Climate Risk Assessment of Urban Mobility in Prishtina

Regional Climate Partnership
GERMANY – WESTERN BALKANS

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Preface

This Climate Risk Assessment (CRA) provides a rigorous, data-driven evaluation of the current and projected climate risks threatening the urban mobility ecosystem of Prishtina, Kosovo. Developed under the regional project "Green Agenda: Climate Change Adaptation in the Western Balkans," implemented by GIZ, this report establishes the empirical evidence base required to integrate climate resilience directly into Prishtina's local climate action planning, future Sustainable Urban Mobility Plan (SUMP) updates, and municipal capital infrastructure procurement frameworks.

Project Context

Funded by the German Federal Ministry for Economic Cooperation and Development (BMZ) and spanning six Western Balkan countries (2024–2026), this regional initiative aims to accelerate the implementation of the Green Agenda. The project focuses on improving decision-making foundations, boosting regional knowledge sharing, and implementing scalable climate adaptation strategies specifically within the agriculture and urban transport sectors.

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EXECUTIVE SUMMARY

This Climate Risk Assessment (CRA) provides a rigorous, data-driven evaluation of the current and projected climate risks threatening the urban mobility ecosystem of Prishtina, Kosovo. Developed under the regional project Climate Change Adaptation in the Western Balkans (WB Adapt) implemented by GIZ, this report establishes the empirical evidence base required to integrate climate resilience directly into Prishtina’s local climate action planning, future Sustainable Urban Mobility Plan (SUMP) updates, and municipal capital infrastructure procurement frameworks.

Prishtina combines a rapidly growing urban core, a high reliance on private motorized vehicles (accounting for 45 – 50% modal split), and an overstretched public transit network. Its topographically constrained basin location, paired with the historical underground channelling of its primary streams (the Veluša and Prištevka), severely limits natural water-absorption and local microclimatic cooling. These baseline environmental conditions make Prishtina one of the most climate-exposed and vulnerable urban centres in the region, with risks directly impacting the safety, comfort, and reliability of daily movement patterns.

The assessment strictly follows the risk-based methodological framework outlined in the **GIZ Climate Risk Sourcebook (2023)**, utilizing the standard core risk paradigm:

Risk = Hazard x Exposure x Vulnerability

To ground the risk profile in local, empirical evidence, the framework normalizes and integrates multi-source geospatial, climatic, and socio-demographic indicators into a standardized five-class scoring system (20% increments) across three core pillars:

- **Hazard Identification**: Derived from the Western Balkans Climate-Proofing Platform (historical baseline 1981–2010), IHMK Hydrometeorological Yearbooks, and Copernicus ERA5 urban downscaling datasets. Long-term climate projections are modeled under the high-emissions RCP 8.5 scenario up to the year 2100.
- **Spatial Exposure Mapping**: Processed in a GIS environment by overlaying calculated climate hazard layers over transport network vectors provided by Prishtina Municipality (including 586.60 km of roads, 192.50 km of sidewalks, 46.50 km of cycling lanes, and 339 bus stops).
- **Vulnerability Metric Integration**: Rooted in the 2024 Kosovo Agency of Statistics (ASK) Census, tracking populations with reduced physiological or socio-economic adaptive capacity to withstand transit disruptions (such as elderly cohorts [12–19%] and children under 14 [20–30%]).

The analytical results identify specific structural and operational vulnerabilities across Prishtina's transport network, categorized by their systemic risk levels:

Critical Tier: Urban Heat Islands (UHI) & Extreme Heatwaves

Extreme summer heatwaves intersect with intense UHI effects to form the city's most critical mobility threat. Driven by a regional warming trend of 0.4°C per decade, the historical baseline of 5–25 days/year exceeding 30°C is projected to reach 40–60 days/year by mid-century under RCP 8.5.

Thermal remote sensing confirms that central urban zones record Land Surface Temperatures (LST) up to 6°C higher than rural baselines, heavily concentrating heat across *Qendra* and *Lakrishtë*. Physical exposure mapping tracks significant vulnerabilities: **100% of pedestrian underpasses**, **68.70% of parking spaces**, **59.50% of traffic signaling nodes**, and **35.10% of cycling paths** sit within high-heat zones. This causes asphalt softening and rutting along high-volume arterials (e.g., Bill Clinton Boulevard), drops active transit safety, and triggers mechanical breakdowns or A/C failures in public buses running steep uphill routes toward *Veternik* and *Kalabria*.

Moderate Tier: Pluvial (Urban) Flooding & Precipitation Extremes

While total annual precipitation (~700 mm) remains stable, short-duration, high-intensity storms exceeding 20 mm/hour are projected to increase to 12–15% of all rainfall events by mid-century. Under the RCP 8.5 pathway, 99.9th percentile daily rainfall events will rise by 20–25%, scaling up to 38–42 mm/day. High surface sealing and an undersized stormwater grid create localized pluvial flooding sinks.

The highest exposure is concentrated at active transport links: **3.40% of cycling paths**, **7.30% of surface parking zones**, **7.10% of traffic signaling electronics**, and **1.30% of pedestrian sidewalks** flood regularly. Standing stormwater collects along low-lying curb cutouts and painted bike lanes, disrupting active mobility, short-circuiting traffic networks, and flooding critical underpasses and transit bottlenecks.

Localized Tier: Geomorphological Instability & Winter Freeze-Thaw Stress

- Landslides & Soil Erosion: Prishtina accounts for 15.38% of all geomorphological slope failures in Kosovo, ranking first in landslide events that directly damage road infrastructure. Intense precipitation events saturate soils and destabilize slopes along steep, un-vegetated inclines, expanding unstable land cover to a projected 3–4% by mid-century. Impacted infrastructure tracks along highly localized peripheral sectors: 33.30% of structural road bridges (1 out of 3 major spans), 3.70% of passenger rail lines, and 1.80% of bus stops are directly exposed, primarily affecting the hillsides of the *Arbëria* neighborhood.
- Freeze-Thaw & Winter Pollution: Freezing days (below 0°C) are projected to drop from 55–60 days/year down to 30–40 days/year by late century. However, volatile freeze-thaw cycles oscillating around 0°C will persist in the near term, affecting 2.20% of cycling lanes, 1.10% of public transport routes, and 0.50% of sidewalks. Moisture expansion within road fissures accelerates severe pavement cracking and deep pothole formation. These winter conditions are severely worsened by intense temperature inversions that regularly trap vehicle and lignite heating emissions, driving the Air Quality Index (AQI) up to an unhealthy 186.

To shift from reactive maintenance to proactive climate risk management, Prishtina must prioritize green infrastructure, including planting tree canopies, constructing bioswales, and replacing 103,000 m^2 of asphalt parking lots with permeable pavers to absorb a projected 42 mm/day storm threshold and lower intense urban heat. Concurrently, the municipality must mandate climate-resilient engineering standards by anchoring automated slope sensors in landslide-prone Arbëria, procuring transit fleets equipped with heavy-duty HVAC systems, and launching a cross-sectoral IoT vulnerability database. These integrated interventions will systematically imbed real-time climate data into future SUMP updates and infrastructure procurement contracts, securing the city's active and public transit networks against escalating weather anomalies.

PRISHTINA PROFILE

The Climate Risk Profile for Prishtina City draws on a wide set of technical and policy resources referenced throughout the report. These include the Western Balkans Climate Proofing Platform[1], the Kosovo's National Energy Strategy[2] and its Implementation Program (ESIP) 2022–20253, which provides a national energy and climate action planning context; Hydrometeorological Yearbooks of Kosovo[4], which offer detailed hydrological analyses; and the Sustainable Urban Mobility Plan (SUMP)[5] and GCAP Prishtina 2021[6] shared by Prishtina Municipality, which contributes mobility system data, infrastructure mapping, and long-term transport planning priorities.

The Western Balkans Climate-Proofing Platform[7] provides climate projections, hazard datasets and harmonised for the region, observed climate data for the 1981–2010 baseline, making it a reliable source for assessing Prishtina's current climate conditions. Variables such as heat days, tropical nights, precipitation intensity, freeze-thaw cycles, snow days, and extreme wind events correspond directly to the selected hazard indicators and accurately describe the climate stresses already affecting urban mobility. Using these observed datasets ensures that the current-state assessment reflects real exposure patterns and aligns with GIZ guidance to ground risk analysis in empirical, locally relevant climate information.

Baseline Environmental and Air Quality Context

The Municipality of Prishtina features a temperate continental climate, sitting at a baseline urban elevation of approximately 573 meters above sea level within a topographically constrained basin framed by hills. Rapid urban growth and limited rainfall have intensified scarcity, with Batllava and Badovci Lakes supplying around 92% of the city's drinking water but struggling to meet rising demand. The city core lacks open natural river systems due to the mid-to-late 20th-century channelling of its historical streams (the Veluša and Prištevka) into enclosed underground pipe networks. This structural loss of open blue infrastructure severely degrades natural water-absorption capacity and eliminates potential localized urban cooling zones.

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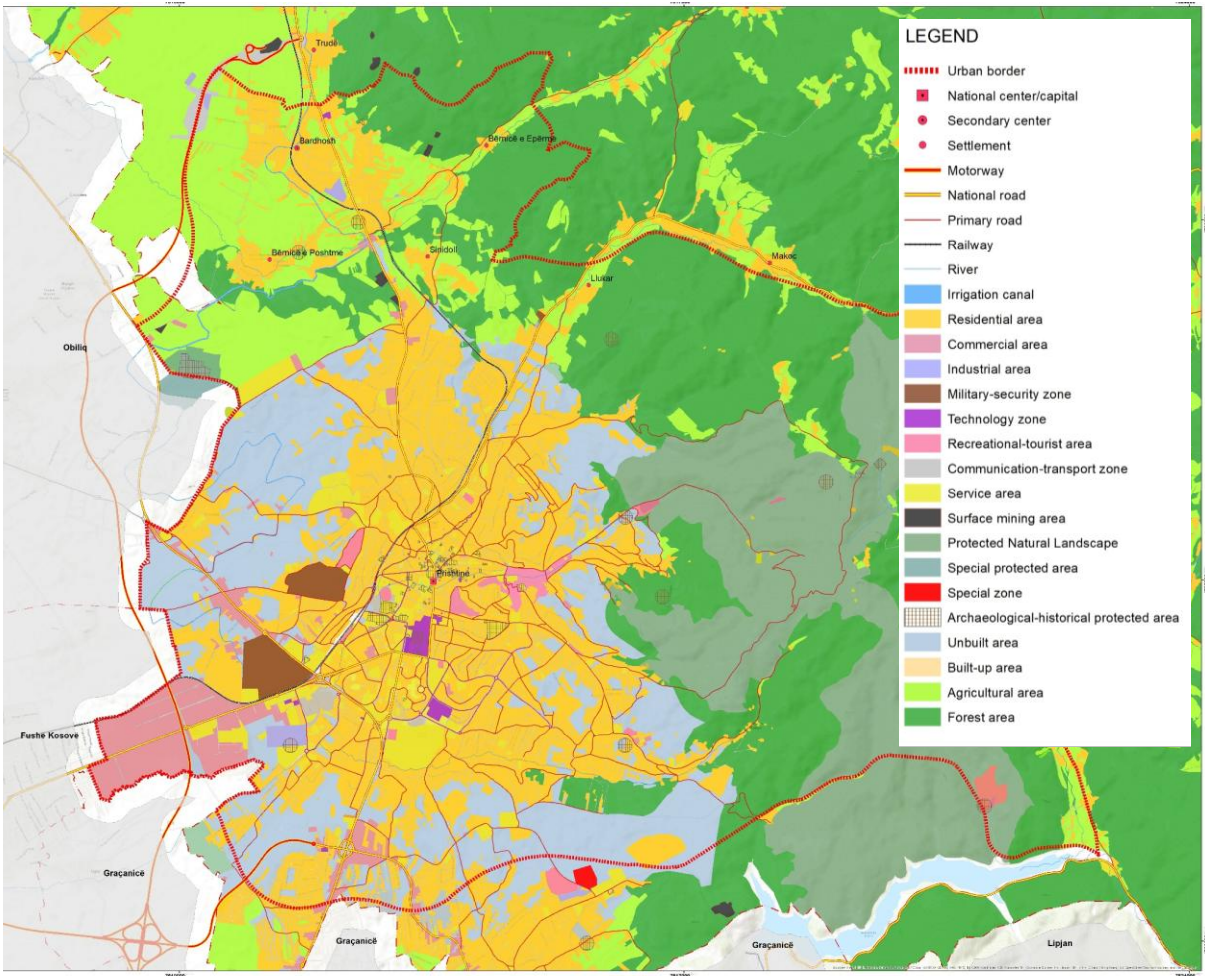
1 https://test.wb-ccp.com/home
2 me.rks-gov.net/wp-content/uploads/2023/04/Energy-Strategy-of-the-Republic-of-Kosovo-2022-2031-1-1.pdf
3 https://me.rks-gov.net/wp-content/uploads/2023/10/PZSEK-2022-2025_SHQ.pdf?utm_source=chatgpt.com
4 https://ammk-rks.net/assets/cms/uploads/files/Vjetari%20Hidrometeorologjik%202023-al-.pdf
5 prishtinaonline.com/uploads/sump_pristina_final_report_en_a.pdf
6 Pristina-GCAP_ENG_August-2021.pdf
7 https://test.wb-ccp.com/#/map?author=boku&dataType=obs

Land use in the urban core is dominated by dense residential, commercial, and institutional development, leaving little space for household gardens or small-scale food production that once characterized the city. Soil fertility has declined due to compaction, runoff, and construction debris, while green spaces are scarce and fragmented.

Figure 1: Map of land use in Prishtina municipality [8]



Prishtina's energy profile is guided by Kosovo's transitional energy strategy, yet the urban core remains heavily dependent on carbon-intensive, lignite-fired power plants that expose residents to chronic air pollution and supply instability. While municipal participation in initiatives like the City Climate Finance Gap Fund signals steps toward low-carbon development, scalable renewable integration and grid resilience planning remain in their early stages. Prishtina's waste management system relies primarily on municipal collection and disposal at the Mirash landfill, but it faces structural challenges due to minimal source separation, low recycling capacity, and informal dumping. These issues reflect the broader environmental pressures of rapid urban growth, making the integrated management of waste, water scarcity, soil degradation, and energy dependence essential for the city to build long-term resilience and meet European sustainability goals.

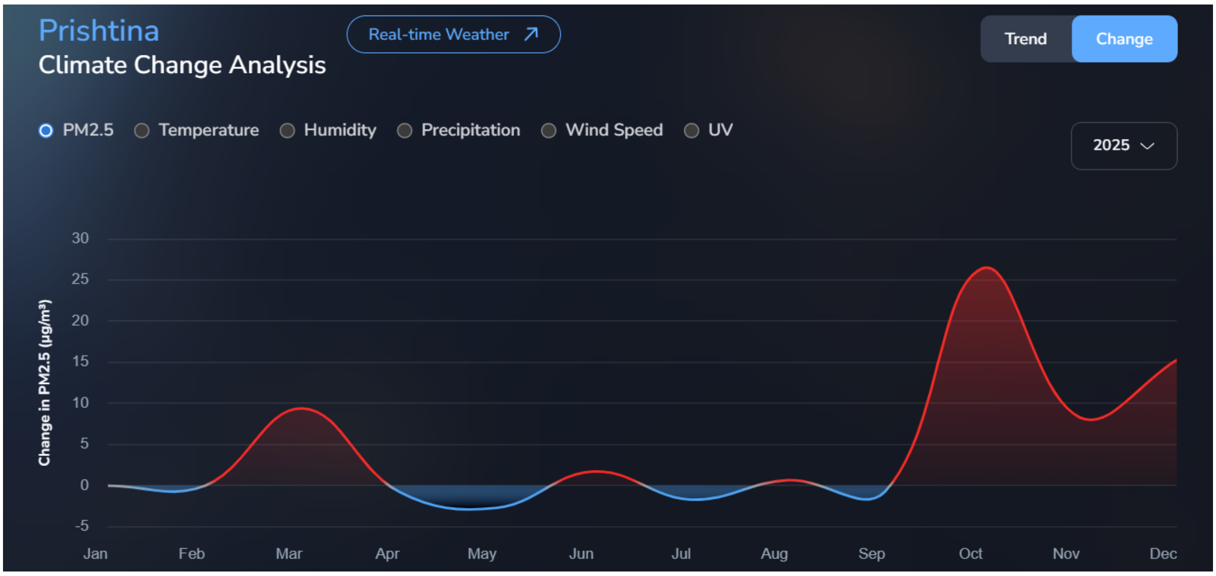
[8] Source: Draft Prishtina Municipal Development Plan 2023 – 2031

Ambient air quality is a major environmental and public health issue, displaying severe seasonal variations driven by urban pollution and meteorology:

- **Particulate Matter (PM2.5) Long-Term Trend**: Longitudinal monitoring demonstrates a clear degradation in air quality. Since 2010, average PM2.5 concentrations within Prishtina have increased by approximately 17.9 µg/m³.
- **WHO Guideline Variance**: Prishtina's annual average PM2.5 concentration stands at 14.2 µg/m³, which is 2.8 times higher than the World Health Organization (WHO) annual guideline threshold of 5 µg/m³.
- **Winter Peak Events**: During the late autumn and winter seasons (particularly October through December), stable atmospheric conditions, shallow boundary layers, and intense temperature inversions prevent pollutant dispersion. These factors trap high emissions from household lignite heating, private transport, and regional coal-fired power plants (Obiliq). Peak single-day monitoring events frequently reach an Air Quality Index (AQI) of 186, placing Prishtina among the most polluted major urban areas internationally during winter inversion episodes.

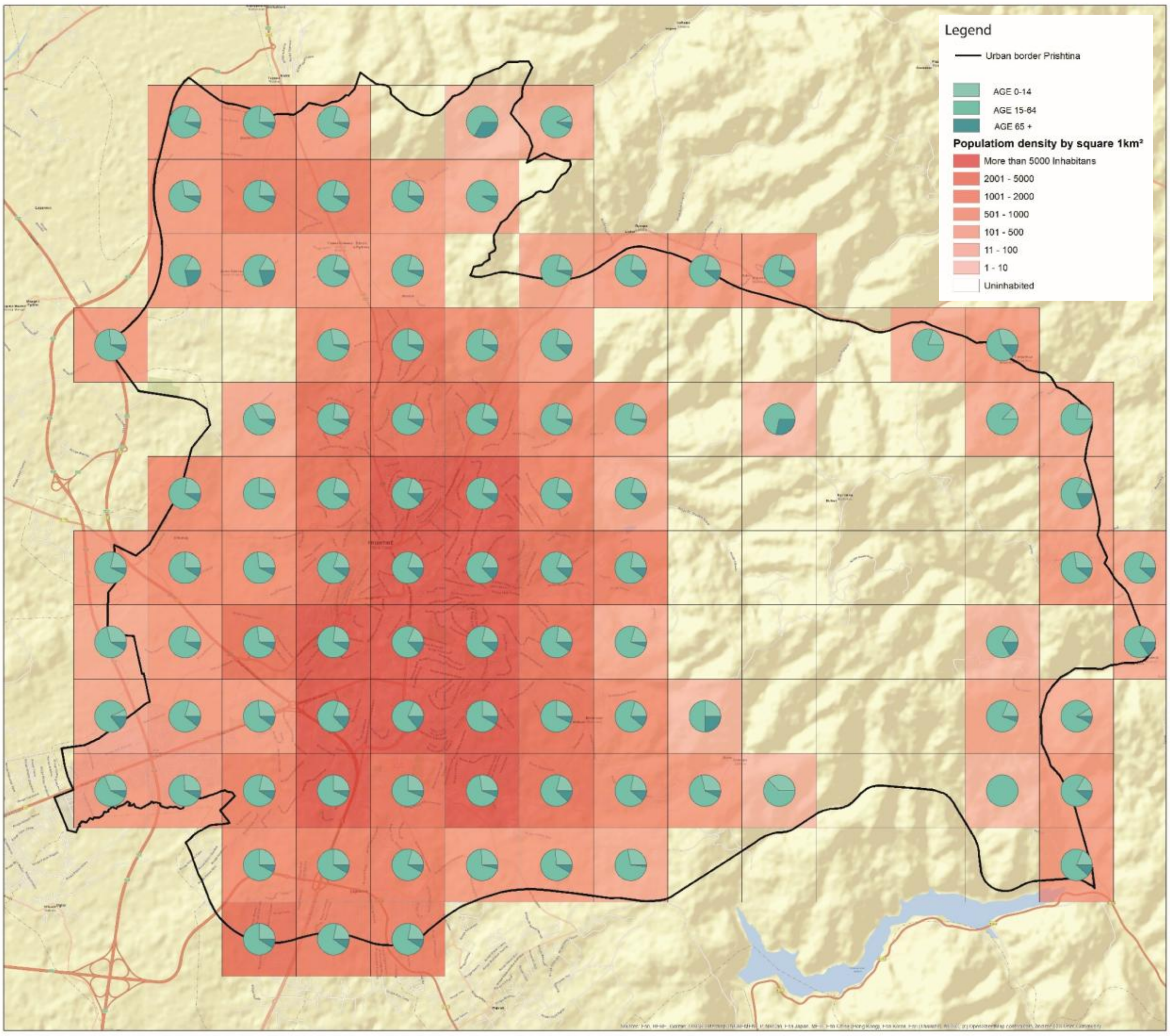
Figure 2: PM2.5 concentrations in Prishtina

Source AQI https://www.aqi.in/in/climate-change/kosovo/pristina/prishtina



Demographic and Social Vulnerability Matrix

Figure 3: Map of population density in Prishtina city[9]



All 227,466 inhabitants of the City of Prishtina lived in 58,710 economic households during the last population census in Kosovo (2024)[10].

Table 1: Quantification of Social Vulnerability indicators

Indicator	*Estimated %*	*Basis for Estimate*
Elderly population (65+)	12-19%	ASK Census 2024
Chidren (<14)	20-30%	ASK Census 2024

[9] Source: Kosovo Agency of Statistics, Census 2024
[10] KAS, Population census ReKos2024, URL: https://ask.rks-gov.net/Events/Details/8430

Low-income households	15-35%	World Bank Consumption Poverty in Kosovo; KIPRED profiles
Chronically ill cohorts	15-25%	WHO Rapid Assessment of Primary Health Care; ASK health surveys
Single-parent households	4-8%	UN DESA Household Composition Database; ASK Census 2024
Disabled population	7-9%	UN Kosovo Team; ASK Census 2024

Transport and Modal Split

Prishtina's mobility framework is characterized by a radial road network that focuses traffic toward central nodes (such as Zahir Pajaziti Square and Mother Teresa Boulevard) along high-volume arterials including Bill Clinton, Agim Ramadani, and Luan Haradinaj Boulevards. Rapid, uncoordinated peri-urban expansion (e.g., Veternik, Lagjja e Muhaxherëve, Aktash, Mati, and Arbëri) has expanded the city footprint beyond the reach of structured public transit networks.

The 2019 Sustainable Urban Mobility Plan (SUMP) baseline modal split shows a highly car-dependent ecosystem:

- Private Motorized Vehicles: Account for 45% – 50% of all daily urban trips.
- Walking: 30% – 35% of daily travel behavior, though walking remains concentrated inside the pedestrianized center and faces significant fragmentation elsewhere.
- Public Transit (Bus): Tracks below 15% of total trips.
- Cycling: Accounts for less than 1.0% due to severe network discontinuities, a lack of physical lane protection, and safety issues.

Public transport logistics are currently undergoing a modernizing shift. Trafiku Urban, the sole public operator, manages 51 standard 12-meter diesel buses across 9 routes. Up to 30 uncoordinated smaller private operators complement the outer radial routes. The Municipality established a dedicated Directorate for Mobility in October 2025[11], to manage the public transport reform currently underway, financed by a loan from EBRD.

Physical infrastructure deficiencies remain widespread. Bus lines are delayed by mixed-traffic congestion since they lack dedicated right-of-way lanes. Most bus stops lack standardized shelters, information displays, and physical shading, which directly exposes waiting passengers to local weather conditions.

Street space is heavily impacted by widespread informal parking practices on sidewalks and public squares. This reduces active mobility access and creates significant traffic blockages.

Figure 4: Isochrone map of public transport stops, and the area they service (500 m walksheds)[12]

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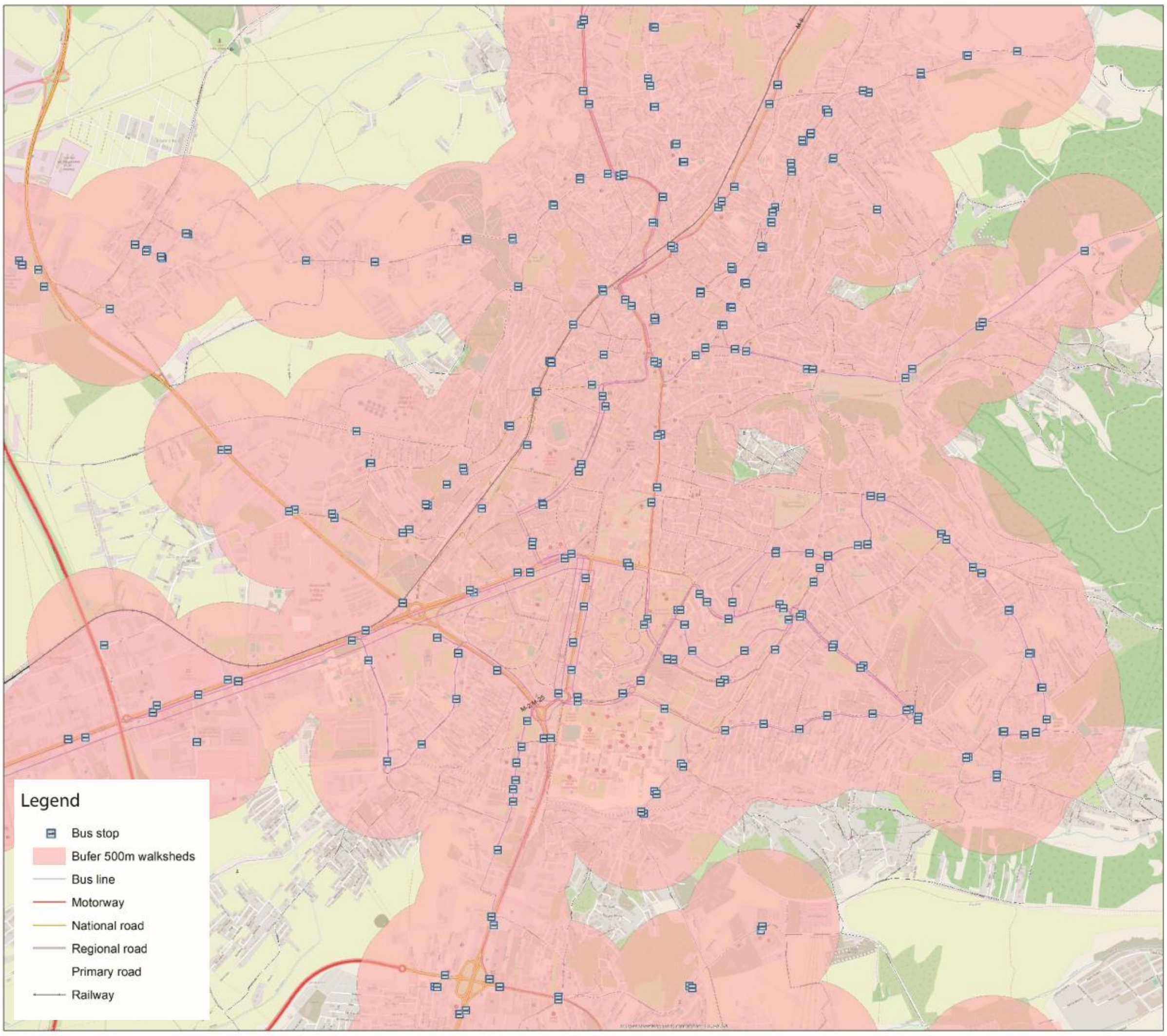
[11] https://prishtina.rks-gov.net/document/vendim-per-emerimin-e-drejtorit-ne-drejtorine-e-mobilitetit-te-kryeqytetit-z-donat-lushaku/

[12] Map generated from the information gathered from Municipality of Prishtina.



Transport-related emissions are rising, with the sector contributing over 30% of local air pollutants.[13] Traffic congestion, noise, and parking stress are daily realities, especially near schools, hospitals, and administrative buildings. These trends threaten both environmental quality and social equity, as low-income residents face longer, costlier, and less reliable commutes.

Strategic Directions of the SUMP

The Sustainable Urban Mobility Plan (SUMP) for Prishtina offers a ten-year roadmap to shift the city toward a more inclusive, efficient, and sustainable transport system. Its vision "a city that moves together, cleanly and safely" is translated into twelve strategic pillars and over sixty measures, aligned with four overarching goals: accessible, green, integrated, and smart mobility.

[13] SUMP Prishtina (2019)

A first set of measures targets the reorganisation of the road hierarchy. Key boulevards will be redesigned as multimodal corridors, with dedicated bus lanes, protected cycle tracks, and widened sidewalks. Traffic calming and pedestrianisation will expand beyond the city centre, creating safer, quieter neighbourhoods. The inner ring will be restructured to prioritise public and active transport, while outer bypasses will absorb through-traffic (Figure 3).

Public transport reform is central. The SUMP proposes a new network structure, integrated ticketing, and real-time passenger information. Fleet renewal will prioritise electric and low-emission buses, supported by depot upgrades and driver training. A new intermodal terminal is planned near the railway station, linking urban buses, regional coaches, and future rail services.

Cycling will be promoted through a citywide network of protected lanes, secure parking, and public bike-sharing (Figure 4). Prishtina's SUMP proposes a citywide cycling network, though at a strategic (conceptual) level rather than as a fully designed network. The Plan foresees the creation of a primary and secondary cycle route network linking residential areas with the city centre, schools, employment zones, and public transport hubs; new and upgraded cycle lanes to address current discontinuities and safety gaps; secure bicycle parking at key destinations and transport interchanges; and the introduction of a public bike-sharing system to support everyday cycling and first/last-mile connections.

Awareness campaigns and school-based programmes will normalise cycling as a daily mode. Walking will be enhanced through continuous sidewalks, safer crossings, and "School Streets" that restrict car access during peak hours.

Parking management will shift from informal control to a regulated system based on pricing, permits, and off-street facilities. Smart sensors and enforcement will reduce illegal parking and free up space for greenery, seating, and active uses. A digital mobility platform will integrate traffic data, air quality, and user feedback to support evidence-based planning.

Finally, equity and safety are cross-cutting priorities. Measures include universal design standards, targeted subsidies for low-income users, and the removal of mobility barriers for women, children, and persons with disabilities. Road safety audits and black spot interventions will reduce accidents and improve confidence in public space.

Together, these actions aim to transform Prishtina from a car-dependent capital into a resilient, people-centred city where walking, cycling, and shared mobility are not only possible, but preferred.

Figure 5: Prishtina SUMP proposed Public Transport, Pedestrian & P+R measures[14]

[14] Source: SUMP Prishtina 2019.

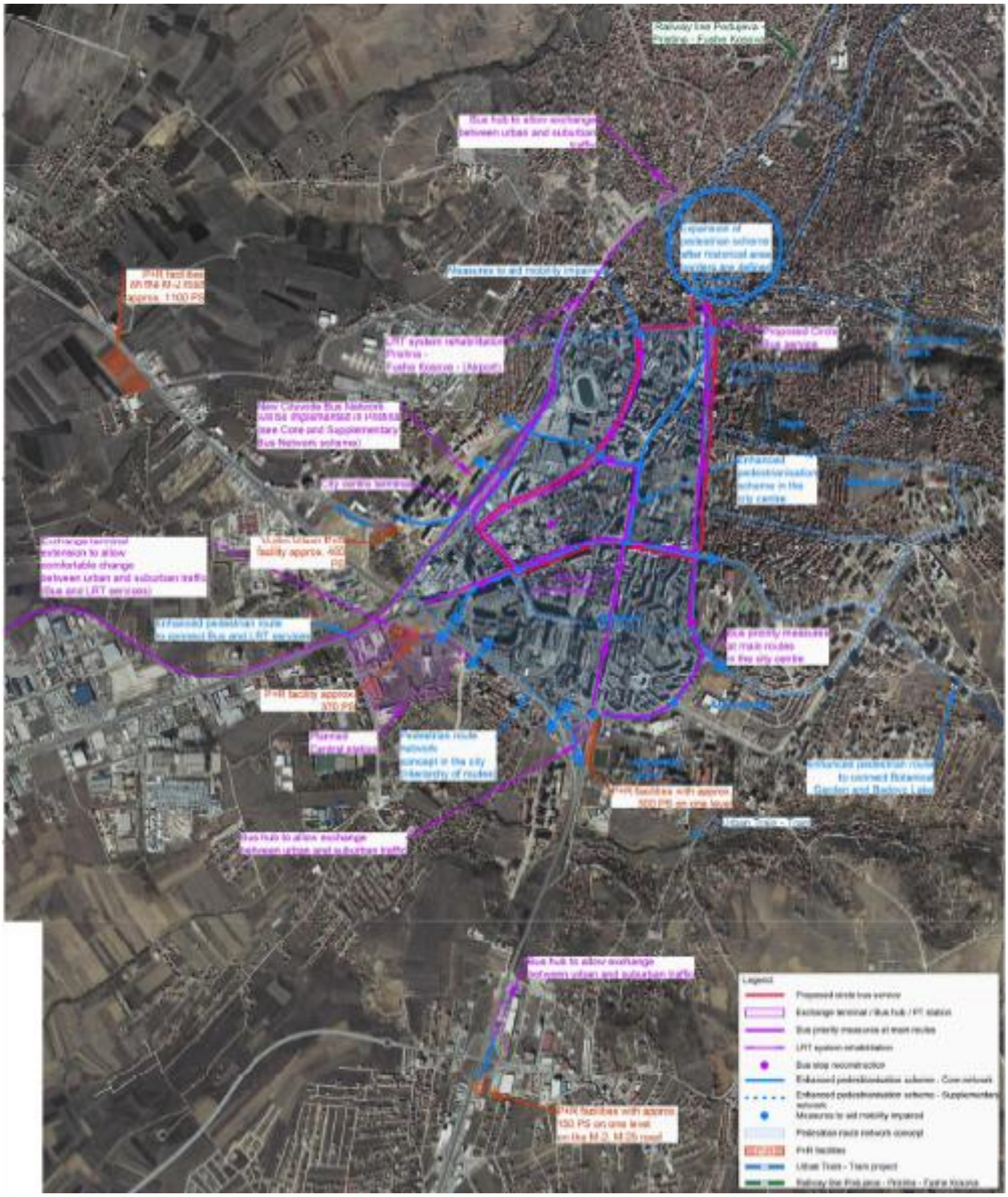


Figure 6: Prishtina SUMP proposed cycling network and measures[15]

[15] Source: SUMP Prishtina 2019


Pristina SUMP Initial Concepts &Strategic Options for Sustainable Travel
Cycling measures
Bike and electric bike sharing system
New cycle path scheme (off road routes/ on road routes/ lanes) up to Kodra e Trimave
New cycle path scheme (off road routes/ on road routes/ lanes) up to Medrese & Camëri
Bike parking facility and cycling facility for cyclists
Special PT routes from the city centre uphill to surrounding areas
New cycle path scheme (off road routes/ on road routes/ lanes)
Existing cycle path improvements
New cycle path to connect Botanical Garden and Badovo Lake via Zllatar

Climate Hazard Deep-Dive and Exposure Metrics

Upon analysing climate conditions and trends using both literature review and georeferenced exposure data (including GIS-based hazard mapping for the defined urban focus area), the results indicate that UHI effects and heatwaves represent the most relevant climate hazards for Prishtina's urban mobility system, followed by heavy rainfall and urban flooding. These hazards affect multiple mobility components, particularly walking and cycling infrastructure, public transport routes, parking areas, and vulnerable users and are therefore analysed in detail in the sections below.

Extreme cold and storms, landslides and soil erosion are also considered in the assessment, as they affect specific mobility components such as road infrastructure, public transport operations, and user safety, despite their more localized spatial extent.

Riverine flooding from the existing underground river (channelled through large pipes during late 1980s), affects indirectly the land capacity to absorb water, hence this impact is calculated in the urban flooding component. Therefore, only a very limited share of the urban mobility network, with minimal exposure within the defined urban focus area. As such, it is considered of secondary relevance for Prishtina's urban mobility system and is not prioritised for further detailed analysis.[16]

Table 2: Quantification of Hazard Indicators

Component	Current Score (%)	Explanation
EXTREME HEAT & UHI		
% of days exceeding average summer temperature	19%	Analysis of observed hot-day patterns for Prishtina (WB-CCP / BOKU, 1981–2010) indicates that more 65–75% of summer days (≈60–70 days/year), corresponding to ≈16–19% of days annually
% of days exceeding heat threshold (≥30°C)	9%	Historical observations indicate approximately 50–65 hot days per year, corresponding to 15–18% of the year. Source WB-CCP: Home | ClimaProof Portal
% of city area with elevated Extreme Heat & UHI	30%	GIS-based UHI mapping shows elevated land surface temperatures concentrated in the city centre, major transport corridors, and high-density residential and commercial areas, broadly affecting around one quarter to one third of the urban area.
URBAN FLOODING		

[16] Prishtina's Forgotten Rivers: What Lies Beneath a Growing City? | by Endrit Sadiku | Medium

% annual heavy rainfall	8%	High-intensity precipitation events (upper-percentile rainfall) account for approximately 6–8% of total annual precipitation in central Kosovo, including Prishtina. Source WB Country Climate and Development report
% of rainfall events exceeding 20 mm/hr	10%	Based on WB-CCP observed mean annual precipitation (1981–2010), Prishtina receives approximately 750–1000 mm of rainfall per year. Including upper-percentile rainfall classes, such events represent approximately 10–12% of rainfall events in Prishtina.
COLD & STORMS		
% of days below freezing	15%	Observed temperature data from the Western Balkans Climate-Proofing Platform (1981–2010) indicate that Prishtina experiences approximately 55–60 days per year with minimum temperatures below 0 °C, corresponding to about 15% of days annually.
% of winter precipitation falling as snow	25%	Prishtina experiences approximately 15–25 snowfall days per year. Based on the frequency of snowfall days relative to total winter precipitation events, it is estimated that around 25% of winter precipitation falls as snow
% of days with ice formation	5%	Based on WB-CCP observed temperature and snowfall data (1981–2010), Prishtina experiences approximately 55–60 days per year with temperatures below 0°C, of which 15–25 days involve snowfall. Ice formation typically occurs during freezing conditions without snowfall, particularly during freeze–thaw cycles. It is therefore estimated that around 15–20 days per year experience ice formation, corresponding to approximately 5% of days annually.
LANDSLIDES		
% of land cover classified as unstable	2%	GIS Survey
% of area with recorded historical landslides	10%	GIS Survey

Urban Heat Islands and Extreme Heatwaves

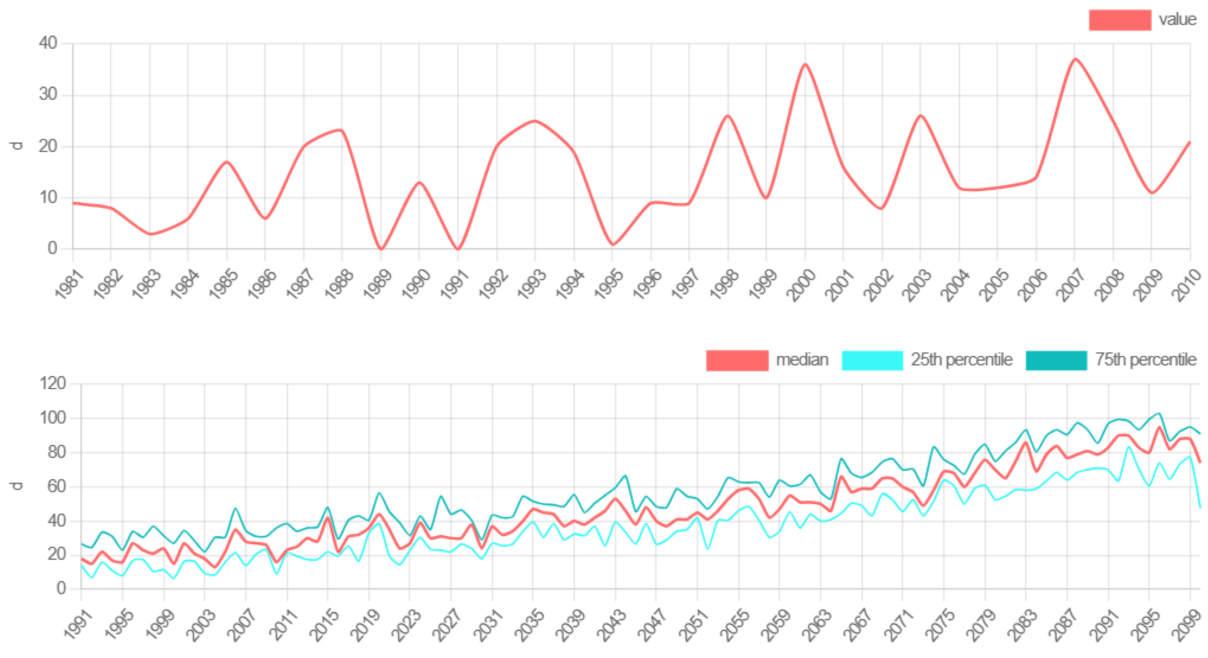
Climate Trends and Projections

The average annual temperature in Prishtina is 11.8°C, with summer highs reaching up to 30°C and winter lows dropping below -6°C. The urban centre of Prishtina is located at an elevation of approximately 573 meters above sea level, which influences its local microclimate and exposure to extreme weather events such as snow, frost, and heatwaves.

Figure 1: Prishtina Weather Condition Changes (Historic Vs 2025)

Over the past six decades, Kosovo has experienced a notable warming trend, with Prishtina showing a consistent increase in average annual temperatures. According to the World Bank's Climate Change Knowledge Portal, the region has warmed by approximately 0.4°C per decade since the 1960s. Looking ahead, projections suggest that by 2050, Prishtina may face a temperature increase of 2 to 2.5°C under moderate emissions scenarios such as RCP4.5 or SSP2. This rise is expected to result in longer and hotter summers, with a growing number of days exceeding 30°C.

Figure 2: Historic observation vs RCP 8.5 scenario for days with maximum temperature exceeding 30°C for Prishtina[17]



[17] Source WBCPP: https://test.wb-ccp.com/

Heatwaves are becoming more frequent and intense, particularly in urban areas like Prishtina were dense infrastructure and limited vegetation. In August 2024, Prishtina recorded a monthly high of 33.2°C, significantly above its historical average of 29.8°C, underscoring the intensification of extreme heat events. These conditions pose increasing risks to public health, energy demand, and the reliability of urban mobility systems.

Observed climate data for the period 1981–2010 based on the Western Balkans Climate Proofing Platform[18] show that Prishtina already experiences a significant and variable number of hot days, defined as days with maximum temperatures exceeding 30°C. Historical records indicate that the annual number of hot days typically ranged between 5 and 25 days per year, with strong interannual variability and occasional peaks approaching 30–35 hot days in particularly warm years. This variability reflects the city's continental climate and sensitivity to regional heatwave patterns, with hotter summers becoming more frequent toward the end of the observation period.

Future climate projections indicate a substantial and sustained increase in the frequency of hot days. Under the RCP8.5 high-emissions scenario, for the period 2036–2065, the median number of hot days in Prishtina is projected to rise to approximately 40–60 days per year, more than doubling the historical average. Model results also show a widening range of outcomes, with the upper percentile reaching 70–80 hot days per year by mid-century, indicating a higher likelihood of prolonged and recurrent heatwave conditions. The comparison between observed and projected data highlights a structural shift in summer temperature regimes, from episodic heat events to chronic seasonal heat exposure. While historically hot days were concentrated in a limited number of summer weeks, future scenarios suggest that extended periods of high temperatures will become the norm, significantly increasing heat stress for urban populations. These changes are expected to intensify extreme heat effects, raise cooling energy demand, and exacerbate heat-related health risks, particularly for vulnerable groups and outdoor workers.

Wind conditions have shown a modest increase, with average speeds reaching 13.8 km/h in 2024 compared to a historical norm of 12.1 km/h. While not extreme, this change may affect pedestrian and cycling comfort, particularly in exposed urban areas. Collectively, these climate trends and projections underscore the urgency of integrating climate resilience into Prishtina's urban planning and mobility strategies.

Recent studies confirm that Prishtina experiences a pronounced UHI effect, especially during summer, with central urban areas recording land surface temperatures (LST) up to 6°C higher than surrounding rural zones. UHI and Heatwaves are one of the eight strategic actions areas of the Kosovo Climate Change Strategy (KCCS) 2019-2028. Temperature rises are obviously especially from the '80s. Data from Kosovo Hydrometeorological Institute, evidenced that there has been movement of average yearly temperatures with a rising trend in Prishtina (see the following table 3). July and August are the driest months founded on data on air

[18] https://test.wb-ccp.com/

temperature from the Kosovo Hydrometeorological Institute19. Duration of UHI waves per year is short.

Table 3: Maximum yearly temperatures in Prishtina[20]

Year	Max. yearly temperatures	Year	Max. yearly temperatures	Max. yearly temperatures	Max. yearly temperatures
2009	17.0	2013	17.6	2017	18.2
2010	17.4	2014	17.5	2018	18.4
2011	16.9	2015	17.9	2019	18.8
2012	17.6	2016	17.3	2020	18.2

Average summer LSTs in the city centre range between 32°C and 36°C, while greener, peripheral areas remain cooler at around 28°C to 30°C.[21]

Based on the WB-CCP observed data (1981–2010) for hot days ≥30°C, heatwaves in Prishtina are already a recurrent summer phenomenon, even if their individual duration remains relatively short. The spatial distribution shown in the map indicates that Prishtina records on average 40–60 hot days per year, placing it among the warmer urban areas in Kosovo. These hot days are concentrated almost entirely between June and September, with peaks in July and August, which also correspond to the driest months. While extreme heatwave events (multi-day episodes) have historically been limited in length, the frequency of hot days has increased markedly since the 1980s, confirming a clear warming trend observed by the Kosovo Hydrometeorological Institute (IHMK). This pattern indicates that heat stress in Prishtina is driven less by isolated extreme events and more by the accumulation of persistently hot days, which amplifies UHI effects, reduces night-time cooling, and increases pressure on public health, infrastructure, and mobility systems during summer months.

This phenomenon is primarily driven by rapid urbanization, low vegetation cover, and high population density. Using remote sensing data and GIS techniques, researchers found that areas with dense residential and commercial development - especially those with impervious surfaces like asphalt and concrete - exhibit the most intense UHI patterns.22 In particular, Qendra (city centre) exhibits the strongest UHI signal, with consistently elevated land surface temperatures linked to dense commercial activity, limited tree cover, and extensive paved surfaces. Adjacent neighbourhoods such as Tophane, Dardania, Ulpiana, Dodona and Kodra e Diellit (lower sections) also show pronounced heat accumulation, especially along major road corridors and around large parking areas and transport nodes. These areas combine high residential density with wide asphalted streets and limited continuous green infrastructure.

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Future climate projections indicate a pronounced intensification of heat stress and UHI effects in Prishtina. Under intermediate emissions pathways, average summer temperatures in central Kosovo are projected to increase by around 2–3°C by mid-century, while high-emissions scenarios (RCP8.5) indicate warming approaching or exceeding 4°C by the end of the century, relative to the 1981–2010 baseline. Observed trends already show a steady rise in heat exposure, with the number of days exceeding 30°C increasing from roughly 20–30 days per year historically to a projected 100–130 days per year by late century, meaning that UHI will become a defining feature of the summer season rather than an occasional event.

Table 4: Quantified Hazard Indicators for UHI in Prishtina

Indicator	Quantification (Current State)	Projection (RCP 8.5 scenario)	Source
% of days exceeding heat threshold (≥30°C)	≈8–9% of days/year (≈28–32 days/year)	≈45–60 days/year by mid-century and ≈70–85 days/year by late century, corresponding to ≈12–16% and ≈19–27% of days annually, respectively.	Analysis of observed hot-day patterns for Prishtina (WB-CCP / BOKU, 1981–2010)
% of days exceeding average summer temperature	19%	≈25–30% of days per year	Under RCP8.5, above-average temperatures become the norm rather than the exception. Source WB-CCP: Home | ClimaProof Portal
% of city area with elevated UHI	30%	≈35–45% of built-up area	Intensification is expected as heat days increase, and vegetation stress grows.

Table 5: Extreme Heat and heatwaves impact on Urban Mobility Components in Prishtina Urban area

Urban Mobility Component	UHI & Heatwaves – Climate Risk Impacts
Walking and Cycling	Prolonged summer heat, recurrent heatwaves, and strong UHI effect significantly reduce the comfort and safety of walking and cycling in Prishtina. The highest exposure is observed within the inner ring of the city centre (Agim Ramadani, UCK, Migjeni, Luan Haradinaj, Kosta Novakovic, Tirana Street, and Bill Clinton Boulevard), as well as in newer dense residential areas with limited vegetation. Scarce shading, blocked ventilation corridors (e.g. Rruga B), and high surface temperatures increase dehydration, heat stress, and sunburn risk. During heatwaves, active mobility becomes less attractive, prompting a shift toward private vehicle use. Wildfire smoke from surrounding areas such as Gërmia

	Park can further degrade air quality and temporarily restrict the use of walking and cycling corridors.
Public Transport	Public transport infrastructure and operations are strongly affected by combined UHI and heatwave conditions. Unsheltered or poorly shaded bus stops expose users to prolonged heat stress, particularly during peak hours. Older buses are more prone to overheating and air-conditioning failure during UHI, leading to higher fuel consumption, service disruptions, and mechanical breakdowns, especially on longer or uphill routes serving areas such as Veternik and Kalabria. During wildfire events, smoke and road closures may cause detours or temporary service suspensions, reducing reliability for users dependent on public transport.
Private Vehicle Use and Traffic	Although thermal comfort inside private vehicles can be partially maintained through air conditioning, UHI and heatwaves increase operating costs due to higher fuel consumption, reduced electric vehicle range, and accelerated vehicle wear. Heatwaves intensify congestion along major corridors such as Bill Clinton Boulevard, Agim Ramadani, and Migjeni Street, reinforcing emissions, local air-quality deterioration, and overall traffic inefficiency.
Urban Logistics and Freight	Rising urban temperatures and heatwave conditions disrupt logistics and freight operations by increasing heat stress for drivers and raising energy demand for cabin and cargo cooling. Refrigerated transport faces particular challenges due to higher power requirements to maintain cold chains, increasing operational costs and reducing efficiency. Exposure is highest across the inner and outer rings of the Prishtina urban core, where dense traffic and impervious surfaces amplify UHI effects.
Parking and Traffic Management	Large asphalted parking areas, especially around the “Boro & Ramizi” outlet, central government institutions, university campuses, and major commercial zones act as localized UHI surface. Vehicles parked in direct sunlight require significantly more energy for cooling when restarted, increasing emissions and operating costs. Informal parking practices in high-demand areas further reduce road capacity and exacerbate congestion during heatwaves, compounding mobility and safety challenges.
Vulnerable Users and Accessibility	Vulnerable groups-including elderly residents, children, people with chronic health conditions, and low-income households-are disproportionately affected by combined UHI and heatwave impacts. These groups rely heavily on walking, cycling, and public transport while navigating heat-exposed streets, crowded bus stops, and vehicles with limited cooling. Impacts are citywide but are most pronounced in high-density neighbourhoods such as Lakrishte, Dardania, Ulpiana, Kodra Trimave, Arberia, and the city centre, increasing inequality in access to safe, comfortable, and inclusive urban mobility.

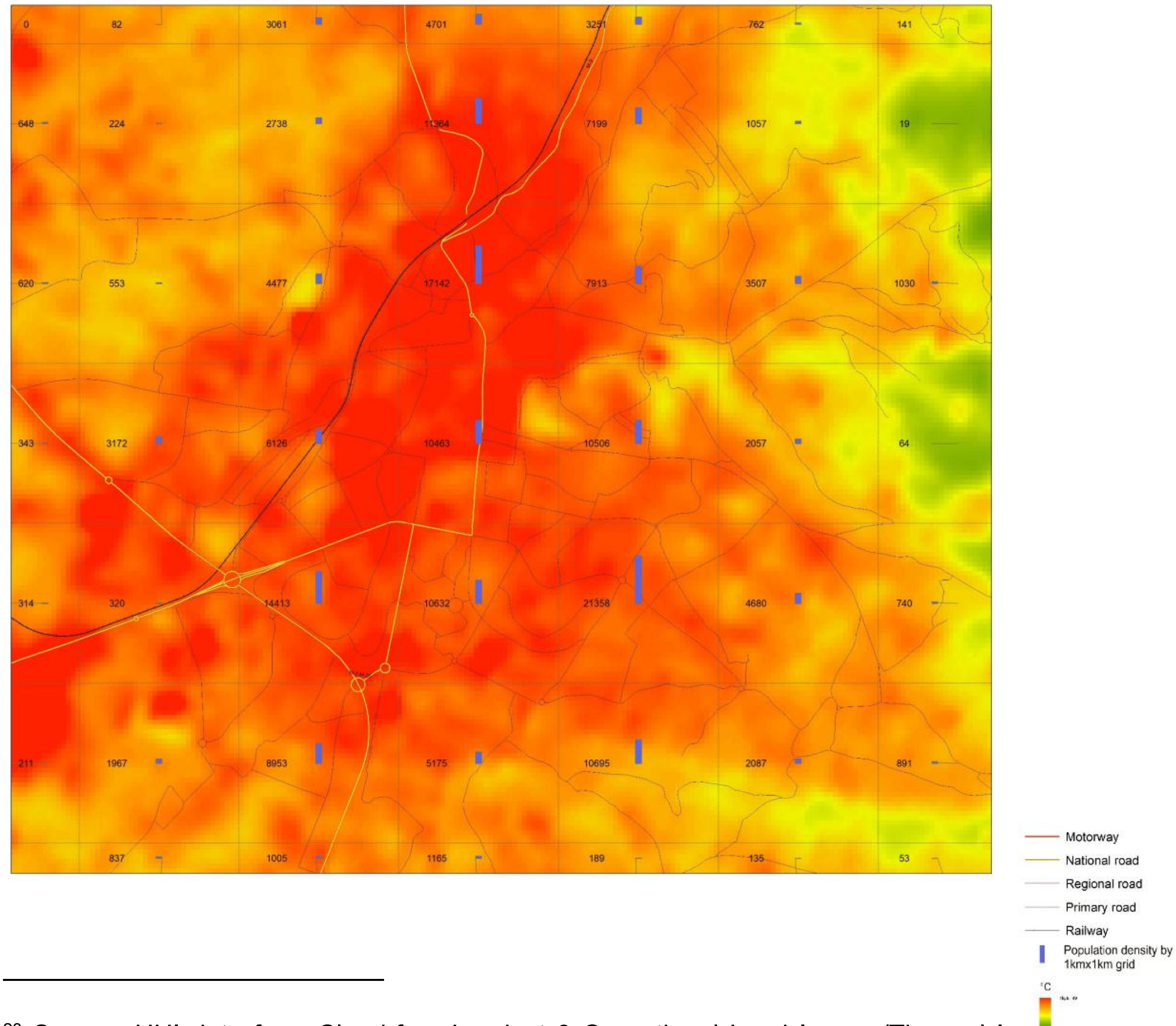
Spatial Extents and Urban Hotspots

Thermal remote sensing via Landsat 8/9 confirms a pronounced UHI profile during summer months. Core urban areas exhibit Land Surface Temperatures (LST) up to 6°C higher than adjacent rural baseline areas. Average summer LST values across the dense urban fabric range between 32°C and 36°C, with severe hotspots tracking above 45°C in industrial corridors, while green zones remain at 28°C to 30°C.

The strongest UHI signals are concentrated within the city center (Qendra) and Lakrishtë. This is driven by dense commercial blocks, extensive dark artificial surfaces, low tree canopy coverage, and concentrated traffic emissions.

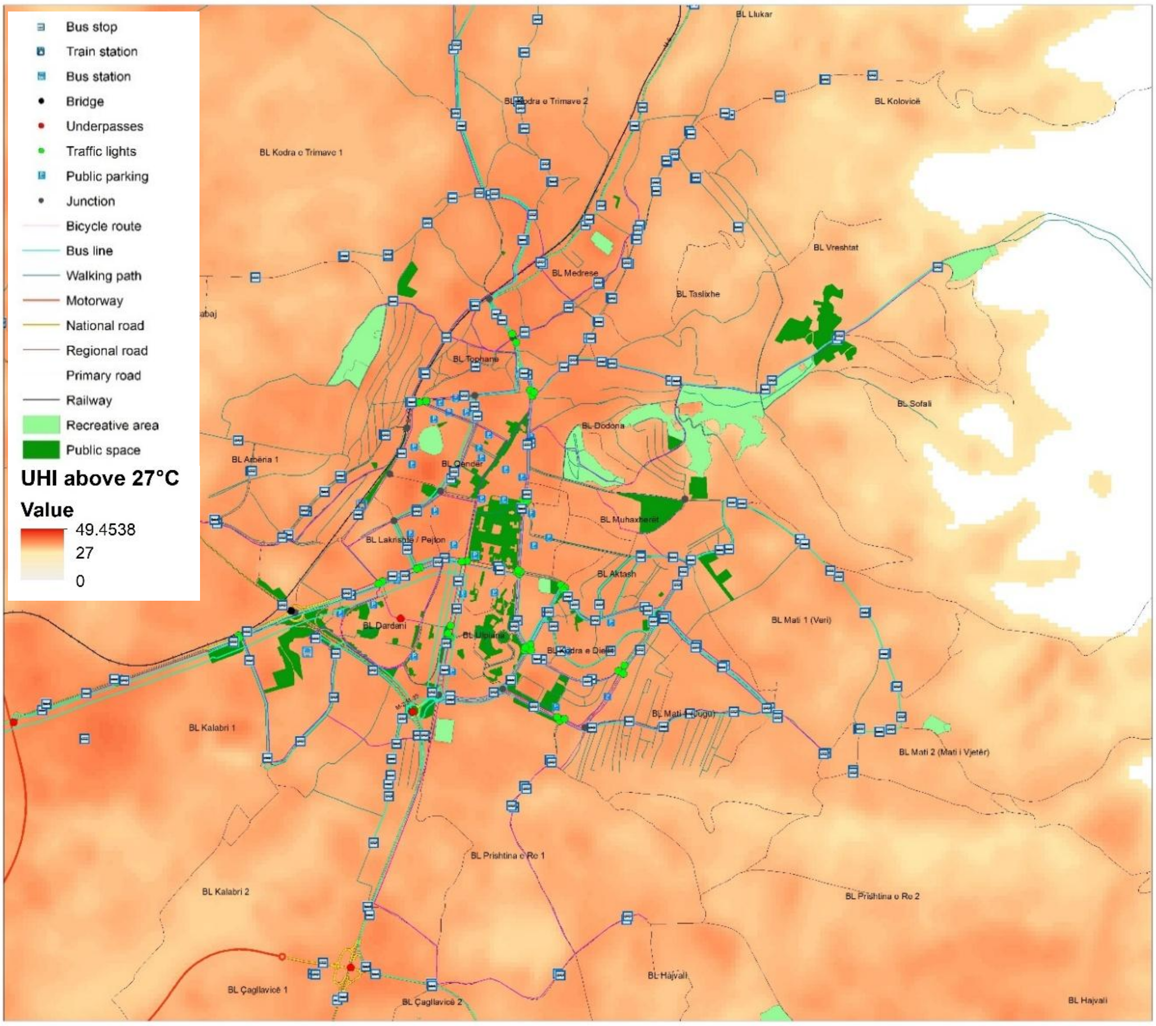
Pronounced heat accumulation also extends along primary transport corridors and adjacent dense neighborhoods, including Tophane, Dardania, Ulpiana, Dodona, and the lower zones of Kodra e Diellit. This spatial distribution maps onto wide, unshaded asphalt axes and large surface parking zones. Conversely, open green spaces like Gërmia Park and Tauk Bashqe function as vital urban cooling assets, showing lower surface temperatures.

Figure 93: Map of population density and heat map[23]



[23] Source: UHI data from Cloud-free Landsat 8 Operational Land Imager/Thermal In[illegible]s (OLI/TIRS) and population data from Kosovo Agency of Statistics, Census 2024.

Figure 10: Hot spots of UHI zone (above 27°C) [24]



Mobility Asset Exposure Metrics

Elements	Unit	Total	Affected Assets	Affected Assets (%)
Number of underpasses	number	1	1	100.00%
Number of parking spaces (including parking lots and on-street parking)	m²	150,000	103,000	68.70%
Nr of traffic lights	number	42	25	59.50%
Length of cycling roads	km	46.5	16.3	35.10%

[24] Source: Cloud-free Landsat 8 Operational Land Imager/Thermal Infrared Sensors (OLI/TIRS)

Length of public transport routes	km	90.2	27	29.90%
Length of walking roads (total of walking roads, and pedestrian areas like Pedonale)	km	192.5	26.97	14.00%
Number of bus stops	number	339	29	8.60%
Length of the road network	km	586.6	29.17	5.00%

Systemic Mobility Risk Analysis

Extreme summer heat waves and UHI accumulation create significant structural and operational issues across Prishtina's transport network:

- **Logistics & Microclimatic Loops:** Surface parking facilities are highly exposed, with 68.7% of their total area sitting within high-heat zones. This causes parked cars to heat rapidly, driving up localized emissions and fuel consumption when drivers turn on air conditioning at startup. Freight operations face higher fuel costs to keep refrigeration systems running in industrial zones, and drivers experience greater fatigue during long congestion delays on heat-prone arterials.
- **Active Mobility Deterioration:** Pedestrian corridors like Mother Teresa Boulevard and the Grand Hotel-Technical Faculty axis lack continuous tree shade. This exposes walkers and cyclists to intense thermal stress and solar radiation, discouraging active travel and driving a shift back to private cars for short urban trips.
- **Public Transit Operational Failures:** Nearly 30% of the public transport route network and 8.6% of bus stops are directly exposed to high UHI stress. Waiting at unsheltered stops increases heat stress for passengers. The transit fleet (particularly older diesel models run by private operators) faces reduced engine efficiency, higher fuel consumption, and frequent air conditioning failures, especially along steep uphill routes toward Veternik and Kalabria.
- **Infrastructure Asset Degradation:** Elevated land surface temperatures soften asphalt pavements, leading to rutting, cracking, and structural joint expansion on primary corridors like Bill Clinton Boulevard. Traffic signaling equipment faces high failure rates, with 59.5% of electronic signal cabinets operating in unshaded UHI zones. The city's single major pedestrian underpass shows 100% heat exposure, trapping stale air due to inadequate mechanical ventilation.

Extreme Cold, Frost and Freeze-Thaw Structural Stress

Prishtina currently records 55 to 60 days per year with minimum temperatures dropping below 0°C, and winter temperatures occasionally fall to -15°C during severe cold waves (like the one recorded in February 2012).[25] Temperatures in January average between -3 and -7°C, and snowfall averages 50 – 70 cm per year. Cold waves bring widespread transport disruption

[25] Climate-Data.org. (2025). Climate: Pristina, Kosovo. URL: https://en.climate-data.org/europe/kosovo/pristina/pristina-912068/

across the city.[26] Snow and ice reduce traction, increase accidents, and make roads and sidewalks difficult to use. During one such storm, 109 road accidents were reported in just 24 hours across Kosovo.[27] The freeze-thaw cycle also damages roads and drains, while power outages during cold spells can interrupt traffic lights and electronic ticketing systems.[28]

Climate projections for Prishtina under the high-emissions scenario (RCP8.5) indicate a progressive weakening of extreme cold conditions over the course of the century. Snowfall days are projected to decrease in both frequency and duration. While Prishtina currently records approximately 15–25 snowfall days per year, future projections indicate fewer snow events and a shorter snow season, with an increasing share of winter precipitation falling as rain rather than snow. This shift reduces the persistence of snow cover but increases the likelihood of wet winter conditions.

Despite fewer freezing days overall, freeze–thaw cycles remain a relevant hazard, especially in the near to mid-term (2036–2065). WB-CCP projections show that freeze–thaw events continue to occur annually, driven by temperatures oscillating around 0°C. Although their frequency declines toward the end of the century, these cycles are expected to remain sufficient to cause surface degradation, cracking, and material fatigue in roads, pavements, and other transport infrastructure.

Ice formation is therefore likely to persist, particularly during late winter and early spring when daytime temperatures rise above freezing but night-time temperatures still drop below 0°C. These conditions increase the risk of slippery surfaces, reduced traction, and localized safety hazards, even as overall winter severity decreases.

Table 6: Quantified Hazard indicators for cold, ice and storms in Prishtina

Indicator	**Quantification (Current State)**	**Projection (RCP 8.5 scenario)**	**Source**
% of days below freezing	15% (≈55–60 days/year with Tmin < 0 °C)	≈8–10% (≈30–40 days/year by mid- to late-century), reflecting a continued decline in freezing days due to winter warming	Observed data from the Western Balkans Climate-Proofing Platform (1981–2010) show that Prishtina records around 55–60 days per year with temperatures below 0 °C, representing approximately 15% of the year.

[26] Balkan Insight. (2012, February 8). Cold Snap Torments Balkans. URL: https://balkaninsight.com/2012/02/08/cold-snap-torments-balkans/
[27] Balkan Insight. (2016, January 5). Kosovo Hit by Snow, Blizzards and Record Road Accidents. URL: https://balkaninsight.com/2016/01/05/kosovo-hit-by-snow-blizzards-and-record-road-accidents-01-04-2016/
[28] Kosovo Hydrometeorological Institute (KMI). Annual Meteorological Report for Kosovo 2023–2024

% of winter precipitation falling as snow	25%	≈10–15%, as rising winter temperatures shift a larger share of cold-season precipitation from snow to rain, shortening snow cover duration	Prishtina records approximately 15–25 snowfall days per year, and it is estimated that around 25% of winter precipitation falls as snow, based on the share of snowfall days relative to total winter precipitation events.
% of days with ice formation	5%	≈3–4% (≈10–14 days/year). Although overall freezing days decline, freeze–thaw conditions persist in the near to mid-term, sustaining periodic ice formation	Based on WB-CCP observed temperature and snowfall data (1981–2010), Prishtina experiences around 55–60 days per year with temperatures below 0 °C, of which 15–25 days involve snowfall. Ice formation mainly occurs during freeze–thaw conditions without snowfall and is estimated at approximately 15–20 days per year, corresponding to about 5% of days annually.

In summary, Prishtina's future winter climate is projected to shift from prolonged cold and snow toward milder, more variable conditions, with fewer snow days but continued risks related to ice formation and freeze–thaw damage. These trends have important implications for winter road maintenance, pedestrian safety, and infrastructure durability.

Spatial Extent & Urban Hotspots

Frost risk and ice formation hotspots map onto cold-air pooling zones identified via terrain wetness modeling. These occur along unshaded peripheral roads, shaded building valleys in dense districts like Lakrishtë, and bridge decks that experience rapid radiative cooling.

Milder conditions occur in the built-up city center due to artificial heat preservation from the baseline UHI effect. However, agricultural fields, open public parks, and low-density hillside borders remain highly exposed to winter frost.

Quantitative Asset Exposure Metrics

Spatial clipping of frost hazard zones across core transport vectors demonstrates low but highly focused infrastructure exposure:

- **Cycling Lanes:** 2.2% exposure (1.0 km of dedicated bike networks).
- **Public Transport Routes & Bus Stops:** 1.1% of route lines (1.0 km) and 0.6% of bus stops (2 out of 339 stations) sit within frost-prone low zones.
- **Primary Road Network:** 0.2% exposure (1.0 km of infrastructure).
- **Pedestrian Spaces & Sidewalks:** 0.5% exposure (1.0 km of pedestrian pathways).

- **Structural Elements:** Railway networks, parking zones, structural bridges, and underpasses show 0% direct spatial exposure under standard winter conditions.

Systemic Mobility Risk Analysis

Winter weather hazards create distinct operational safety challenges:

- **Traction Loss & Accidents:** Freeze-thaw cycles cause sub-surface moisture to expand and contract, which accelerates pothole formation, cracks pavement materials, and delaminates road surfaces. Ice formation creates slippery conditions on un-maintained sidewalks, crosswalks, and bike lanes, increasing pedestrian falls and vehicle collisions.
- **Fleet Operational Strain:** Severe cold spells delay public transit services. The private bus fleet features an average vehicle age of 26 years and lacks cold-weather adaptation. These older buses suffer high rates of mechanical breakdowns, air brake freezing, and starter failures in low temperatures.
- **Vulnerability Gaps:** Passengers face extended wait times at exposed, unsheltered bus stops during winter storms. This lack of shelter increases cold exposure risks for low-income residents, children, and elderly riders who rely on public transit.

Figure 11: Hot spots of Extreme Cold (frost risk zone)[29]

[29] Source: Copernicus, ERA5 climate data (March 2026)

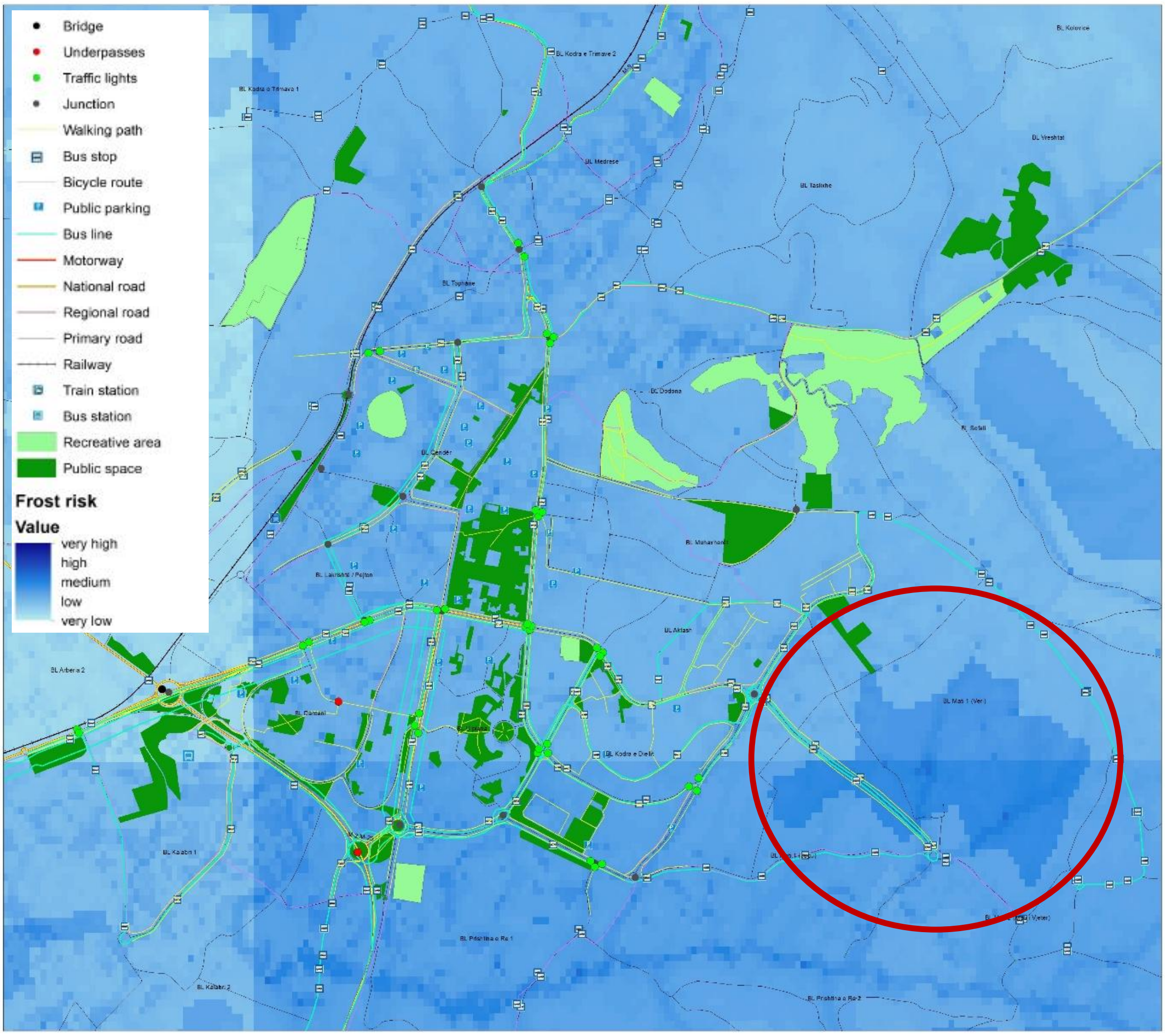


Table 7: Quantified Exposure Indicators for Extreme Cold (frost risk zone) for Prishtina Urban area

Elements	Unit	Total	Affected Assets	% of Affected Assets
Length of cycling roads	km	46.5	1	2.20%
Length of public transport routes	km	90.2	1	1.10%
Number of bus stops	number	339	2	0.60%
Length of walking roads (total of walking roads, and pedestrian areas like Pedonale)	km	192.5	1	0.50%
Length of the road network	km	586.6	1	0.20%

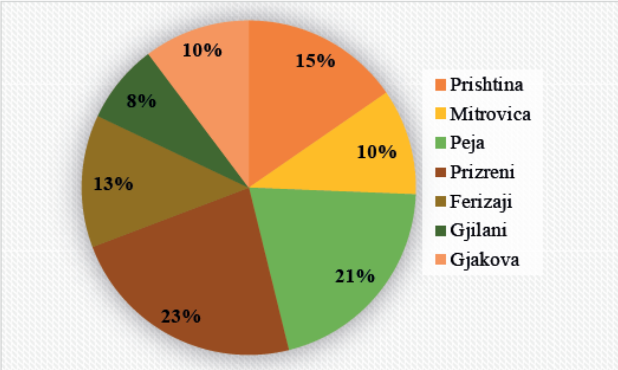
Geomorphological Instability: Landslides and Soil Erosion

Climate Trends and Projections

Prishtina has high baseline landslide vulnerability, ranking third across Kosovo for total occurrences and accounting for 15.38% of all national events. When filtering data to look specifically at landslides that damage transport infrastructure, Prishtina records the highest number of incidents nationally. However, when focusing specifically on landslides affecting road infrastructure, Prishtina registers the highest number of incidents, concentrated along key road segments within its municipal boundaries.[30]

Figure 4: Spread of landslides by region in Kosovo[31]

Region	Nr.of. Locations	[%] Percentage
Prishtina	6	15.38
Mitrovica	4	10.26
Peja	8	20.51
Prizreni	9	23.08
Ferizaji	5	12.82
Gjilani	3	7.69
Gjakova	4	10.26



While Prishtina continues to expand into hillside and peri-urban zones, landslide and soil erosion risks are expected to intensify. Climate variability may lead to more frequent short-duration downpours, which destabilize slopes and increase the likelihood of landslides. These events can block key road segments, damage retaining structures, and disrupt transport services across the urban core.

Soil erosion is projected to increase in newly developed residential areas and informal settlements near vulnerable slopes. Without proper slope stabilization or runoff control, embankments and roadside infrastructure will degrade more quickly, requiring frequent repairs and increasing maintenance costs. The persistence of erosion will also weaken drainage systems, contributing to long-term mobility challenges and reduced safety for pedestrians and cyclists in affected corridors.

Table 8: Quantified Hazard indicators for landslides and soil erosion in Prishtina

Indicator	Quantification (Current State)	Projection (RCP 8.5 scenario)	Source
% of land cover classified as unstable	2%	≈3–4% by mid- to late-century, reflecting increased slope	GIS survey; WB-CCP precipitation intensity projections;

[30] Cadraku H., Bejta S., Landslide in Kosovo and Necessity for Their Monitoring, 2018, pg. 16. URL: https://ijnes.org/index.php/ijnes/article/view/307/281

[31] Cadraku H., Bejta S., Landslide in Kosovo and Necessity for Their Monitoring, 2018, pg. 16, fig. 5. URL: https://ijnes.org/index.php/ijnes/article/view/307/281,

		instability driven by more frequent short-duration, high-intensity rainfall events and continued urban expansion into hillside and peri-urban areas without adequate slope stabilization measures	
% of area with recorded historical landslides	10%	≈12–15%, as areas with past landslide activity are expected to experience reactivation under intensified rainfall and soil saturation conditions, particularly where drainage and erosion control remain insufficient	GIS Survey; Western Balkans Climate-Proofing Platform;

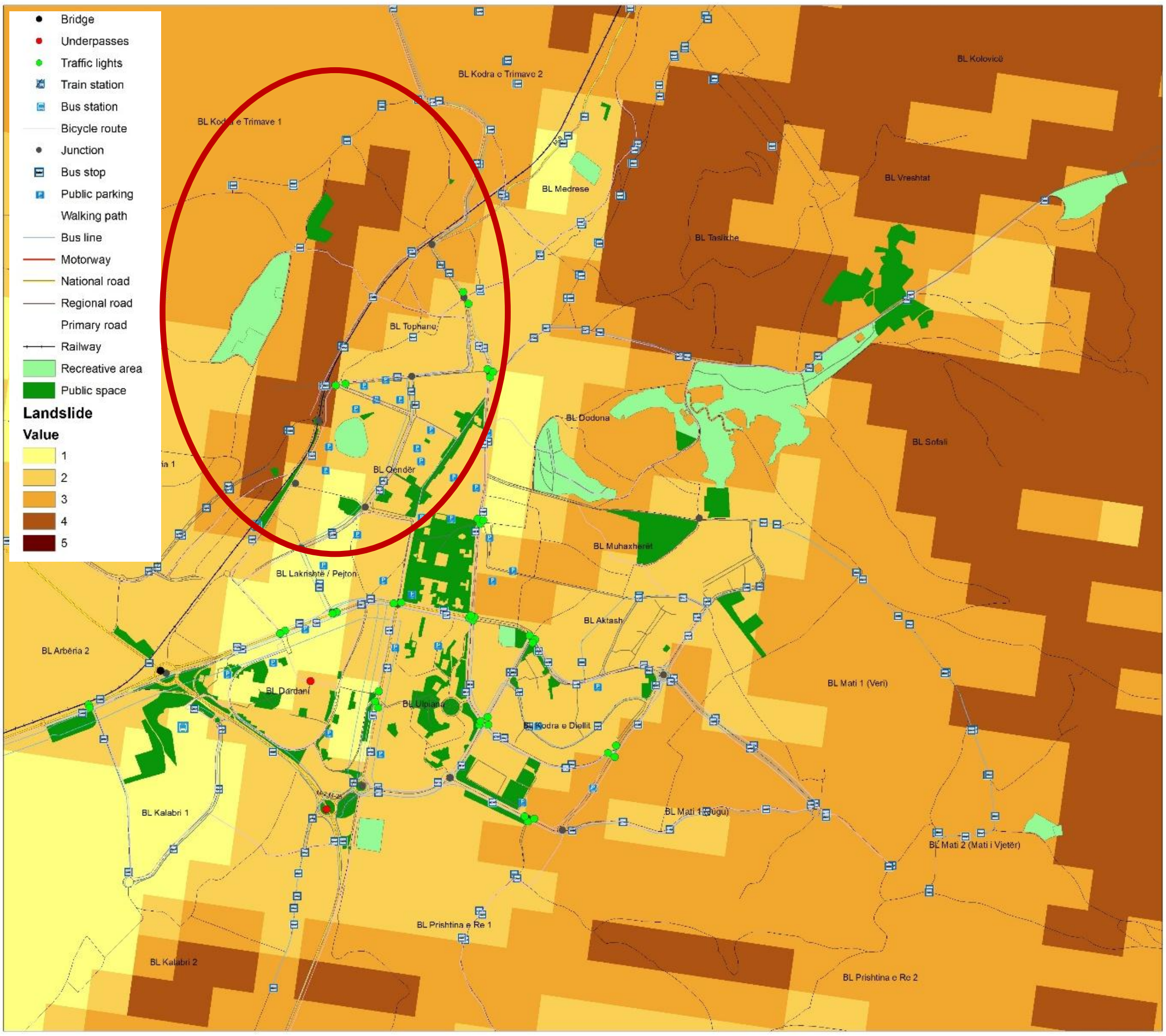
Under RCP 8.5, increased rainfall intensity combined with ongoing peri-urban development is expected to expand both unstable land cover and the spatial extent of landslide-prone areas, increasing the likelihood of road blockages, infrastructure damage, and recurring maintenance needs.

Prishtina faces significant risks from landslides and soil erosion, particularly in areas with steep terrain and unstable slopes. Key road segments in Arbëria can be impacted, with landslides blocking arterial routes and disrupting traffic flow. Road surfaces and retaining structures can be damaged. Pedestrian safety is compromised, as soil movement and debris can obstruct sidewalks, destabilize slopes near footpaths, and create hazardous walking conditions.

Spatial Extents and Urban Hotspots

Figure 12: Prishtina Landslides zone[32]

[32] Source: European Landslide Susceptibility Map version 2 (ELSUS v2)



Asset Exposure Metrics

Table 9: Quantified Exposure Indicators for Urban landslides for Prishtina Urban area

Elements	Unit	Total	Affected Assets	% of Affected Assets
Nr of road bridges	number	3	1	33.30%
Railway Length	km	13.6	0.5	3.70%
Nr of traffic lights	number	42	1	2.40%
Number of bus stops	number	339	6	1.80%
Length of public transport routes	km	90.2	1	1.10%
Length of walking roads (total of walking roads, and pedestrian areas)	km	192.5	1.1	0.60%
Length of the road network	km	586.6	1.4	0.20%

Systemic Mobility Risk Analysis

Geomorphological hazards create localized but highly destructive structural impacts on transit infrastructure:

- **Arterial Blockages & Congestion:** Slope failures along the hillsides of Arbëria deposit mud, rock debris, and collapsed pavement onto primary roads. This debris blocks traffic lanes, undermines retaining walls, and forces immediate street closures. These sudden closures trigger widespread traffic congestion as vehicles divert onto alternative routes.
- **Public Transit Cancellations:** Landslide events directly impact 1.1% of public transport corridors and 6 bus stops. When key hillside roads are blocked, bus routes must be detoured or canceled, leaving hilly neighborhoods disconnected from the public transit system.
- **Structural Infrastructure Damage:** Landslides pose severe structural risks to specialized assets, including 3.7% of local rail tracks (0.5 km) and 33.3% of structural road bridges (1 out of 3 major structures). Soil movement around bridge abutments, structural foundations, and retaining walls can cause sudden failures, requiring expensive structural repairs and long-term reconstruction budgets.
- **Erosion Gaps:** Continuous soil erosion slowly washes away soil support from beneath road shoulders and pedestrian sidewalks. This erosion clogs stormwater drainage ditches, increasing pluvial flood risks during heavy rains and creating hazardous drops along sidewalk edges.

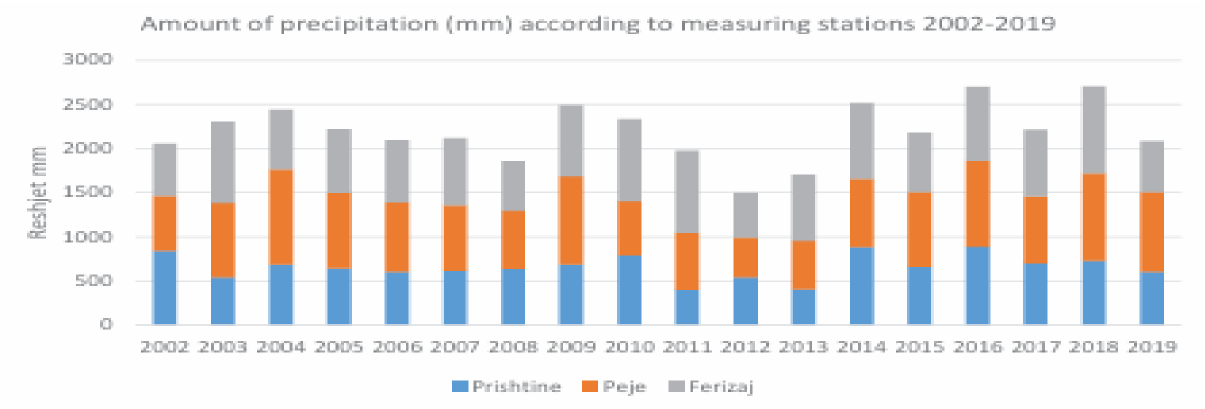
Pluvial (Urban) Flooding and Intense Precipitation Runoff

Climate Trends & Projections

Long-term climate models project an intensification of precipitation extremes for Prishtina. Currently, annual precipitation averages 700 mm, distributed relatively evenly throughout the year, with higher intensity during spring and autumn months. According to Prishtina Green City Action Plan (GCAP)[33], the phenomena of water shorting and flooding are evident, but the city has not yet implemented a plan to collect rainwater or sewage, nor has it created any system to do so. Urbanization has multiplied peak rainfall flow due to an excessive surge in areas, resulting in flooding where aging channels downstream are unable to absorb coming water and heavy rainfall as predicted by climate change as the number of both flooding and water purity are negatively affected by this.

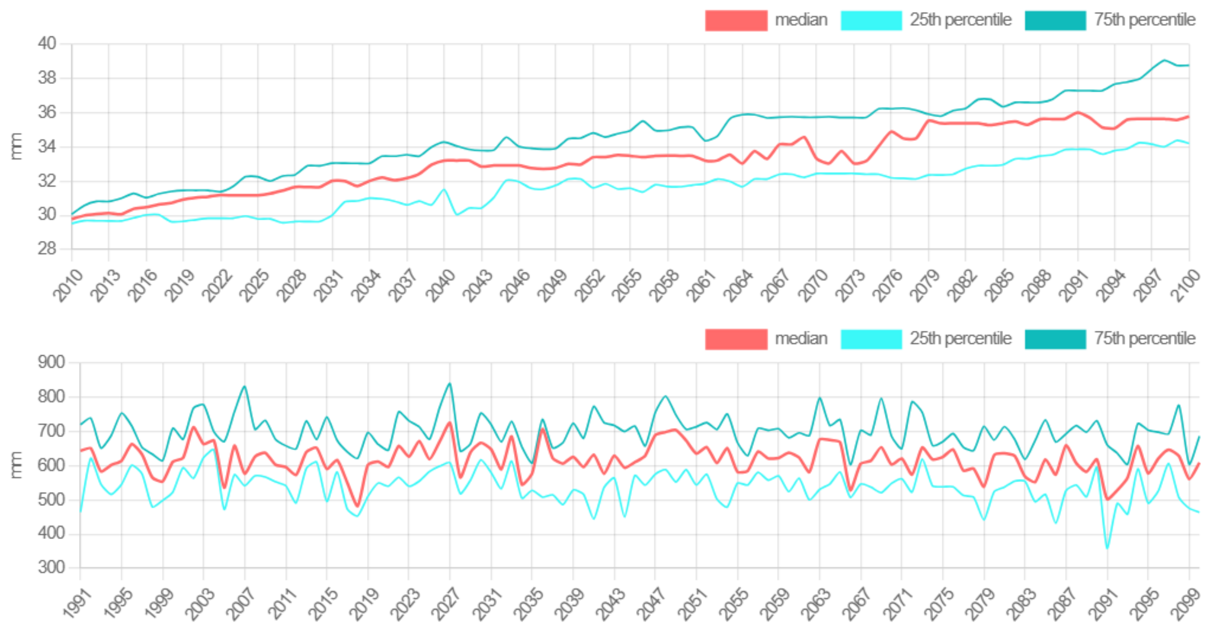
Figure 5: Precipitation (mm) in Prishtina measuring station[34]

[33] https://ebrdgreencities.com/assets/Uploads/PDF/Pristina-GCAP_ENG_August-2021.pdf
[34] KEPA, 2020 "Report on environmental indicators"



Precipitation patterns are also shifting, with rainfall becoming more erratic and concentrated in shorter, more intense episodes. This trend has led to a 44.4% increase in daily precipitation extremes during the wettest year on record, placing considerable stress on drainage systems and road infrastructure. Seasonal changes are expected to continue, with spring and autumn becoming wetter, while summers may trend drier but hotter, heightening the risk of drought and water scarcity.

Figure 14: Trends for precipitation extremes and mean precipitation using scenario RCP 8.5[35]



The municipality has not yet implemented a rainwater harvesting or stormwater management system, and institutional capacity to address these risks remains limited. There is no integrated plan for runoff collection, nor sufficient data on transport network vulnerabilities to guide adaptation.

[35] Source: WBCPP

Kosovo Water Strategy 2017 - 2036[36] in its strategic objective for water protection foresees the provision of flood protection through: flood risk warning, flood prevention, reducing the effects of floods and emergency support.

Projections for precipitation extremes indicate a clear upward trend in the intensity of heavy rainfall events. The median magnitude of extreme precipitation events increases steadily from approximately 30 mm per event in the early 2010s to around 35-36 mm by the end of the century, with upper-range values approaching 38-40 mm. This reflects an increasing probability of short-duration, high-intensity rainfall, even in years where total precipitation does not increase significantly.

Under the high-emissions RCP8.5 scenario, according to WB CCP, climate projections for Prishtina indicate only modest changes in total annual precipitation, with median values remaining broadly within the historical range (approximately 600–700 mm/year). However, this apparent stability masks a significant intensification of precipitation extremes. By mid- to late-century, the upper-percentile (75th percentile) precipitation totals increase, indicating wetter years occurring more frequently, while the 25th percentile declines, pointing to greater interannual variability and more pronounced dry years.

Daily precipitation extremes show a clearer signal of change. The 99.9th percentile of daily rainfall is projected to rise from roughly 32–34 mm/day (2010 baseline) to 38–42 mm/day by 2100, reflecting an increase of approximately 20–25% in extreme rainfall intensity. This shift implies that short-duration, high-intensity rainfall events will become more frequent, even if annual totals change little. For Prishtina, these trends substantially increase the risk of pluvial (urban) flooding, particularly in densely built neighbourhoods with high impervious surface coverage and limited drainage capacity and will place growing pressure on stormwater infrastructure under future climate conditions.

Table 10: Quantified Hazard indicators for Urban Flooding in Prishtina

Indicator	Quantification (Current State)	Projection (RCP 8.5 scenario)	Source
% annual heavy rainfall	Upper-percentile precipitation events (99.9th percentile daily rainfall, typically **125–175 mm per event**) account for approximately **6–8% of total annual precipitation** in central Kosovo, including Prishtina. These events are infrequent but contribute disproportionately to annual	Under RCP 8.5, the share of annual rainfall occurring during extreme events is projected to increase modestly to around **8–10%,** driven by higher precipitation intensity rather than higher annual totals. While total annual precipitation remains broadly stable, extreme rainfall contributes a	WB-CCP *Precipitation extremes* (Observation, 1981–2010); World Bank Country Climate & Development Report

36 https://mjedisi.info/wp-content/uploads/2023/03/National-water-management-strategy-2036-Kosovo.pdf

	rainfall totals and urban flood risk.	growing proportion of yearly totals, increasing urban flood risk.	
% of rainfall events exceeding 20 mm/hr	Based on WB-CCP observed precipitation patterns (1981–2010), rainfall events exceeding **~20 mm/hr** are most frequent in **autumn and winter** and represent approximately **10–12% of rainfall events** in Prishtina. These high-intensity events are a key driver of pluvial flooding due to limited infiltration capacity in urban areas.	Climate projections under RCP 8.5 indicate an increase to approximately **12–15%** of rainfall events exceeding 20 mm/hr by mid- to late-century, reflecting intensification of short-duration, high-intensity storms. This trend significantly raises the likelihood of pluvial flooding in urban areas with high impervious surface coverage.	WB-CCP observed precipitation amount & intensity classes; author's interpretation

CONCLUSIONS AND WAY FORWARD

Prishtina's capital transport network faces immediate structural strain from climate change. High summer UHI exposure compromises passenger safety and damages pavements, while intense storms trigger pluvial flooding that closes underpasses and interrupts traffic management systems.

To build long-term climate resilience, the Municipality of Prishtina must move away from reactive repairs and implement targeted engineering adaptations across five strategic areas:

1. Shading and Cooling Infrastructure

- **Action:** Implement urban greening interventions along major active mobility corridors (such as Mother Teresa Boulevard, Agim Ramadani, Luan Haradinaj, and the Grand Hotel–Technical Faculty axis). Plant high-density, native, drought-resistant tree canopies along unshaded sidewalks to lower local land surface temperatures.
- **Engineering Specifications:** Upgrade all 29 UHI-exposed bus stops with structural passenger shelters featuring reflective coatings, integrated shade trellises, wooden benches, and solar-powered water fountains.

2. Sustainable Stormwater Management & Permeable Surfaces

- **Action:** Redesign stormwater drainage systems in chronic pluvial flood zones (including Kalabria, Mati, Lakrishtë, and the city center) to handle projected 99.9th percentile intense rainfall events (42 mm/day).
- **Engineering Specifications:** Convert the city's 103,000m^2 of heat-exposed surface parking lots into permeable surfaces. Replace solid asphalt with open-cell concrete

grass pavers and bioswales to encourage natural rainwater infiltration, lower runoff volumes, and reduce the UHI effect.

3. Climate-Resilient Public Transport Fleet

- **Action:** Modernize the municipal transit network by phasing out old, inefficient diesel buses run by private operators.
- **Engineering Specifications:** Mandate that future public transport tenders specify low-emission, hybrid, or electric buses equipped with heavy-duty HVAC cooling compressors, electronic component insulation, and high-traction braking systems designed to operate safely during summer heatwaves and winter freeze-thaw cycles.

4. Geotechnical Slope Stabilization

- **Action:** Secure transport infrastructure in landslide-prone hillside neighborhoods (such as Arbëria and expanding peri-urban zones).
- **Engineering Specifications:** Construct retaining walls, rock-fall netting, and deep sub-surface drainage trenches along vulnerable slopes. Implement continuous slope-monitoring sensors around structural bridges and rail lines to detect soil movement early.

5. Unified Climate Vulnerability Database

- **Action:** Establish a unified, cross-sectoral digital database to monitor climate risks, combining efforts from the Directorate for Mobility, urban planning teams, and environmental departments.
- **Engineering Specifications:** Deploy an Internet of Things network of smart sensors to monitor pavement temperatures, water-logging levels at underpasses, and slope movement in real time. Embed these climate resilience metrics directly into all future updates of the Sustainable Urban Mobility Plan (SUMP) and infrastructure procurement contracts.