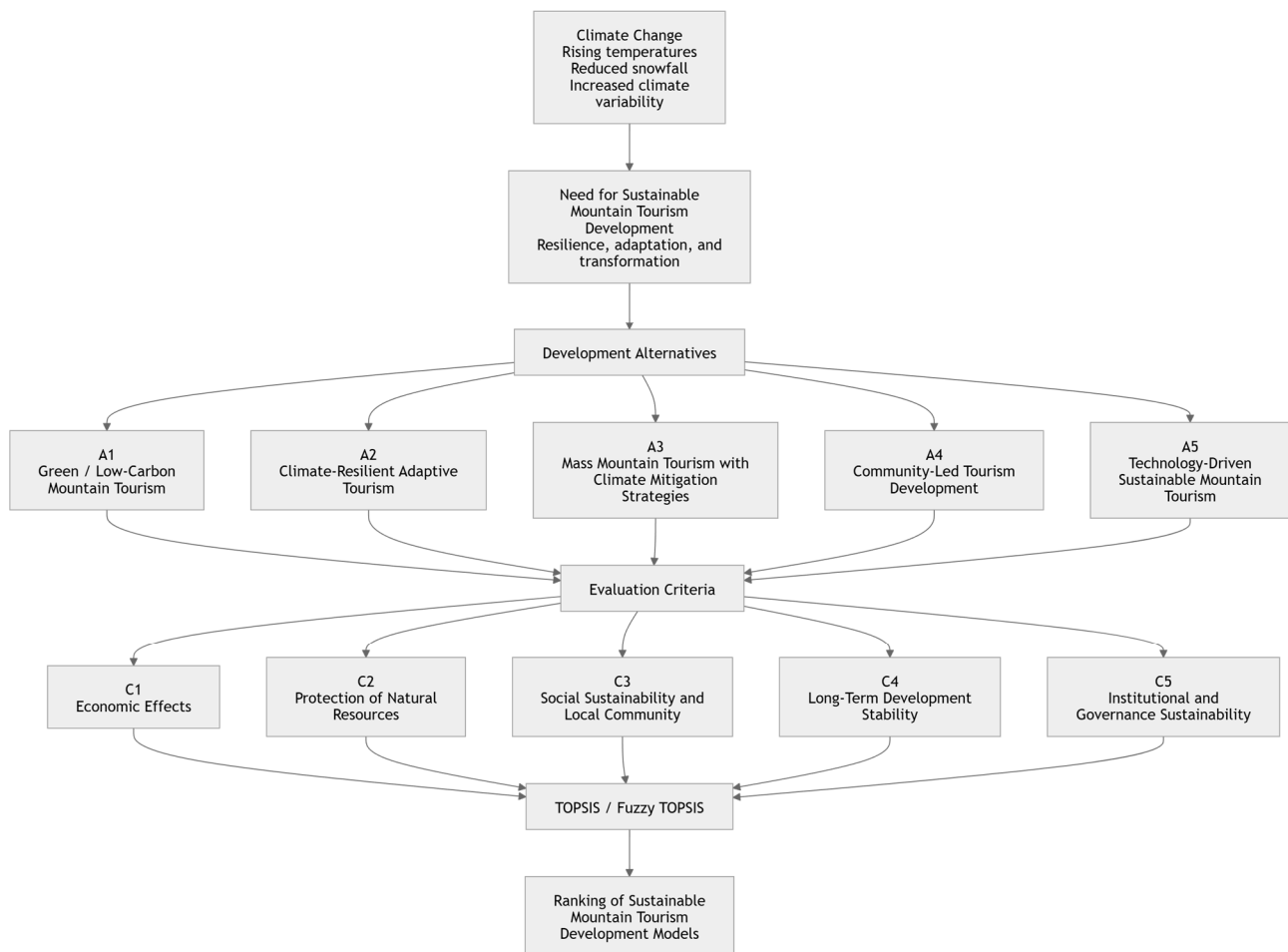


Figure 2. Conceptual framework for the evaluation of sustainable mountain tourism development (source: created by the authors).

A1—Green (low-carbon) mountain tourism. This scenario entails the development of tourism characterized by a minimal carbon footprint and a high level of environmental protection. It can be implemented through the use of renewable energy sources, such as solar and wind power, in ski resorts and hotels, the development of energy-efficient accommodation facilities, the promotion of electric vehicles for transportation to mountain destinations, and the conservation of forests and biodiversity. While these measures ensure long-term sustainability, they are associated with slower short-term economic growth and higher initial investment costs.

A2—Climate-resilient adaptive tourism. This scenario involves adapting tourism development to changing climatic conditions, including reduced snowfall, more frequent and intense rainfall, and warmer summers. It can be implemented through the development of year-round tourism, investment in summer-based activities such as hiking trails, cycling routes, and eco-tours, diversification of tourism products including spa and wellness facilities, rural tourism, and local gastronomy, and the modernization of ski resorts with reduced dependence on natural snow. These investments reduce vulnerability to climate change; however, they also require a fundamental transformation of the existing tourism model.

A3—Mass mountain tourism with climate mitigation strategies. This scenario emphasizes sustaining high tourist volumes in mountain regions through the expansion of accommodation capacity and infrastructure, including hotels, ski lifts, and transport networks, while integrating environmental mitigation measures such as reforestation, implementation of green construction standards, and improved management of waste and wastewater.

Although this approach can enhance revenue generation and employment opportunities, it simultaneously increases pressure on natural ecosystems and local resources.

A4—Community-led tourism development. This alternative is based on the growth of small-scale, family-owned enterprises and tourism initiatives managed by local communities. It is implemented through support for rural households and eco-friendly accommodation, promotion of local products and traditional crafts, and safeguarding the cultural heritage and traditions of mountain regions. This approach offers clear benefits in terms of social sustainability and reduced environmental impact, while its main limitation relates to lower overall revenue generation compared to mass tourism.

A5—Technology-driven sustainable mountain tourism. This scenario involves the application of advanced technologies aimed at reducing environmental impacts and improving system efficiency. It includes smart energy grids in tourism centers, digital visitor management systems for regulating tourist flows during peak periods, climate risk monitoring systems, and precision-based, minimal artificial snowmaking. This alternative enables high operational efficiency and improved control of tourism processes. However, it is associated with high costs and significant technological requirements.

To bridge the gap between theoretical development models and practical implementation, the alternatives were formulated as strategic options that can be understood by regional authorities, tourism operators, hospitality stakeholders, and local communities. A1 focuses on low-carbon infrastructure, renewable energy, and environmental protection. A2 emphasizes diversification toward year-round, climate-resilient tourism activities that reduce dependence on snow-based tourism. A3 reflects a growth-oriented model in which mass tourism is maintained but accompanied by mitigation measures. A4 prioritizes local ownership, rural tourism networks, traditional products, and community participation. A5 introduces digital and technological solutions for monitoring, resource efficiency, visitor management, and climate-risk reduction. This formulation enables the alternatives to be evaluated not only as abstract scenarios, but also as practically implementable development pathways.

The evaluation of alternatives for mountain tourism development was conducted based on the following criteria (Figure 2). All criteria were treated as benefit criteria, meaning that a higher score indicates a more favorable contribution of a given alternative to sustainable mountain tourism development.

C1—Economic effects. This criterion evaluates the economic benefits generated by tourism for both the local and national economy. It includes tourism revenue growth, job creation, development of local entrepreneurship, attraction of investments, and tourist expenditure per visitor. A higher score indicates a stronger contribution of tourism to the economic development of Serbia and its mountain regions.

C2—Protection of natural resources. This criterion assesses the extent to which a given alternative ensures the protection of natural resources, biodiversity, and ecosystems in mountain regions. It includes the conservation of forests, water resources, soil, and wildlife habitats; reduction in pollution; limitation of construction activities in protected zones; reduction in the carbon footprint of tourism activities; and sustainable management of natural resources. A higher score indicates a lower negative environmental impact of tourism and a higher level of environmental protection.

C3—Social sustainability and local community. This criterion measures the extent to which tourism contributes to the well-being of the local population and the broader social community. Key elements include the involvement of local residents in tourism activities, the preservation of traditions, culture, and identity of mountain regions, the equitable distribution of tourism-generated income, the prevention of over-urbanization and gentrification, and the improvement of the overall quality of life in local communities.

A higher score indicates that tourism primarily benefits local inhabitants rather than large investors.

C4—Long-term development stability. This criterion assesses the extent to which a given alternative ensures continuity and sustainability in mountain tourism development over the long term. It includes resilience to economic and climate-related changes, balanced development without overexploitation of resources, long-term investment viability, planned spatial and infrastructural management, and the preservation of natural and social values for future generations. A higher score indicates a greater capacity of a destination to maintain stable development, minimize risks, and secure lasting benefits for both the local community and the economy.

C5—Institutional and governance sustainability. This criterion assesses the extent to which a given alternative ensures long-term financing and effective management of mountain tourism development. It includes the availability and stability of funding sources, cost-benefit performance, capacity to attract investments, efficiency of the institutional framework and coordination among stakeholders, transparency and quality of governance processes, as well as the implementation of modern technologies and sustainable management practices. A higher score indicates a greater likelihood of successful project implementation, efficient resource utilization, and long-term sustainability of tourism development.

Methodological Contribution and Transferability of the Framework

The proposed framework was developed as a decision-support tool for evaluating alternative mountain tourism development pathways under conditions of climate uncertainty and expert-based assessment. Although the empirical application focuses on mountain destinations in Central Serbia, the methodological structure may be adapted to comparable mountain tourism regions characterized by environmental sensitivity, seasonal tourism demand, climate vulnerability, and complex stakeholder interests. The methodological contribution of this study lies in the integration of five development alternatives and five sustainability criteria within a combined TOPSIS–Fuzzy TOPSIS framework. This structure enables the simultaneous consideration of economic, environmental, social, developmental, and governance-related dimensions of tourism development, while fuzzy logic allows uncertainty in expert evaluations to be incorporated into the decision-making process.

The framework supports strategic decision making by enabling policy makers, destination managers, tourism businesses, and local communities to compare alternative development pathways according to predefined sustainability objectives. Its application in other mountain regions would require the adjustment of evaluation criteria, criterion weights, and expert assessments according to local environmental, institutional, and socio-economic conditions. Therefore, the case study of Central Serbia should be understood as an application of the proposed framework, rather than as its only possible field of relevance.

3.3. Application of the TOPSIS and Fuzzy TOPSIS Methods

Multi-criteria decision-making (MCDM) methods [84] constitute an important analytical framework for the evaluation and ranking of strategic priorities in the field of sustainable development. Given the complexity of sustainable mountain tourism, decision making requires the simultaneous consideration of economic, environmental, social, developmental, and governance-related criteria, often without a single optimal solution. In this study, conventional TOPSIS was used as the baseline ranking framework, while Fuzzy TOPSIS was applied to incorporate uncertainty associated with expert-based assessments. The conventional TOPSIS calculations were performed using Microsoft Excel for Microsoft 365, Version 2604 (Build 19929.20136; Microsoft Corporation, Redmond, WA, USA). The Fuzzy TOPSIS calculations were performed using the OnlineOutput Fuzzy TOPSIS web applica-

tion (version not available; <https://onlineoutput.com/fuzzy-topsis-software/> (accessed on 5 May 2026)).

The TOPSIS method enables the ranking of alternative development priorities based on their distance from the ideal and anti-ideal solutions. In other words, the optimal alternative is the one characterized by the shortest distance from the positive ideal solution (PIS) and the greatest distance from the negative ideal solution (NIS). In the context of mountain tourism, this method was used to evaluate alternative development models, including green/low-carbon mountain tourism, climate-resilient adaptive tourism, mass mountain tourism with climate mitigation strategies, community-led tourism development, and technology-driven sustainable mountain tourism. The evaluation criteria included economic effects, protection of natural resources, social sustainability and local community, long-term development stability, and institutional and governance sustainability.

Fuzzy TOPSIS (FTOPSIS) (Figure 3) represents an extension of the classical TOPSIS method, as it enables the incorporation of uncertainty and subjectivity into the decision-making process. In the field of mountain tourism, where assessments are often based on both quantitative indicators and qualitative expert judgments, the use of fuzzy numbers allows imprecise evaluations to be represented in a more flexible analytical form. This is particularly relevant in mountain tourism planning, where different stakeholders, including local communities, investors, public institutions, and environmental organizations, may assign different levels of importance to economic, environmental, social, and governance-related criteria.

The application of the TOPSIS and FTOPSIS methods is particularly relevant for the evaluation of strategic priorities such as sustainable natural resource management, eco-tourism development, infrastructure improvement with minimal environmental impact, and the strengthening of local communities. These approaches enable the integration of multiple criteria and stakeholder perspectives, thereby supporting balanced and sustainability-oriented decision making. Their application ensures a systematic and transparent assessment of strategic priorities while accounting for the inherent complexity of sustainable development processes. Accordingly, TOPSIS and FTOPSIS represent robust decision-support tools for planning the sustainable development of mountain tourism destinations.

The steps of the TOPSIS method are presented as follows [85–87]:

1. Construction of the decision matrix

The alternatives and criteria are defined by organizing the performance of each alternative with respect to each criterion into a decision matrix $X = [x_{ij}]$, where x_{ij} represents the performance rating of alternative i according to criterion j .

2. Normalization of the decision matrix

The following Formula (1) is used for normalization.

$$r_{ij}(x) = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \quad i = 1, \dots, m; j = 1, \dots, n \quad (1)$$

where x_{ij} represents the performance rating of alternative i with respect to criterion j .

3. Calculation of the weighted normalized decision matrix

According to the following Formula (2), the normalized matrix $r_{ij}(x)$ is multiplied by the weight of criterion w_j .

$$v_{ij}(x) = w_j r_{ij}(x) \quad i = 1, \dots, m; j = 1, \dots, n \quad (2)$$

4. Determination of the positive ideal and negative ideal solutions

The objective of the TOPSIS method is to calculate the degree of separation of each alternative from the positive and negative ideal solutions. Therefore, in this step, the positive ideal solution A^+ and the negative ideal solution A^- were determined according to Formulas (3) and (4).

$$A^+ = (v_1^+, v_2^+, \dots, v_n^+) \quad (3)$$

$$A^- = (v_1^-, v_2^-, \dots, v_n^-) \quad (4)$$

So that

$$v_j^+ = \{(\max v_{ij}(x) | j \in j_1), (\min v_{ij}(x) | j \in j_2)\} \quad i = 1, \dots, m$$

$$v_j^- = \{(\min v_{ij}(x) | j \in j_1), (\max v_{ij}(x) | j \in j_2)\} \quad i = 1, \dots, m$$

where j_1 and j_2 denote the negative and positive criteria, respectively.

5. Calculation of the distance from the positive and negative ideal solutions

The TOPSIS method ranks each alternative based on its relative closeness to the positive ideal solution A^+ and its distance from the negative ideal solution A^- . Therefore, in this step, the distances between each alternative and the positive ideal solution d_i^+ , as well as the negative ideal solution d_i^- , were calculated using the following Formulas (5) and (6).

$$d_i^+ = \sqrt{\sum_{j=1}^n [v_{ij}(x) - v_j^+(x)]^2}, \quad i = 1, \dots, m \quad (5)$$

$$d_i^- = \sqrt{\sum_{j=1}^n [v_{ij}(x) - v_j^-(x)]^2}, \quad i = 1, \dots, m \quad (6)$$

6. Calculation of the relative closeness of alternatives to the ideal solution

In this step, the relative closeness coefficient C_i of each alternative to the ideal solution was calculated using the following Formula (7). If the relative closeness value is close to 1, it indicates that the alternative has a shorter distance from the positive ideal solution and a greater distance from the negative ideal solution.

$$C_i = \frac{d_i^-}{(d_i^+ + d_i^-)}, \quad i = 1, \dots, m \quad (7)$$

7. Ranking of alternatives

The alternatives were ranked according to their relative closeness to the ideal solution. The alternative with the highest C_i value is considered the most preferable option.

The introduction of the Fuzzy TOPSIS (FTOPSIS) method into the standard TOPSIS framework enables more effective management of uncertainty in the decision-making process, particularly when criteria and alternatives are based on subjective or expert-based assessments. FTOPSIS is grounded in fuzzy set theory and allows decision-makers to express evaluations through linguistic terms, which are typically transformed into triangular fuzzy numbers (TFNs). A TFN is defined as $X = (L, M, U)$, where L represents the lower-bound or conservative assessment, M represents the most probable or middle assessment, and U represents the upper-bound or optimistic assessment. In this study, such representation enables expert judgments to be expressed as intervals rather than fixed values, thereby reducing dependence on a single deterministic score and allowing uncertainty to be incorporated into the evaluation of alternatives and criteria.

Expert assessments were initially expressed using linguistic variables and subsequently transformed into triangular fuzzy numbers according to the scale presented in Table 2. This approach enables qualitative expert judgments to be incorporated into quantitative analysis. In the present study, L represents the lower-bound or conservative assessment, M represents the most probable assessment, and U represents the upper-bound or optimistic assessment.

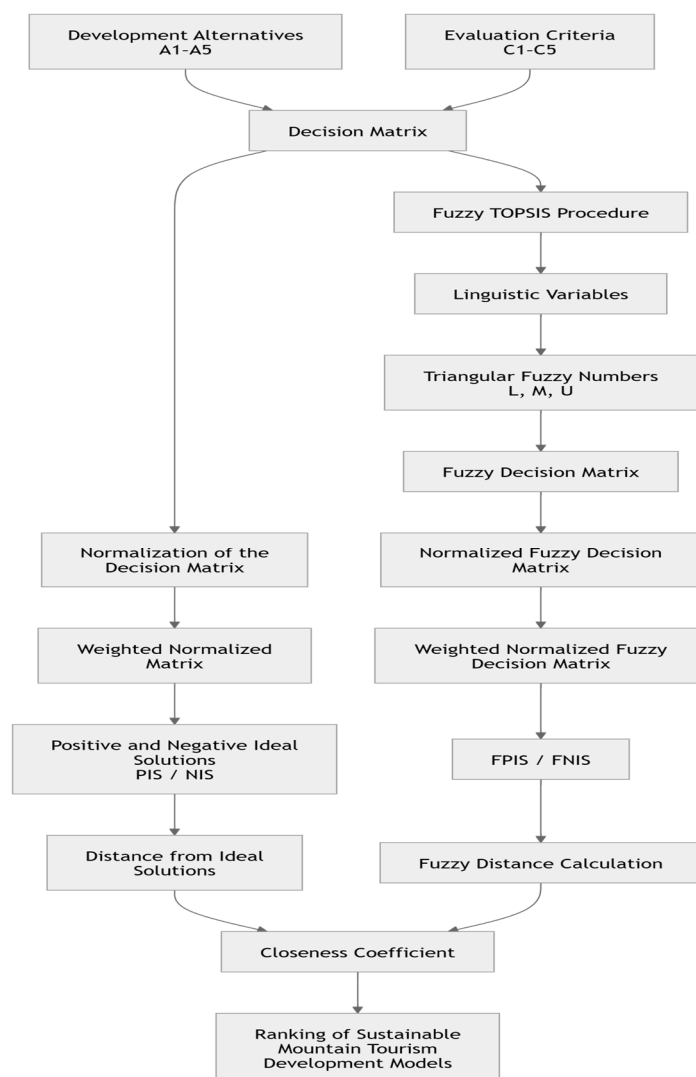


Figure 3. Methodological framework of the TOPSIS and Fuzzy TOPSIS approach (source: created by the authors).

Table 2. Linguistic variables and corresponding triangular fuzzy numbers (source: created by the authors).

Code	Linguistic Terms	L	M	U
1	Very low	1	1	3
2	Low	1	3	5
3	Medium	3	5	7
4	High	5	7	9
5	Very high	7	9	9

The values in the fuzzy decision matrix were obtained through expert evaluation of the five development alternatives against the five sustainability criteria. For each criterion, experts provided assessments in the form of triangular fuzzy numbers. For example, the assessment of climate-resilient adaptive tourism (A2) under the criterion of economic effects (C1) was expressed as (5.5, 7.5, 9.0), indicating that the minimum expected economic contribution was assessed at 5.5, the most probable contribution at 7.5, and the maximum plausible contribution at 9.0. This representation captures uncertainty more effectively than a single numerical value and allows the decision-making process to incorporate a range of expert judgments.

To illustrate the role of triangular fuzzy numbers in the Fuzzy TOPSIS procedure, the alternative A2 under criterion C1 can be considered. During the normalization process, each component of the triangular fuzzy number was divided by the maximum upper value observed within the criterion, resulting in the normalized value presented in the normalized fuzzy decision matrix. After multiplication by the corresponding criterion weight, the weighted normalized value was obtained and subsequently used in the calculation of distances from the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS). This example illustrates how uncertainty represented by lower, middle, and upper values remains incorporated throughout the decision-making process rather than being reduced to a single deterministic score.

The following steps were applied in the FTOPSIS method as modifications of the conventional TOPSIS procedure:

1. Construction of the fuzzy decision matrix

Using triangular fuzzy numbers (TFNs), a fuzzy decision matrix $\hat{X} = [\tilde{x}_{ij}]$ was constructed, where each element $\tilde{x}_{ij}$ represents the performance of alternative i with respect to criterion j as a fuzzy number.

2. Create the normalized decision matrix

Based on the positive and negative ideal solutions, a normalized decision matrix can be calculated by the following relation in (8) and (9):

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \right); \quad c_j^* = \max_i c_{ij}; \text{ Positive ideal solution} \quad (8)$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}} \right); \quad a_j^- = \min_i a_{ij}; \text{ Negative ideal solution} \quad (9)$$

3. Construction of the weighted normalized fuzzy decision matrix

Considering the different weights assigned to each criterion, the weighted normalized fuzzy decision matrix is obtained by multiplying the normalized fuzzy decision matrix by the corresponding criterion weights, according to the following Formula (10).

$$\tilde{v}_{ij} = \tilde{r}_{ij} \cdot \tilde{w}_{ij} \quad (10)$$

where $\tilde{w}_{ij}$ represents weight of criterion c_j .

4. Determine the fuzzy positive ideal solution (FPIS, A^*) and the fuzzy negative ideal solution (FNIS, A^-)

The FPIS and FNIS of the alternatives can be defined as follows in (11) and (12):

$$A^* = \{\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_n^*\} = \left\{ \left(\max_j v_{ij} \mid i \in B \right), \left(\min_j v_{ij} \mid i \in C \right) \right\} \quad (11)$$

$$A^- = \{\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-\} = \left\{ \left(\min_j v_{ij} \mid i \in B \right), \left(\max_j v_{ij} \mid i \in C \right) \right\} \quad (12)$$

where $\tilde{v}_i^*$ is the max value of i for all the alternatives and $\tilde{v}_1^-$ is the min value of i for all the alternatives. B and C represent the positive and negative ideal solutions, respectively.

5. Calculate the distance between each alternative and the fuzzy positive ideal solution A^* and the distance between each alternative and the fuzzy negative ideal solution A^-

The distance between each alternative and FPIS and the distance between each alternative and FNIS are respectively calculated as follows in (13) and (14):

$$S_i^* = \sum_{j=1}^n d(\tilde{v}_{ij}, \tilde{v}_j^*) \quad i = 1, 2, \dots, m \quad (13)$$

$$S_i^- = \sum_{j=1}^n d(\tilde{v}_{ij}, \tilde{v}_j^-) \quad i = 1, 2, \dots, m \quad (14)$$

d is the distance between two fuzzy numbers; when given two triangular fuzzy numbers (a_1, b_1, c_1) and (a_2, b_2, c_2) , the distance between the two can be calculated as follows (15):

$$d_v(\tilde{M}_1, \tilde{M}_2) = \sqrt{\frac{1}{3} [(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]} \quad (15)$$

Note that $d(\tilde{v}_{ij}, \tilde{v}_j^*)$ and $d(\tilde{v}_{ij}, \tilde{v}_j^-)$ are crisp numbers.

6. Calculate the closeness coefficient and rank the alternatives

The closeness coefficient of each alternative can be calculated as follows (16):

$$CC_i = \frac{S_i^-}{S_i^+ + S_i^-} \quad (16)$$

The best-ranked alternative is the one closest to the FPIS and farthest from the FNIS. In this way, FTOPSIS provides a structured procedure for ranking sustainable mountain tourism development alternatives while incorporating uncertainty in expert-based assessments.

4. Results

The application of the Fuzzy TOPSIS method in evaluating strategic priorities for the sustainable development of mountain tourism in Central Serbia enabled the quantitative ranking of alternative development models based on multi-criteria analysis. This study considered five alternatives: green/low-carbon mountain tourism (A1), climate-resilient adaptive tourism (A2), mass mountain tourism with climate mitigation strategies (A3), community-led tourism development (A4), and technology-driven sustainable mountain tourism (A5). These alternatives were evaluated according to five key sustainability criteria: economic effects (C1), protection of natural resources (C2), social sustainability and local community (C3), long-term development stability (C4), and institutional and governance sustainability (C5).

4.1. Construct the Decision Matrix

The decision matrix forms the foundation of the evaluation process and was constructed based on expert judgments expressed through triangular fuzzy numbers (Table 3). Each value is represented as a triplet consisting of the lower bound (L), middle value (M), and upper bound (U). This approach enables the incorporation of uncertainty and

subjectivity into the assessment of complex phenomena such as sustainable mountain tourism development.

Table 3. Decision matrix (source: created by the authors).

Criteria/Alternatives	C1	C2	C3	C4	C5
A1	(2.500, 4.000, 6.000)	(7.000, 9.000, 9.000)	(3.500, 5.500, 7.500)	(7.000, 9.000, 9.000)	(5.500, 7.500, 8.500)
A2	(5.500, 7.500, 9.000)	(5.000, 7.000, 9.000)	(5.000, 7.000, 9.000)	(6.500, 8.500, 9.000)	(6.500, 8.500, 9.000)
A3	(7.000, 9.000, 9.000)	(1.000, 1.500, 3.500)	(5.000, 7.000, 8.500)	(1.000, 1.500, 3.500)	(1.000, 2.500, 4.500)
A4	(6.000, 8.000, 9.000)	(4.000, 6.000, 8.000)	(5.500, 7.500, 9.000)	(5.500, 7.500, 8.500)	(6.000, 8.000, 9.000)
A5	(1.000, 2.000, 4.000)	(5.000, 7.000, 9.000)	(3.000, 5.000, 7.000)	(4.500, 6.500, 8.500)	(2.000, 4.000, 6.000)

https://soft.onlineoutput.com/fuzzytopsis/Output?project_id=16678_764620 (accessed on 5 May 2026).

The initial expert assessments indicate that climate-resilient adaptive tourism (A2) and community-led tourism development (A4) achieve high values across most criteria, suggesting their balanced sustainability performance. In contrast, mass mountain tourism with climate mitigation strategies (A3) demonstrates strong performance in economic effects (C1), but much weaker performance in natural resource protection (C2), long-term development stability (C4), and institutional and governance sustainability (C5). This imbalance indicates its limited suitability within the framework of sustainable mountain tourism development. Green/low-carbon mountain tourism (A1) stands out due to high scores in natural resource protection (C2) and long-term development stability (C4), while technology-driven sustainable mountain tourism (A5) shows moderate performance overall, with weaker results in the economic dimension (C1).

4.2. Normalization of the Decision Matrix

Normalization of the decision matrix eliminates the influence of different measurement scales, thereby enabling direct comparison among alternatives. Values closer to one indicate better performance with respect to the considered criterion. The results presented in Table 4 show that green/low-carbon mountain tourism (A1) achieves the highest values in natural resource protection (C2) and long-term development stability (C4), while climate-resilient adaptive tourism (A2) records consistently high values across all criteria, confirming its balanced performance. Mass mountain tourism with climate mitigation strategies (A3) exhibits significantly lower values in environmental protection and long-term development stability. Community-led tourism development (A4) demonstrates particularly strong performance in social sustainability and local community (C3), reflecting its emphasis on local participation and the distribution of tourism benefits. Technology-driven sustainable mountain tourism (A5) demonstrates variable performance across criteria, with stronger results in environmental components and weaker outcomes in economic and social dimensions. These results confirm that, in the mountain regions of Central Serbia, development models that integrate environmental, social, and adaptive dimensions possess a clear comparative advantage.

4.3. Construction of the Weighted Normalized Decision Matrix

In the next step, criterion weighting was performed (Table 5). The weighted normalized decision matrix provides a more precise evaluation of each alternative across the five criteria, taking into account their relative importance as reflected in the assigned weights. The weights assigned to each criterion in the TOPSIS procedure were as follows: $w_1 = 0.27$ for C1, $w_2 = 0.33$ for C2, $w_3 = 0.20$ for C3, $w_4 = 0.13$ for C4, and $w_5 = 0.07$ for C5. These weights reflect the relative importance of each criterion in the evaluation and prioritization of sustainable mountain tourism development.

Table 4. Normalized decision matrix (source: created by the authors).

Criteria/Alternatives	C1	C2	C3	C4	C5
A1	(0.278, 0.444, 0.667)	(0.778, 1.000, 1.000)	(0.389, 0.611, 0.833)	(0.778, 1.000, 1.000)	(0.611, 0.833, 0.944)
A2	(0.611, 0.833, 1.000)	(0.556, 0.778, 1.000)	(0.556, 0.778, 1.000)	(0.722, 0.944, 1.000)	(0.722, 0.944, 1.000)
A3	(0.778, 1.000, 1.000)	(0.111, 0.167, 0.389)	(0.556, 0.778, 0.944)	(0.111, 0.167, 0.389)	(0.111, 0.278, 0.500)
A4	(0.667, 0.889, 1.000)	(0.444, 0.667, 0.889)	(0.611, 0.833, 1.000)	(0.611, 0.833, 0.944)	(0.667, 0.889, 1.000)
A5	(0.111, 0.222, 0.444)	(0.556, 0.778, 1.000)	(0.333, 0.556, 0.778)	(0.500, 0.722, 0.944)	(0.222, 0.444, 0.667)

https://soft.onlineoutput.com/fuzzytopsis//Output?project_id=16678_764620 (accessed on 5 May 2026).

Table 5. The weighted normalized decision matrix (source: created by the authors).

Criteria/Alternatives	C1	C2	C3	C4	C5
A1	(0.068, 0.120, 0.198)	(0.231, 0.330, 0.363)	(0.070, 0.122, 0.183)	(0.091, 0.130, 0.143)	(0.039, 0.058, 0.073)
A2	(0.149, 0.225, 0.297)	(0.165, 0.257, 0.363)	(0.100, 0.156, 0.220)	(0.085, 0.123, 0.143)	(0.046, 0.066, 0.077)
A3	(0.189, 0.270, 0.297)	(0.033, 0.055, 0.141)	(0.100, 0.156, 0.208)	(0.013, 0.022, 0.056)	(0.007, 0.019, 0.039)
A4	(0.162, 0.240, 0.297)	(0.132, 0.220, 0.323)	(0.110, 0.167, 0.220)	(0.072, 0.108, 0.135)	(0.042, 0.062, 0.077)
A5	(0.027, 0.060, 0.132)	(0.165, 0.257, 0.363)	(0.060, 0.111, 0.171)	(0.059, 0.094, 0.135)	(0.014, 0.031, 0.051)

https://soft.onlineoutput.com/fuzzytopsis//Output?project_id=16678_764620 (accessed on 5 May 2026).

This step is particularly important because it allows decision-makers to give priority to alternatives that demonstrate strong performance across key sustainability criteria while remaining aligned with strategic development objectives. The highest weights were assigned to natural resource protection (C2) and economic effects (C1), which reflects the need to balance environmental protection and economic viability in environmentally sensitive mountain ecosystems.

4.4. Determination of the Positive Ideal and Negative Ideal Solutions

The definition of the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS) enables the establishment of reference points for the evaluation of alternatives (Table 6). The positive ideal solution represents the most favorable combination of criterion values, while the negative ideal solution represents the least favorable combination. In this study, the FPIS is characterized by the highest weighted fuzzy values across the evaluated criteria, while the FNIS is defined by the lowest weighted fuzzy values. This approach enables each alternative to be compared against both an optimal and a least favorable sustainability profile.

Table 6. The positive and negative ideal solutions (source: created by the authors).

Criteria	Positive Ideal A ⁺	Negative Ideal A [−]
C1	(0.189, 0.270, 0.297)	(0.027, 0.060, 0.132)
C2	(0.231, 0.330, 0.363)	(0.033, 0.055, 0.141)
C3	(0.110, 0.167, 0.220)	(0.060, 0.111, 0.171)
C4	(0.091, 0.130, 0.143)	(0.013, 0.022, 0.056)
C5	(0.046, 0.066, 0.077)	(0.007, 0.019, 0.039)

https://soft.onlineoutput.com/fuzzytopsis//Output?project_id=16678_764620 (accessed on 5 May 2026).

4.5. Calculation of the Separation Measures

The calculated distances from the positive and negative ideal solutions provide additional insight into the relative positioning of each alternative. Based on the results presented

in Table 7, climate-resilient adaptive tourism (A2) exhibits the smallest distance from the positive ideal solution (0.106) and the greatest distance from the negative ideal solution (0.515), identifying it as the most favorable alternative. Community-led tourism development (A4) also shows a high level of closeness to the positive ideal solution, with a distance of 0.132, while green/low-carbon mountain tourism (A1) occupies an intermediate position, with a distance of 0.172. Mass mountain tourism with climate mitigation strategies (A3) is the most distant from the positive ideal solution (0.379) and the closest to the negative ideal solution (0.221). These results indicate that development models that neglect environmental protection, long-term stability, and governance dimensions cannot serve as a strong foundation for the sustainable development of mountain tourism destinations.

Table 7. Distance from positive and negative ideal solutions (source: created by the authors).

	Distance from Positive Ideal	Distance from Negative Ideal
A1	0.172	0.429
A2	0.106	0.515
A3	0.379	0.221
A4	0.132	0.480
A5	0.348	0.267

https://soft.onlineoutput.com/fuzzytopsis//Output?project_id=16678_764620 (accessed on 5 May 2026).

4.6. Calculation of the Relative Closeness to the Ideal Solution

Based on the calculated closeness coefficients, the final ranking of the alternatives was performed (Table 8). The obtained results (Figure 4) indicate that climate-resilient adaptive tourism (A2) represents the optimal development model, with the highest closeness coefficient ($C_i = 0.829$). This model ensures a strong balance between economic benefits, natural resource protection, social sustainability, and long-term development stability. Its flexibility and capacity to adapt to contemporary challenges, including climate change and reduced snow reliability, make it particularly suitable for mountain regions in Central Serbia.

Table 8. Closeness coefficient (source: created by the authors).

Alternatives	C_i	Rank
Adaptive tourism	0.829	1
Community tourism	0.784	2
Green tourism	0.713	3
Technologically sustainable tourism	0.434	4
Mass tourism	0.368	5

Community-led tourism development (A4) ranks second ($C_i = 0.784$), primarily due to its strong integration of local communities and its contribution to socio-economic development. Green/low-carbon mountain tourism (A1) ranks third ($C_i = 0.713$), highlighting the importance of environmental protection and long-term stability, although it demonstrates weaker economic performance than the highest-ranked alternatives. Technology-driven sustainable mountain tourism (A5) ranks fourth ($C_i = 0.434$), indicating that technological solutions may support sustainability but are not sufficient as a standalone development model when economic, social, and governance dimensions remain limited. In contrast, mass mountain tourism with climate mitigation strategies (A3) ranks last ($C_i = 0.368$), confirming that a growth-oriented model based on high visitor volumes remains the least

sustainable option despite the inclusion of mitigation measures. The closeness coefficients and the resulting ranking of the alternatives are presented in Figure 5.

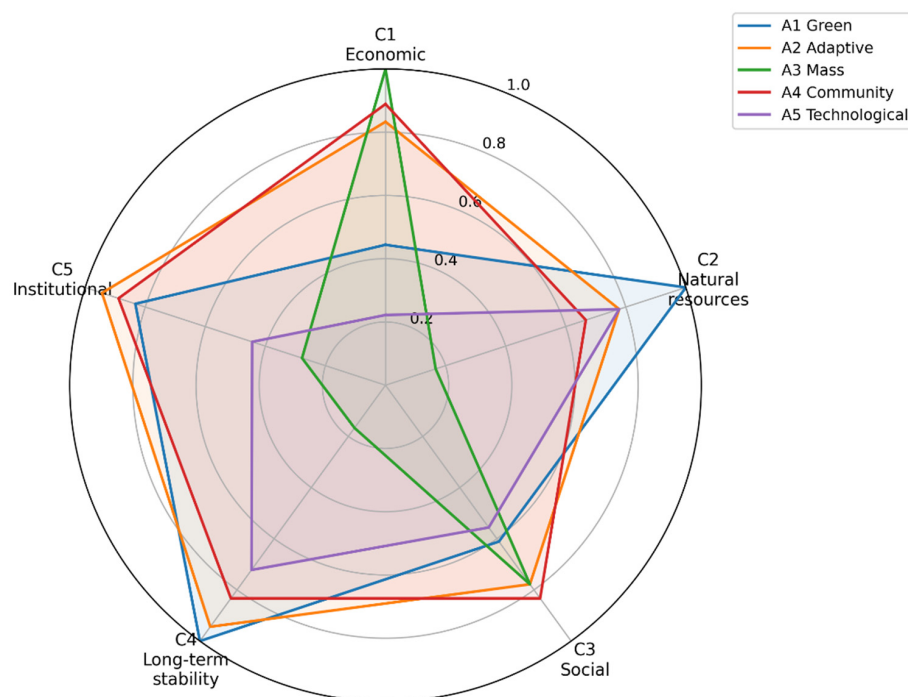


Figure 4. Comparative performance of tourism development alternatives (source: created by the authors).

The results confirm that development models based on climate adaptation, diversification of tourism products, and the inclusion of local communities are more effective in achieving long-term sustainability in mountain tourism than models primarily oriented toward mass tourism growth. The findings are consistent with the theoretical framework of the study, which emphasizes the need to integrate economic viability, environmental protection, social sustainability, long-term resilience, and governance capacity in the planning of mountain tourism development.

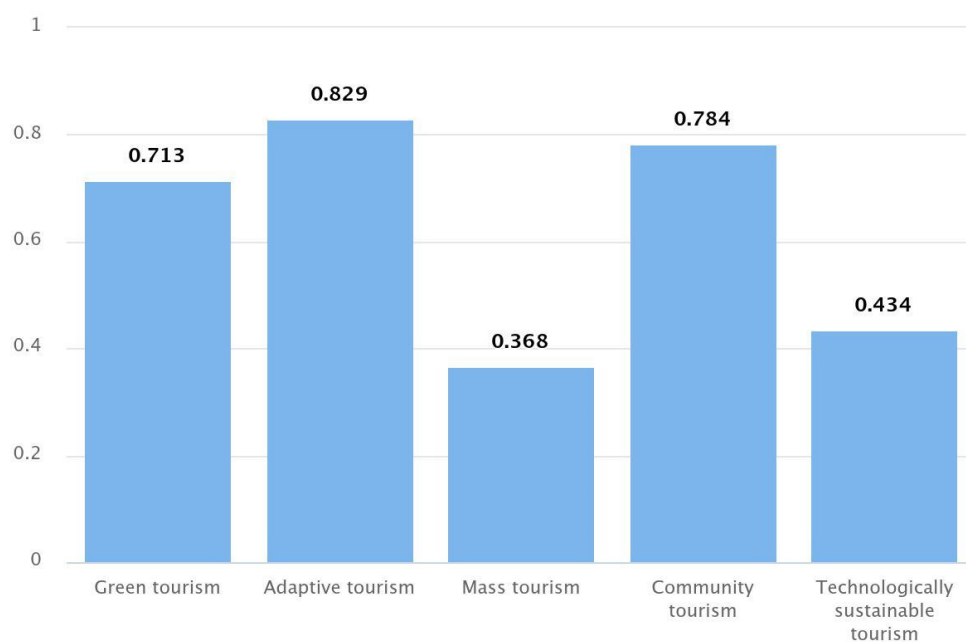


Figure 5. Closeness coefficient graph for the alternative mountain tourism development models (source: created by the authors).

4.7. Methodological Implications of the Results

Beyond the ranking of tourism development alternatives, the results demonstrate the analytical usefulness of the integrated TOPSIS–Fuzzy TOPSIS framework as a decision-support methodology. The framework enabled the simultaneous assessment of multiple sustainability dimensions while incorporating uncertainty associated with expert judgments. This is particularly relevant in mountain tourism planning, where future development is influenced by climate change, market fluctuations, environmental constraints, and diverse stakeholder priorities.

The results also show that the methodology differentiates between development models with distinct sustainability profiles. Alternatives emphasizing climate adaptation, balanced development, and local community involvement achieved higher rankings than those primarily oriented toward economic expansion. From a methodological perspective, the findings support the use of combined MCDM and fuzzy logic approaches in the evaluation of complex tourism systems characterized by uncertainty and qualitative assessments.

5. Discussion

5.1. Recommendations Based on the Research Findings

The research results indicate that the sustainable development of mountain tourism in Central Serbia should be based on models that ensure a balance between economic, environmental, social, and governance-related objectives. In line with current climate change trends, development policy should prioritize climate-resilient adaptive tourism as the leading development model, given its highest closeness coefficient ($C_i = 0.829$). This implies the design of flexible strategies that enable adaptation to climate change, seasonality, reduced snow reliability, and shifts in tourist demand. Accordingly, sustainability principles should be integrated into spatial plans, tourism strategies, and local development documents, while funding should be directed toward projects that contribute to natural resource protection, diversification of tourism products, and year-round tourism development.

Based on the research results, mountain tourism destinations in Central Serbia should develop an integrated management model combining elements of climate-resilient adaptive tourism, community-led tourism development, and green/low-carbon mountain tourism. Such a model would enable long-term sustainability by linking climate adaptation, local participation, and environmental protection. Since community-led tourism development achieved a high ranking in the evaluation ($C_i = 0.784$), the strengthening of local initiatives, rural tourism, traditional settlements, authentic tourism products, and local supply chains is strongly recommended. This also requires participatory governance, in which local communities are actively involved in planning, management, and benefit distribution.

Given that economic effects represent an important criterion in sustainable spatial development, the results indicate that economic objectives must be aligned with environmental constraints. Investments should therefore be directed toward projects with high added value and low environmental impact, including energy-efficient accommodation, small and medium-sized tourism facilities, sustainable mobility, and products based on local natural and cultural resources. Particular attention should be given to avoiding investments that reinforce mass tourism models, which were identified in the analysis as the least sustainable option ($C_i = 0.368$), even when climate mitigation measures are included.

Considering that natural resource protection carries the highest weight in the model, environmental conservation must be treated as a central priority in the sustainable development of the analyzed area. This implies the introduction of stricter nature protection standards within tourism zones, the restriction of construction activities in ecologically sensitive mountain regions, and the development of environmentally friendly tourism forms

such as hiking, cycling, ecotourism, and nature-based recreation. In addition, educational programs for tourists and the local population should be implemented in order to raise awareness of the importance of preserving natural resources.

The high ranking of community-led tourism development confirms the importance of the local population in the tourism development process. Accordingly, it is recommended to support small family businesses, rural households, local food producers, traditional crafts, and cultural heritage initiatives. The Ministry for the Care of Rural Areas of the Republic of Serbia contributes to rural development and sustainable development objectives through public calls and funding programs [88]. Support for tourism development in local communities is also provided by the Ministry of Tourism and Youth of the Republic of Serbia through funding programs and public calls related to tourism development, promotion, education, and training [89]. These instruments may contribute to a more balanced distribution of tourism benefits and reduce the risk of rural depopulation.

Although technology-driven sustainable mountain tourism is not highly ranked ($C_i = 0.434$), its role remains important as a supporting component of sustainable development models. Digital tools may improve destination management through visitor-flow monitoring, environmental impact monitoring, climate-risk assessment, resource efficiency, and digital promotion of sustainable tourism products. However, the results suggest that technological solutions should not be treated as a standalone development model, but rather as an instrument supporting adaptive, community-led, and green tourism strategies.

Based on the analysis of the closeness coefficients for all alternatives, the future development of mountain tourism in Central Serbia should be based on a hybrid model in which climate-resilient adaptive tourism is the dominant component, complemented by strong elements of community-led tourism and green/low-carbon mountain tourism. Such an approach enables long-term sustainability, resilience to external shocks, and a balanced relationship between economic development and resource conservation.

5.2. Theoretical Implications of the Research

The results of applying the Fuzzy TOPSIS method in evaluating strategic priorities for the sustainable development of mountain tourism in Central Serbia contribute to the advancement of the theoretical framework of sustainable tourism in several respects. The study confirms the importance of an integrated sustainability approach, which requires the simultaneous consideration of economic, environmental, social, developmental, and governance-related dimensions. The obtained results indicate that no single dimension can dominate without potentially generating negative consequences for the overall sustainability of the system, which is consistent with the multi-dimensional understanding of sustainable development [90].

The study further supports the application of fuzzy logic in tourism research, particularly in situations where evaluation depends on expert judgment and uncertain future conditions. By introducing triangular fuzzy numbers, the model enables a more flexible representation of uncertainty and subjectivity in the assessment of development alternatives. In this study, the lower, middle, and upper values of triangular fuzzy numbers allowed expert assessments to be expressed as intervals rather than fixed deterministic values. This is particularly important in mountain tourism planning, where decision making is influenced by climate variability, market uncertainty, environmental constraints, and different stakeholder priorities.

From a methodological perspective, the research contributes to the application of multi-criteria decision-making methods in tourism by demonstrating how Fuzzy TOPSIS can be used to rank development alternatives under conditions of conflicting criteria. The results show that alternatives achieving a balance between climate adaptation, environmental

protection, local community involvement, and economic viability perform better than alternatives primarily oriented toward short-term economic expansion. This confirms the practical relevance of trade-off analysis in sustainable tourism planning [91–94].

A key theoretical implication lies in the identification of climate-resilient adaptive tourism as the most suitable development model for mountain tourism in Central Serbia. This result is consistent with contemporary concepts of resilience and adaptability in tourism destinations, particularly in the context of climate change. At the same time, the high ranking of community-led tourism development confirms the importance of local participation, social sustainability, and equitable benefit distribution as essential elements of long-term destination sustainability.

5.3. Alignment with International Research

The results of this study are largely consistent with findings from contemporary international research on sustainable tourism development, particularly in mountain and environmentally sensitive ecosystems. The high ranking of climate-resilient adaptive tourism aligns with studies emphasizing the importance of flexible and resilient development models. Lew [95] highlights that sustainable tourism destinations need adaptive capacities to respond to change, while Scott et al. [2] emphasize the critical role of adaptation strategies in the context of climate change and its increasing impact on tourism systems.

The strong performance of community-led tourism development confirms findings from previous studies that underline the importance of local participation in tourism planning and management. Research shows that the involvement of local communities contributes to a more equitable distribution of benefits, the preservation of cultural identity, and the long-term sustainability of destinations [96,97]. The existing literature also stresses that environmentally oriented tourism models should be integrated with economic strategies in order to ensure long-term viability [27].

The low ranking of mass mountain tourism with climate mitigation strategies further supports research indicating the negative impacts of intensive tourism development on the environment and local communities. Mass tourism is frequently associated with pressure on natural resources, infrastructure overload, and degradation of sensitive landscapes, particularly in protected or mountain areas [98,99].

The application of the Fuzzy TOPSIS method in this study is also consistent with contemporary trends in international tourism research. Previous studies confirm the usefulness of Fuzzy TOPSIS and related hybrid approaches in evaluating tourism sustainability, destination performance, and development alternatives under conditions of uncertainty and multi-criteria decision making [23,100,101]. More broadly, TOPSIS and other multi-criteria decision-making methods are widely applied in sustainability research because they enable the structured comparison of alternatives across multiple, and often conflicting, criteria [102,103]. The results of this study therefore support existing theoretical assumptions while extending them through empirical application in the regional context of Central Serbia.

5.4. Sensitivity of Results to Triangular Fuzzy Numbers

Since expert assessments were represented through triangular fuzzy numbers, an additional sensitivity check was conducted to examine the stability of the obtained ranking with respect to moderate variations in fuzzy parameters. The lower (L) and upper (U) bounds were modified by $\pm 10\%$, while the middle value (M) was kept unchanged. The resulting rankings were then compared with the original ranking obtained from the Fuzzy TOPSIS procedure.

The sensitivity check showed that the ranking order of the alternatives remained unchanged. Climate-resilient adaptive tourism (A2) retained the highest position, followed by community-led tourism development (A4), green/low-carbon mountain tourism (A1), technology-driven sustainable mountain tourism (A5), and mass mountain tourism with climate mitigation strategies (A3). These findings indicate that the obtained ranking is stable under moderate variations in expert judgments and that the proposed framework provides a consistent basis for strategic decision making.

6. Conclusions

The conducted analysis enabled the identification and ranking of development pathways with the greatest potential for the long-term sustainable management of mountain tourism in Central Serbia. By applying the TOPSIS and Fuzzy TOPSIS methods, the study provided a structured basis for evaluating alternative development models under complex and uncertain conditions. The results indicate that climate-resilient adaptive tourism represents the most suitable development model, achieving the highest closeness coefficient ($C_i = 0.829$), followed by community-led tourism development and green/low-carbon mountain tourism.

The findings provide clear answers to the research questions formulated in the introduction. Regarding RQ1, the analysis demonstrates that climate-resilient adaptive tourism represents the most appropriate long-term development pathway for mountain tourism in Central Serbia, outperforming the other evaluated alternatives through its balanced performance across economic, environmental, social, and governance dimensions. Concerning RQ2, the results indicate that climate adaptation, environmental protection, local stakeholder participation, and sustainable governance are the key factors influencing the assessment of mountain tourism development models. Finally, with respect to RQ3, the integrated multi-criteria decision-making framework was implemented to be an effective decision-support tool for evaluating alternative tourism development strategies under conditions of uncertainty, enabling a more comprehensive and transparent assessment of sustainable development options.

The main contribution of this study extends beyond the empirical evaluation of mountain tourism development alternatives in Central Serbia. The research introduces and applies an integrated TOPSIS–Fuzzy TOPSIS framework designed to support strategic decision making in mountain tourism destinations operating under conditions of climate uncertainty, environmental sensitivity, seasonal demand, and competing sustainability objectives. By integrating economic, environmental, social, developmental, and governance-related criteria within a unified decision-support structure, the framework enables a comprehensive evaluation of alternative tourism development pathways.

The results indicate that development models achieving stable performance across multiple sustainability dimensions are more successful than those focused primarily on a single aspect. Approaches characterized by adaptation capacity, diversification, local participation, and environmental protection emerge as particularly important, while models based on intensive tourism growth and high visitor volumes reveal significant long-term limitations. The findings also emphasize the importance of aligning tourism development with the carrying capacity of the local environment in order to maintain the balance between tourism growth and resource conservation.

An additional value of the research lies in the application of a method that accounts for uncertainty and imprecision in the evaluation process. The use of triangular fuzzy numbers enabled expert judgments to be expressed through lower, middle, and upper values, rather than as single deterministic assessments. This provided a more realistic representation of the relationships among the analyzed alternatives, particularly in situations where devel-

opment planning depends on qualitative assessments, heterogeneous data, and uncertain future conditions.

An additional implication of the obtained results concerns the growing importance of geotourism as a complementary strategy for the sustainable development of mountain destinations. Given that Central Serbia possesses considerable geodiversity, distinctive geomorphological features, and valuable geoheritage resources, geotourism represents an important opportunity for diversifying the tourism offer beyond traditional winter-based activities. By integrating geological and geomorphological attractions with cultural heritage, traditional settlements, local identity, and mountain landscapes, geotourism can enhance the overall visitor experience while promoting the conservation of natural and cultural resources. Such an approach is particularly relevant under current climate change conditions, as rising temperatures and increasingly shorter snow seasons reduce the reliability of winter tourism. The development of geotourism products, including geoheritage interpretation, educational trails, geoparks, and landscape-based experiences, may therefore strengthen destination resilience, reduce seasonal dependence, and contribute to more balanced year-round tourism development. Consequently, geotourism should be considered an integral component of future sustainable tourism strategies for mountain regions, complementing climate-resilient, community-led, and green tourism development models identified in this study.

The study confirms that the sustainable development of mountain destinations must be carefully aligned with the principles of climate adaptation, environmental protection, local participation, and long-term governance capacity. In practical terms, the future development of mountain tourism in Central Serbia should be based on a hybrid model in which climate-resilient adaptive tourism is the dominant component, complemented by community-led and green/low-carbon tourism strategies. Such an approach may contribute to greater resilience to climate change, reduced dependence on winter tourism, and a more balanced distribution of tourism benefits within local communities.

Although the empirical application focuses on Central Serbia, the proposed methodological framework may be adapted to comparable mountain tourism regions facing similar challenges related to climate change, seasonality, environmental sensitivity, and stakeholder complexity. Its application in other contexts would require the adjustment of evaluation criteria, criterion weights, and expert assessments according to local environmental, institutional, and socio-economic conditions.

Future research should expand the analytical framework by including a larger number of destinations, additional sustainability indicators, and broader stakeholder groups. Further methodological development may also include sensitivity analysis, scenario-based modeling, or comparative applications in other mountain regions. Such extensions would improve the robustness of strategic decision making and provide a broader basis for sustainable mountain tourism planning under conditions of climate and market uncertainty.

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Abbreviations

The following abbreviations are used in this manuscript:

TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
FTOPSIS	Fuzzy Technique for Order Preference by Similarity to Ideal Solution
MCDM	Multi-Criteria Decision Making
FIS	Fédération Internationale de Ski (International Ski Federation)
GDP	Gross Domestic Product
PIS	Positive Ideal Solution
NIS	Negative Ideal Solution
FPIS	Fuzzy Positive Ideal Solution
FNIS	Fuzzy Negative Ideal Solution
TFN	Triangular Fuzzy Number

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