From Caspian Shores to Mountain Peaks: ICT-Powered Tourism Resilience in Azerbaijan

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Abstract. Azerbaijan's diverse geography – from mountain resorts and forested national parks to coastal areas along the Caspian Sea and historic urban centers – makes the country increasingly vulnerable to climate-related risks that affect tourism. The country spans 9 out of 11 major climate types, which generates highly varied tourism patterns, including more than 2 million annual visitors to Baku and approximately 250-300 thousand to major mountain resorts such as Shahdag and Gabala. These hazards – including heatwaves, landslides, flooding, coastal storms and pressures on heritage sites pose challenges to visitor safety and long-term sustainable development. This paper examines how information and communication technologies (ICT) can strengthen tourism risk management and climate adaptation in Azerbaijan, including regions with still-developing digital infrastructure. The paper highlights a range of accessible ICT tools (weather monitoring platforms, mobile alert systems, open-source GIS mapping and digital route guidance) that can support early warning, visitor management and spatial planning. Special attention is given to the role of crowdsourced information, including tourist feedback, geotagged images and community-based reporting. These sources can provide valuable insights even in the absence of costly technological systems. Based on this analysis, the paper proposes a practical model for integrating ICT into local governance and destination management in Azerbaijan. The findings suggest that even simple digital solutions can enhance climate resilience, protect cultural and natural heritage and improve the overall safety and experience of visitors. This approach supports Azerbaijan's broader strategy to develop smart, sustainable and competitive tourism destinations.

Keywords: Azerbaijan Tourism, Climate Adaptation, Risk Management, ICT Tools, Resilient Tourism Planning, Sustainable Destinations

1 Introduction

Tourism is one of the fastest-growing sectors of the global economy, significantly contributing to employment, income generation and cultural exchange. However, this industry is highly sensitive to climate change, as it is dependent on natural landscapes, seasonal weather patterns and environmental quality [1]. Extreme heat, floods and un-

predictable weather events can disrupt tourism activities, reduce visitor safety and negatively impact the socioeconomic stability of host territories. Research shows that tourism is often more vulnerable to climate change than many other economic sectors, highlighting the need to develop and implement proactive adaptation strategies [1].

In this context, the example of Azerbaijan, a country with exceptional natural and climatic diversity and a wide range of tourism resources, is particularly illustrative. Situated at the crossroads of Europe and Asia, Azerbaijan encompasses nine of the eleven main climate types, ranging from the subtropical coastal plains along the Caspian Sea to the snow-capped highlands of the Greater Caucasus. This diversity provides the basis for the development of various tourism segments: ski and mountain resorts, beach holidays, ecotourism and cultural and historical routes. In particular, the mountain resorts of Shahdag and Gabala, beach destinations on the Absheron Peninsula, ecotourism in the forests of Lankaran and cultural centers such as Icheri Sheher, Shusha and Sheki generate a stable tourist flow [2].

A well-developed system of specially protected areas adds additional value to the country's tourism potential. Key sites include the Shirvan National Park, Absheron National Park, Hirkan National Park and the Gizilagach biosphere reserve. Collectively, these areas occupy more than 10% of the country's territory and include internationally recognized ecosystems [3]. As tourism activity near these areas increases, the need to integrate climate change adaptation and environmentally sound management principles into spatial planning processes grows.

Climate challenges in Azerbaijan are exacerbated by natural, geographical and geodynamic factors. Approximately 25-30% of the country's territory is prone to landslides, particularly on the slopes of the Greater and Lesser Caucasus and adjacent foothills, posing risks to the development of mountain tourism clusters and infrastructure. Additionally, approximately 1300 km^2 of territory is in a potential flood zone due to river flooding and fluctuating water levels. Furthermore, the entire country is located within a seismically active zone [4; 5]. Thus, tourism development in Azerbaijan is taking place in the context of complex climate and geohazard sensitivity, requiring a systemic and interdisciplinary approach to spatial planning.

The geographic specificity of tourist destinations exacerbates the significance of these risks. Mountain resorts such as Shahdag (1300-2435 m) and Gabala (600-1500 m) face challenges with unstable snow cover and landslide activity. Meanwhile, the coastal areas of the Absheron Peninsula, with a coastline of approximately 800 km are experiencing increasing exposure to heat waves, storm surges and coastal erosion. Tourist flows reflect this spatial diversity: Baku hosts approximately 2 million foreign tourists annually, Shahdag attracts approximately 150-200 thousand seasonal visitors and Lankaran attracts 150-200 thousand tourists in the summer season (table 1.). The concentration of tourist flows in vulnerable areas increases the pressure on infrastructure and highlights the need to consider climate risks in regional planning.

Despite its wealth of natural and cultural resources. Azerbaijan's tourism sector faces increasing climate threats that could impact both the quality of the tourism product and its long-term sustainability. Rising average annual temperatures, changing precipitation patterns, more frequent extreme weather events and water shortages can negatively impact coastal resorts, mountain routes and cultural heritage sites. Scientific

research emphasizes that sustainable tourism development concepts should integrate climate factors into spatial and strategic planning systems, combining environmental and socio-economic aspects [6].

Table 1. Major tourism clusters in Azerbaijan and their climate-risk profile.

Tourism cluster	Core tourism activities	Key climate and geohazards	Visitor load (annual)	Planning priorities
Shahdag (Gusar)	Winter sports, mountain tourism	Snow variability, avalanches, landslides	250-300 thds.	Slope stabilization, climate adaptive ski infrastructure
Gabala	Resorts, adventure parks, nature tourism	Landslides, heavy precipitation, forest fire risk	200-250 thds.	Hazard-sensitive zoning, forest-interface management
Sheki-Zagatala	Heritage tourism, mountain villages	Landslides, flash floods	120 thds.	Protection of heritage zones, flood-risk spatial planning
Khinaliq (Guba)	Highland ecorouts, rural tourism	Avalanches, road closures, erosion	80-100 thds.	Climate-proof road network, controlled visitor access
Baku (Absheron)	Urban tourism, cultural heritage, coastal leisure	Heatwaves, coastal erosion, flooding	2 mln.	Coastal protection, heat-stress mitigation, digital visitor management
Lankaran, Lerik	National parks, humid forest	Flooding, landslides	150-200 thds.	Buffer zones around protected areas, slope monitoring
Naftalan	Heath tourism	Heatwaves	50-70 thds.	Climate-resilient health facilities
Goygol	Lake and national park tourism	Landslide, erosion	60-80 thds.	Visitor-capacity control, ecosystem protection

In response to these challenges, information and communication technologies (ICT) are playing an increasingly significant role as a tool for increasing the adaptability of tourist areas. Even without the implementation of a complex technological infrastructure – such as large-scale IoT sensor networks or centralized climate databases – ICT-based solutions can significantly support risk management processes. These include weather monitoring systems, open geographic information platforms, mobile alert systems and crowdsourced data collection mechanisms [7].

Given the high level of digital accessibility in the country – over 80% mobile penetration and approximately 79% Internet coverage – Azerbaijan has the necessary foundation for implementing such tools. This creates the preconditions for engaging both large tourist destinations and small operators in basic monitoring processes, participation in GIS risk assessments and the use of mobility warning systems.

Thus, in the face of growing climatic and geo-ecological challenges, a conceptual rethinking of tourism management is needed. This study proposes a conceptual ICT-based risk management model adapted to the tourism landscape of Azerbaijan. It summarizes international practices and formulates strategies aimed at increasing the resilience of tourism destinations, protecting visitors and ensuring long-term sustainable development without relying on complex technological infrastructure.

2 Literature review

The integration of information and communication technologies (ICT) into the tourism industry has become a transformative force. ICT reshapes how destinations manage services, engage stakeholders and respond to emerging challenges. Numerous studies demonstrates that ICT supports data-driven decision-making and enhances strategic planning by improving operational efficiency and communication among industry actors [8]. These technologies influence all aspects of tourism management, from reservations and marketing to service delivery and visitor experience [9].

Within the broader context of sustainable development, ICT has also recognized as a key driver of environmental quality and resource efficiency. For instance, research in China indicates that long-term ICT adoption correlates with improved environmental indicators, as digital platforms and efficiency gains help mitigate pressures from increased tourism activity [7]. These findings support the global discourse digitalization's role in balancing tourism growth with ecological sustainability.

A growing body of scholarship emphasizes the integrating disaster risk reduction (DRR) with sustainable tourism. Systematic reviews show that DRR measures – from advance planning to early warning systems – are fundamental for building resilient tourism destinations and mitigating environmental impacts [10]. Embedding risk awareness into both policy and daily management protects visitors and local communities alike.

Although research on digital twins and advanced simulation technologies in tourism is still emerging, early studies indicate substantial potential. Digital frameworks can support destination management and help preserve cultural heritage at the site level [11]. As the field devolves, digital replicas of real-world tourist environments may offer new paths for planning and resilience modeling.

ICT can strengthen collective action and coordination among stakeholders responsible for sustainable tourism management. For instance, studies of remote Arctic tourism sites illustrate that digital tools help unify dispersed actors, improve communication and promote shared sustainable norms. However, researchers note that ICT effectiveness is influenced by users' technological capabilities and broader social capacity [12].

Despite notable progress in understanding ICT's role in tourism, significant gaps remain, particularly its application to climate-related risk management in destinations with limited technological infrastructure. Most studies focus on data-rich contexts, with fewer exploring how ICT can be adapted to emerging economies with nascent digital ecosystems. This underscores the need for contextually tailored models that leverage accessible ICT solutions to strengthen tourism resilience, especially in countries like

Azerbaijan, where tourism assets are vulnerable to climate variability and infrastructure is still developing.

Recent research in Azerbaijan is beginning to addressed this gap. Studies on regional tourism development illustrate how tourism growth can support local economic and community stability across rural and urban destinations [13]. Furthermore, research on the cultural tourism sector emphasizes the importance of heritage preservation, cultural products and diversified tourism offerings in enhancing competitiveness and promoting sustainable growth [14].

3 Methodology and conceptual framework

The proposed conceptual framework for ICT-supported tourism resilience in Azerbaijan builds on the principle that digital data, spatial analysis and analytics can improve destination planning, risk assessment and decision-making, even where advanced sensor networks are not yet widespread. International research shows that geographic information systems (GIS) and digital tools increasingly inform tourism planning, visitor behavior analysis and sustainable destination management. For example, GIS technologies have been successfully applied to map points of interest and analyze visitor flows, providing evidence to guide spatial planning in historic or environmentally sensitive areas [15].

At its core, the framework integrates spatial, behavioral and contextual data layers to develop a dynamic understanding of tourism flows and climate-related vulnerabilities. Spatial data include geographic and environmental information from open platforms such as OpenStreetMap, topographic models, land cover datasets and national GIS repositories. These layers help identify risk zones, accessibility patterns and the spatial distribution of tourism assets.

A second data category encompasses digital traces of tourism activity, such as aggregated mobile traffic patterns, web searches and social media presence. These data sources have proven valuable for analyzing tourism dynamics and forecasting demand [16]. Early research indicates that user-generated content, device data, transaction and booking information can reveal patterns in visitor behavior and support strategic planning. Even without extensive IoT infrastructure [16].

Additionally, studies on nature-based tourism highlight the role of mobile applications, geospatial platforms and interactive digital tools in managing visitor flows and supporting environmental sustainability [17]. These examples suggest that digital tools can extend beyond marketing and engagement into monitoring and planning and resilience-building functions.

From these foundations, the framework envisions integrated ICT applications, including GIS-based spatial analysis, digital dashboards, aggregated behavioral indicators and scenario modelling, can be aligned into a unified system for resilience planning. Accessibility is central: initial implementation relies on open or publicly available data, while future stages may incorporate real-time IoT sensor or advanced predictive models. Research on digital twin applications in tourism shows that these tools remain emergent and exploratory, not yet widely operational [11].

In practical terms, operationalizing this conceptual framework for Azerbaijan would begin with the development of an integrated GIS database of tourism assets, risk factors and climatic variability indicators. Simple analytical dashboards can visualize seasonal patterns and hazard probabilities. Aggregated behavioral data can highlight high-pressure zones and forecast tourist flows. This system allows local authorities, tourism agencies and community organizations to make data-informed decisions that enhance visitor safety, protect natural and cultural heritage and support sustainable destination development. As ICT capacity grows, additional layers, such as predictive analytics and machine learning models, can refine resilience strategies and align them with international best practices.

This approach combines spatial clustering of tourism regions, climate-risk profiling and an assesment of ICT applicability under varying infrastructural conditions. Such a composite method allows integrating environmental risk, territorial specificity and digital capacities into a single spatial-planning oriented analytical framework.

4 ICT Applications for climate risk management in tourism

The integration of digital technologies into tourism planning has gained substantial attention in recent years, driven by the increasing need to address climate-related risk and to strengthen destination resilience. ICT tools offer mechanisms for monitoring environmental conditions, informing visitors, analyzing mobility patterns and supporting early warning systems, all of which are critical for minimizing the impact of climate variability on tourism destinations.

Environmental monitoring systems represent of the most direct applications of ICT in climate risk management. These systems collect and interpret meteorological, hydrogeological and geospatial data to support early detection of hazards. International examples show that weather-monitoring platforms, remote sensing technologies and automated alert systems substantially improve preparedness and response capacity in tourism areas. For instance, studies demonstrate that digital early warning systems significantly reduce vulnerability to extreme weather events by enhancing real-time communication with tourists and local stakeholders [18].

In Azerbaijan, the State Agency for Hydrometeorology increasingly utilizes remote sensing products and short-term forecasting models warnings about floods, landslides and heatwaves – hazards that affect tourism hub such as Guba, Lankaran and Shahdag. While these systems are not yet fully integrated into tourism applications, they form a foundation for future ICT-enabled monitoring and warning tools tailored specifically for the tourism sector.

Spatial datasets generated through ICT tools can directly support urban planning decisions, such as defining buffer zones around heritage sites, mapping evacuation corridors, regulating tourist density in fragile landscapes or adapting building codes in hazard-prone territories. GIS-based tools allow destinations to visualize risk-exposed zones, evaluate accessibility routes and assess interactions between natural hazards and

tourism infrastructure. Research highlights the use of spatial risk models, climate exposure maps and multi-criteria decision-making for evaluating hazard vulnerability in tourism destinations [19].

Such GIS-based techniques are particularly relevant for Azerbaijan, where highly diverse geography and topography create differentiated spatial planning challenges. Mountain tourism clusters such as Gabala and Shahdag are exposed to landslide activity and snow-cover variability, while coastal destinations (including Absheron, Khachmaz and Lankaran) face sea-level fluctuation, shoreline erosion and intensifying heat stress. Historic urban centers – most notably Baku's Icheri Sheher, Sheki and Ordubad - require spatial planning approaches that accounts for microclimate impacts on architectural heritage and the cumulative pressures of visitor flows. International experience demonstrates that GIS-supported vulnerability mapping, widely applied in countries such as Italy, Japan and Norway, can be effectively adapted to these conditions to inform infrastructure decision and strengthen environmental management [15].

Understanding visitor mobility pattern is equally critical for anticipating exposure to climate-related hazards and managing congestion in vulnerable areas. ICT-enabled tools such as mobile positioning data, social media analytics and geotagged imagery have proven effective for examining the spatiotemporal dynamics of tourism. Existing research confirms that mobile big data can substantially enhance the accuracy of demand forecasting, congestion detection and flow prediction [20], while social media data - from platforms such as Instagram and Twitter -provide valuable information on visitor preferences, perceived risk and real-time responses to climate-induced disruptions [21]. These digital traces, when integrated into spatial decision-making frameworks, offer a scalable source of evidence for climate-sensitive planning in Azerbaijan's tourism regions.

For Azerbaijan, such approaches can offer valuable evidence into seasonal visitor flows in Naftalan, Shahdag ski resort and Goygol National park, heat-related behavioral changes in Baku's urban tourism areas and demand fluctuations in Lahich, Guba and Sheki during periods of unstable weather.

These data can support the development of adaptive scheduling, crowd management strategies and climate-informed marketing for tourism destinations.

Mobile applications have become essential for disseminating real-time information on hazard, weather alerts and safe routes. International studies show that location-based services enhance visitor safety by providing personalized alerts and route recommendations [22; 23; 24].

Globally, destinations such as New Zealand, Japan and Switzerland already use mobile apps for avalanches alerts, heatwave notifications, trail closures and flooding updates.

In Azerbaijan, where smartphone penetration exceeds 80%, developing lightweight apps or integrating tourism functions into existing state platforms (e.g., myGov, ASAN services, Meteo.az) could ensure cost-effective and scalable communication channels for climate-related risk information.

5 Discussion

The finding and conceptual propositions presented in this study highlight that ICT-supported resilience frameworks hold significant potential for strengthening tourism sustainability in Azerbaijan, but their implementation requires a nuanced understanding of both technological capacities and socio-institutional contexts. Consistent with global research, the analysis shows that geospatial data, digital communication tools and behavioral analytics can enhance the capacity of destinations to anticipate, respond to and recover from climate-induced risks [15]. The operationalization of these tools depends on factors including data availability, institutional readiness and disparities between urban and rural digital infrastructures. Given the spatial differentiation of Azerbaijan's tourism region – mountainous, coastal, forested and heritage-urban zones – the degree of climate exposure and planning requirements vary, reinforcing the need for an ICT-supported approach where digital monitoring, early-warning tools and GIS-based zoning align risk management with territorial planning priorities.

Approximately one-quarter of Azerbaijan's territory is landslide-prone, flood-exposed areas cover substantial river basins and the entire nation is seismically active. These hazards highlight the importance of spatially informed ICT integration into urban and regional planning [4; 5]. International studies show that ICT-driven solutions – particularly GIS-based risk maps, mobile early warning systems and big data analytics – are most effective when integrated into long-term destination management strategies [25]. Countries such as Japan, New Zealand and Italy demonstrate how multi-stakeholder digital platforms combine hazard monitoring, tourist mobility data and emergency communication [26]. Compared to Italy, where coastal tourist zones host millions of visitors annually, Azerbaijan's coastal destinations receive 250-300 thousand tourists each summer, indicating smaller scale but highly climate-sensitive management needs. ICT-based tools can support hazard-sensitive zoning, infrastructural adaptation and local-specific development strategies – elements that remain underdeveloped in Azerbaijan's planning practice.

At the same time, Azerbaijan possesses comparative advantages that can accelerate digital adoption, including high mobility phone penetration, expanding broadband coverage and e-government initiatives (e.g., ASAN, eGov portal) - providing a strong foundation for ICT applications in tourism resilience. Its diverse climatic structure, - nine climate zones - generates highly differentiated vulnerability patterns. Mountain areas such as Gabala, Gusar and Shahdag face snow-cover variability, landslides and glacial melt dynamics, where coastal areas including Absheron, Lankaran and Khachmaz are exposed to heat stress, shoreline erosion and episodic storm surges. Cultural heritage sites – most notably Sheki, Baku's Old city, Ganja and Ordubad – experience humidity variation, localized heat islands and rising visitor pressure, making digital monitoring platforms and predictive modeling valuable for conservation-oriented spatial planning.

By aligning ICT applications with these region-specific climatic patterns, Azerbaijan can formulate differentiated resilience strategies that correspond to the distinct environmental and cultural profiles of its tourism destinations. This approach also addresses

the limitation of generic climate adaptation frameworks commonly presented in international studies, demonstrating the need for localized, spatially sensitive and heritage-conscious digital solutions.

Compared to large-scale protected landscape in countries like Italy or New Zealand, Azerbaijan's preserved zones - from semidesert ecosystems of Shirvan National park to the humid forests of Hirkan National park - are similar in area but extremely diverse in ecological function. This increases the spatial planning challenge. So, even small disturbances like tourist inflow, erosion, unauthorized access, can create disproportionately large impact. Therefore ICT-supported climate risk tools should be integrated not only into tourism strategies, but also into land-use regulation around these preserved territories to ensure ecologically stability resilience.

A critical insight emerging from this study is that institutional collaboration is as important as technological capability. Tourism resilience requires coordination among the Ministry of Ecology and Natural Resources, the State Tourism Agency, local authorities and private tourism operations. Without shared data protocols and inter-agency platforms, ICT tools risk becoming fragmented.

Successful integration of ICT into climate-risk management requires embedding digital monitoring and geospatial analytics into regional master plans, general plans of tourism zones and protected-area management strategies.

Global evidence shows that destinations with strong governance mechanisms – such as those in Norway and South Korea – tend to adopt ICT-based risk tools more successfully. Azerbaijan's ongoing reforms in digital governance are promising, but tourism-specific integration remains limited. The absence of formal data-sharing mechanisms, limited training in GIS and analytics for regional tourism departments and insufficient involvement of local communities create obstacles that must be addressed before the full potential of digital resilience systems can be realized.

Another dimension revealed by the analysis related to equity and accessibility. While mobile phone penetration is high nationally, disparities persist between urban centers like Baku and remote mountain settlements. ICT-based systems may unintentionally reinforce inequalities if local tourism operators – guesthouses, ecolodges, small tour companies – lack the digital literacy necessary to participate in data sharing or use mobility dashboards.

From spatial planning perspective, unequal access to ICT between urban and rural territories may translate into uneven adaptive capacities, influencing regional development trajectories and resilience planning.

Research from developing regions highlights that ICT-driven resilience frameworks are effective only when accompanied by efforts to increase digital skills and ensure inclusive access. In Azerbaijan, this calls for targeted capacity-building programs, especially in Guba-Khachmaz, Sheki-Zagatala and Shirvan tourism clusters where small-scale tourism enterprises dominate.

Implementing the proposed framework can generate tangible benefits across institutional, economic and community domains. For policymakers, it enhances the capacity to delineate high-risk tourism zones, prioritize spatial investments and integrate climate-sensitive criteria into regional and urban planning processes. For tourism enterprises, the framework contributes to more reliable demand projections by incorporating

mobility and behavioral evidence, while also reducing operational vulnerabilities through earlier warnings and more flexible scheduling. For local communities, improved risk management strengthens the stability of tourism-dependent livelihoods by mitigating climate-related disruptions and provides new avenues for participation in monitoring and reporting mechanisms supported by ICT tools. These practical benefits reinforce that ICT-enabled resilience should be viewed not simply as a technological enhancement but as an essential strategic component of sustainable tourism development in Azerbaijan.

ICT-based resilience approaches are increasingly recognized as consistent with global sustainability agendas. Studies from China, Europe and the Pacific show that digitalization can promote environmentally responsible form of tourism by reducing resource inefficiencies, alleviating pressure in sensitive landscapes and improving the spatial coordination of land-use decisions [17]. In the context of Azerbaijan – where tourism development intersects with culturally significant sites and ecologically fragile territories – the use of ICT instruments can meaningfully contribute to broader national objectives, including the preservation of biodiversity within protected areas, the safeguarding of UNESCO-recognized heritage, the promotion of low-impact tourism practices and the reduction of extensive dependence on climate-sensitive seasonal activities. In this sense, digitalization functions not only as a mechanism for climate-risk mitigation but also as a catalyst for more sustainable and balanced territorial development [17].

Further research is nevertheless needed to strengthen the empirical basis for ICT-enabled resilience in Azerbaijan. Important directions include the application of the proposed framework to specific destinations such as Shahdag or Goygol, the integration of localized climate datasets from the Ministry of Ecology and Natural Resources with tourism indicators to refine spatial modelling and the exploration of digital twin methodologies for safeguarding cultural heritage sites in Baku and Sheki. Additional attention should be given to understanding community-level digital literacy, which may shape the feasibility of ICT uptake, as well as to evaluating the potential of mobile early-warning applications designed specifically for tourists. Advancing these research areas will support the development of more grounded, context-sensitive strategies for climate adaptation and digital transformation within Azerbaijan's tourism system.

6 Urban and spatial planning strategies for ICT-enhances tourism resilience

The findings of this study highlight that the integration of ICT into urban and regional planning is essential for building resilient tourism destinations in Azerbaijan. Spatial planning functions as a coordinating framework that links tourism management, climate adaptation and sustainable development, ensuring that growth is guided by coherent environmental, social and economic principles. Given the country's diverse geography – from the Caspian coastal plains to the high mountain systems of the Greater Caucasus – planning approaches must be sensitive to regional variability in climate exposure, topography and tourism dynamics.

Mountain destinations such as Gabala, Guba (including Shahdag and Khinalig) and Gusar are characterized by complex terrain and climate-sensitive conditions, including landscape-prone slopes, snow-cover fluctuations, and meltwater processes. In such settings, planners can rely on GIS-based slope analysis, hazard overlays and trail optimization models to inform the design of safe hiking routes, ski trails and transport access. For instance, the Shahdag ski resort could strengthen safety management by integrating snow-depth sensors with GIS-supported visitor-flow simulations, thereby reducing congestion and minimizing accident risks. Similarly, ecotourism areas in Gabala may benefit from seasonal runoff modelling and landslide susceptibility analysis, which can guide local zoning and infrastructure placement.

Coastal regions such as Absheron, Lankaran and Khachmaz face distinct pressures associated with shoreline erosion, heat stress and periodic storm surges. Spatial planning responses in these areas include coastal setback regulations for tourism infrastructure, buffer-zone designation and climate-informed strategies for urban expansion. Open-access GIS mapping of erosion-prone coastal segments on the Absheron peninsula can assist local authorities in development control, while real-time meteorological alerts and hazard maps embedded in tourist applications enhance visitor safety and preparedness.

Heritage-rich urban centers – including Baku's Icheri Sheher, Sheki, Ganja, Ordubad and the historical settlements of Ismayilli (Lahij and Basgal) – require planning approaches that balance conservation priorities with climate adaptation and visitor management. ICT-enabled monitoring systems can track visitor density, microclimatic variations and structural sensitivity of heritage buildings. For example, the Palace of the Sheki Khans would benefit from microclimate sensors integrated with GIS-based visitor tracing to mitigate pressure on fragile interiors, while urban planning could reinforce pedestrianization and adaptive routing strategies to reduce local congestion.

ICT tools can strengthen these spatial-planning strategies by improving the visibility, coordination and analytical capacity of decision-makers. GIS-based hazard and asset mapping supports real-time visualization of risk patterns and land-use constraints, while digital dashboards and scenario-modelling platforms enable simulations of tourism flows, urban growth trajectories and climate impacts [27]. Crowdsources data and mobile analytics deepen the understanding of visitor behavior and seasonal dynamics, informing adaptive zoning, mobility planning and operational readiness [28]. Integrating these digital resources into municipal and regional planning platforms ensures that tourism, environmental and urban datasets converge, reducing fragmentation and enhancing the coherence of planning decisions. These stages from a progressive, multi-level approach to ICT-enabled resilience that links spatial planning with digitalization (Table 2).

Table 2. ICT-integrated spatial planning model for climate-resilient tourism in Azerbaijan

Adaptive stage	Planning focus	ICT-function	Typical tools/Application

Reactive (Vulnerability is acute)	Short-term responses; hazard awareness; temporary restrictions in high-risk areas	Basic information flows; initial digital mapping; early notifications	SMS alerts, simple weather monitoring, isolated GIS risk maps, basic crowdsources reporting
Transitional (Vulnerability is chronic)	Medium-term adjustments; route optimization; early elements of climate-sensitive zoning	Integrated datasets; municipal tourism data exchange; monitoring of visitor flows	Mobile route apps with hazard information, open-source GIS in municipal workflows, crowdsourced hazard mapping, mobility pattern analytics
Transformative (Vulnerability is reduced)	Long-term strategic planning; resilient infrastructure design; climate-adaptive regional policies	Fully integrated digital ecosystem supporting predictive modelling and coordinated decision-making	Digital twins of tourism areas, AI-based risk forecasting, unified ICT planning platforms, real-time environmental sensors, data-driven zoning tools

Institutional coordination remains crucial. Effective and sustainable ICT adoption requires close collaboration between urban planners, environmental agencies, tourism authorities and local communities. Shared spatial-data platforms can consolidate hazard information, mobility indicators and development constraints, preventing isolated decision-making and reinforcing resilience at multiple governance levels. Embedding climate adaptation criteria in zoning regulations, expanding the use of GIS in municipal workflows and promoting participatory planning where communities contribute to monitoring and data validation can further support integrated territorial management. Strategically differentiated resilience strategies – tailored separately for mountainous areas, coastal zones and heritage cities – are essential to balance visitor management with environmental and cultural preservation.

Advantages arising from this integrated approach are evident across different territorial categories. In mountain regions, ICT-supported planning can reduce landslide exposure, optimize ski and ecotourism infrastructure and enhance safety. In coastal zones, climate-informed land-use strategies strengthen protection against erosion and flooding while improving heat mitigation. In heritage cities, digital monitoring contributes to reducing visitor pressure, adapting public spaces to climatic stressors and safeguarding culturally significant buildings.

For the preserved territories of Azerbaijan, spatial planning should prioritize climate-buffer corridors, impact-controlled visitation routes and strict construction limitations near sensitive ecosystems. Ecosystem-oriented development guidelines are particularly relevant for highland parks, where erosion risks are elevated. Embedding ICT-based environmental and visitor monitoring into these planning processes ensures that tourism development remains compatible with biodiversity protection and long-term climate resilience.

7 Conclusion

This study examines how ICT-supported frameworks can enhance climate resilience within Azerbaijan's tourism sector, emphasizing the intersections between tourism planning, urban development and spatial management. The results demonstrate that even in the absence of extensive IoT networks or full-scale digital twin systems, Azerbaijan can effectively rely on accessible geospatial tools, open-data platforms and behavioral indicators to reinforce destination resilience and support the integration of sustainable tourism into wider territorial planning processes.

From a spatial planning perspective, the analysis underscores the value of climate-sensitive GIS mapping, visitor-flow and hazard monitoring as core components of urban and regional development strategies. Heritage centers such as Baku's Old city, Sheki and Ganja illustrate the need for planning approaches that balance accessibility with conservation imperatives and the protection of microclimatic conditions surrounding historic structures. Mountain tourism clusters including Gabala, Shahdag, Zagatala and Guba, as well as coastal zones such as Absheron and Lankaran, similarly benefit from risk-informed zoning, infrastructure optimization and corridor design that anticipate landslides, erosion, heat stress and other hazards. These approaches facilitate multi-criteria spatial evaluation and strengthen adaptive urban management [29].

International research further supports the conclusion that integrating ICT with urban planning methodologies enhances resilience outcomes. Evidence from Italy and Japan demonstrates that GIS-based hazard mapping improves the planning of urban infrastructure, emergency access routes and heritage-site protection. Studies from emerging economies show that digital resilience tools can be effective even in low-capacity environments, especially when built upon open-source geospatial platforms and mobile-based alert systems.

Azerbaijan's diverse climate zones, rapid ongoing digitalization and existing e-governance initiatives – such as ASAN service and national eGov platform – provide enabling conditions for expansion of ICT-supported spatial planning. Incorporating digital dashboards, hazard maps and mobility datasets into municipal and regional decision-making can help authorities optimize land use, safeguard natural and cultural assets and enhance visitor safety, while also supporting broader objectives related to sustainable economic development.

Several conceptual and methodological gaps identified in this study indicate the need for continued research. Future work should include empirical testing of ICT-based spatial planning tools in both urban and rural destinations, along with the integration of tourism and climate indicators into local authorities' GIS systems to support unified territorial management. Further inquiry into community-based digital platforms could strengthen participatory planning in environmentally and culturally sensitive areas, while the development and evaluation of predictive models may improve scenario planning for climate-indices risks. Strengthening interagency coordination – particularly between urban planners, tourism authorities and environmental institutions – remains essential to ensure that ICT tools are applied coherently and effectively.

In summary, ICT-enabled spatial planning frameworks represent a practical, scalable and context-sensitive pathway for improving the resilience of Azerbaijan's tourism

sector. Aligning digital tools with climate adaptation strategies and integrated urban planning can enhance the protection of natural and cultural heritage, strengthen territorial governance, and support sustainable growth across both urban and rural destinations.

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