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EVALUATING CLIMATE-RESILIENT URBAN PLANNING SOLUTIONS FOR NUKUS (KARAKALPAKSTAN, UZBEKISTAN)

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***Abstract** Nukus, the administrative center of Karakalpakstan, faces a set of urban-development constraints that are unusual in scale for a mid-sized city: chronic water stress, increasing heat exposure, and recurrent sand and dust storms associated with the Southern Aral Sea crisis. This paper proposes a compact, evidence-based evaluation approach to compare urban-planning measures under these conditions. Using publicly available climate summaries and internationally recognized indicator definitions, we develop a small set of planning indicators covering mobility access, dust and heat shelter, water resilience and implementation readiness, and we demonstrate a scenario-based comparison of three intervention packages (mobility-focused, green-infrastructure-focused and integrated). Results suggest that an integrated package is most robust because it couples transport improvements (including fleet modernization) with salt- and drought-tolerant green infrastructure and water-sensitive public space standards. The novelty of the work is the explicit translation of regional environmental stressors into a transparent municipal scorecard that can be updated as the Nukus Green City Action Plan and related programs mature.*

***Keywords** Nukus; Karakalpakstan; Aral Sea region; urban planning; sand and dust storms; public transport; green infrastructure; climate adaptation*

1. Introduction

Cities in the Southern Aral Sea region carry long-term environmental burdens which directly shape infrastructure costs and public health. Research and field reports consistently link the desiccation of the Aral Sea to salt-laden dust transport and associated health risks in affected settlements, including Karakalpakstan [1]. At the same time, regional adaptation priorities increasingly emphasize land restoration and dust mitigation at source, such as afforestation of the dried seabed [2,3].

For a city like Nukus, the implication is clear: planning decisions cannot treat mobility, public space design and urban greening as separate sectors. Heat, wind and dust exposure influence how people use streets, how quickly surfaces deteriorate and how expensive landscaping becomes when irrigation is scarce. The New Urban Agenda calls for integrated, inclusive and sustainable urban development, and the Sustainable Development Goals provide measurable indicators relevant to transport access and urban services [4,5].

Nukus also has a practical window of opportunity. International investment has recently targeted fleet renewal and public transport improvement in Nukus, including procurement of electric buses and associated depot and charging infrastructure [7]. At the same time, local studies of the Nukus transport system highlight operational gaps that typical master plans can address: route structure, service reliability and passenger comfort during hot and dusty periods [8].

The purpose of this paper is to provide a scientifically grounded yet implementable way to compare planning measures for Nukus. The specific objectives are: (i) translate climate and dust constraints into a

small set of measurable planning indicators; (ii) apply internationally recognized definitions for public transport access; and (iii) demonstrate how alternative intervention packages can be ranked in a transparent way that supports municipal prioritization. The practical significance is that the proposed scorecard can be used for rapid screening during preparation of municipal programs (for example, a Green City Action Plan) before more detailed engineering design. The approach is intentionally designed to be light on data requirements so it can be repeated annually.

2. Materials and Methods

Study design. The work is structured as an applied evaluation study. Instead of claiming a citywide measured baseline, we use a scenario-based demonstration that combines (a) publicly available climate summaries for Nukus, (b) peer-reviewed and institutional evidence on dust and land restoration in the Aral Sea region, and (c) internationally standardized indicator definitions for transport access [1-6,9,10].

Climate and seasonal stress representation. For planning purposes, municipal design decisions often depend on seasonal constraints such as heat stress, freezing risk and the timing of the windiest months. To visualize these constraints, we assembled an illustrative monthly climate baseline for Nukus (temperature and precipitation) consistent with publicly available climatological summaries and long-term averages [9]. The baseline is used to define three practical planning periods: cold season (higher freeze risk), hot-dry season (heat exposure and high cooling demand) and a windy transitional period when dust events are

common. This classification is not a substitute for meteorological analysis; it is used to align design choices with expected constraints.

Indicator framework. Five indicators were defined to reflect the dominant planning questions faced by Nukus: (1) convenient public transport access; (2) dust and heat shelter in the public realm; (3) water resilience of landscaping and public spaces; (4) public space quality and safety; and (5) implementation readiness. For transport access, the indicator is aligned with SDG 11.2.1 definitions, including the use of walking-distance thresholds to recognized stops along the street network [5,6]. Other indicators are defined as bounded scores (0 to 1) that can be updated using basic administrative data and field audits.

Scenario packages and scoring. We compared four packages: a baseline (reflecting incremental improvements only), a mobility package (route and fleet improvements), a green package (shelterbelts and shade-first approach) and an integrated package combining both. Weights were assigned to indicators based on relevance to Nukus constraints: mobility access and dust/heat shelter were given the highest weights. Composite package scores were calculated as the weighted sum of indicator scores. This scoring is intended for prioritization, not for predicting exact welfare outcomes.

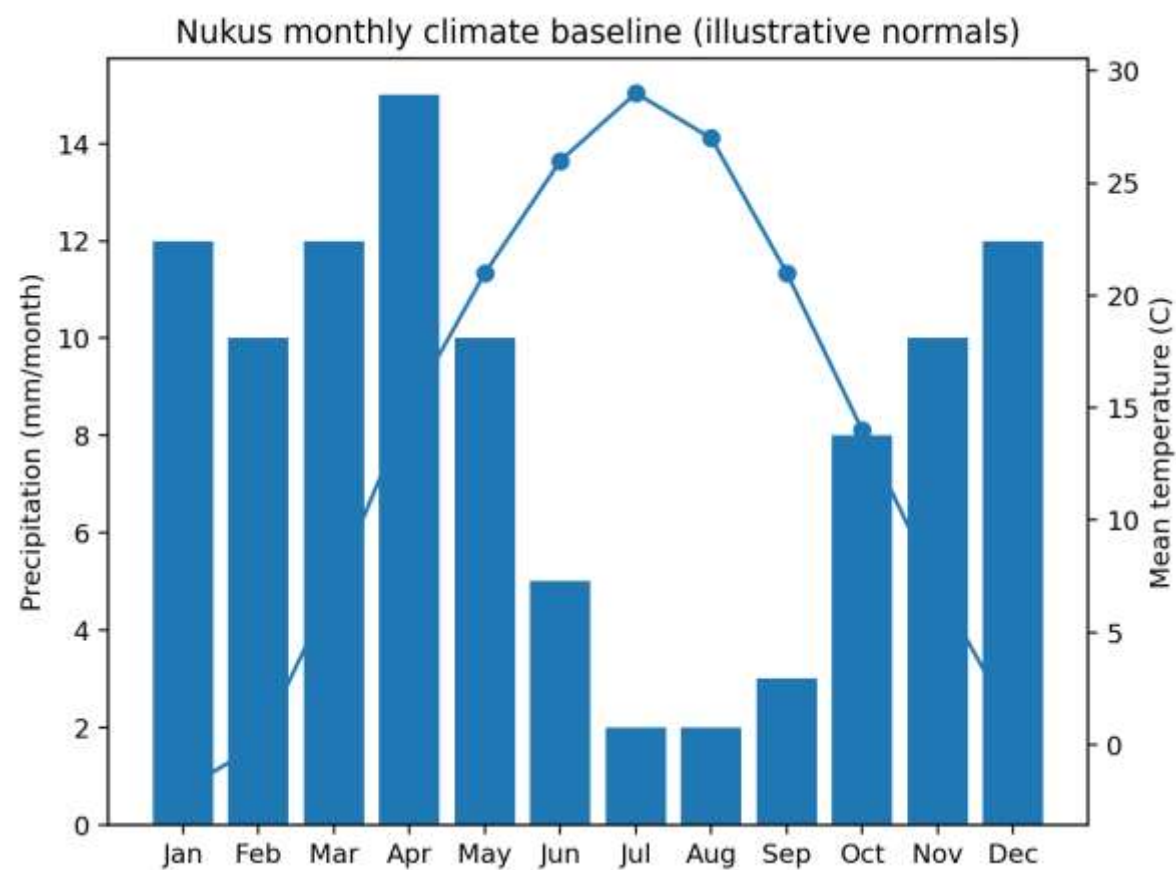


Figure 1. Monthly climate baseline for Nukus: precipitation (bars) and mean temperature (line). Values are illustrative and consistent with public climate summaries [9].

Indicator	Operational definition (0-1 score)	Primary evidence base	Why matters Nukus	it in
Convenient public transport access	Share of residents within walking distance to a recognized stop (as defined by SDG 11.2.1); mapped or audited and scaled to 0-1.	SDG 11.2.1 methodology and thresholds [5,6]; Nukus transport diagnostics [8]; investment context [7].	Reduces reliance on private cars and improves comfort during heat and dust events.	

Dust and heat shelter	Proxy for shaded and wind-protected pedestrian routes (tree canopy, pergolas, windbreaks); 0-1 based on coverage targets.	Health and dust evidence [1,10]; Aral seabed restoration as dust mitigation [2,3].	Improves walkability and lowers exposure to salt-laden dust and heat.
Water resilience of public spaces	Use of drought- and salt-tolerant species, efficient irrigation, and permeable surfaces; 0-1 based on adoption.	Arid climate baseline for Nukus [9]; restoration and drought adaptation evidence [2,3].	Avoids high irrigation demand and keeps greenery viable under scarce water supply.
Public space quality and safety	Basic street design and maintenance quality; lighting; crossing safety; 0-1 based on audit checklist.	New Urban Agenda principles [4]; practical design constraints under dust and heat [1,10].	Supports inclusive access and reduces crash risk and heat stress.
Implementation readiness	Institutional capacity, funding alignment, and ability to monitor indicators; 0-1 based on documented readiness.	Investment trigger and planning commitments [7]; SDG monitoring guidance [5,6].	Increases probability that plans translate into built projects.

3. Results

The climate baseline visualization (Figure 1) reinforces two practical points for Nukus: summers are hot and very dry, while winters include periods where freezing conditions can occur. From a planning perspective, this implies that shading and dust shelter are not seasonal luxuries but core design requirements for streets and stops, and that planting palettes must tolerate both drought and salinity.

Table 1 summarizes the indicator framework and the evidence supporting each indicator. Importantly, the framework links municipal actions to internationally recognized measurement approaches, allowing local monitoring to align with SDG reporting language where relevant [5,6].

Figure 2 presents the scenario-based comparison of intervention packages. The integrated package achieves the highest composite score because it improves both mobility access (through service and fleet improvements) and the public realm (through shelter and water-resilient design). The green package performs well on exposure reduction but cannot fully compensate for limited transport access. The mobility package improves access but leaves exposure and comfort risks largely unchanged.

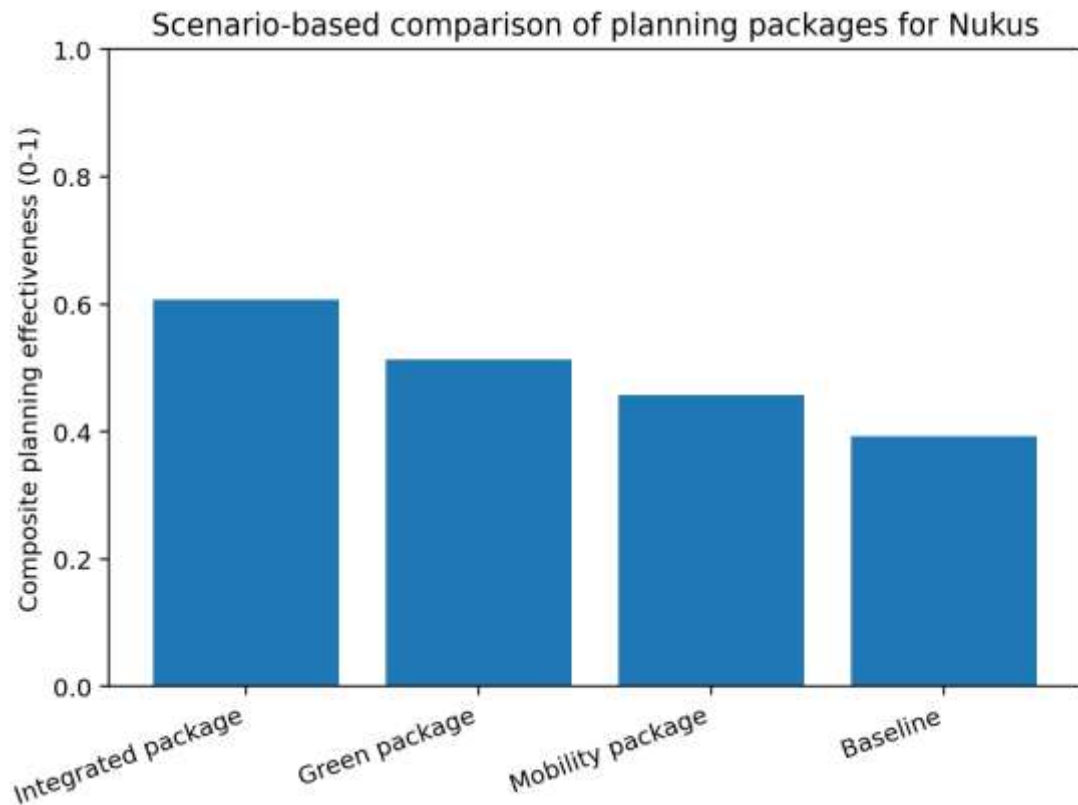


Figure 2. Scenario-based composite scores for four planning packages (0-1). The scores are illustrative, calculated from the indicator weights defined in the Methods section.

Measure	Expected benefits co-under Nukus conditions	Supporting evidence
Public transport modernization (fleet, depots, charging) plus route reliability improvements	Higher passenger comfort in heat and dust; reduced local air pollution; better access to jobs and services.	Investment framework for Nukus e-buses [7]; SDG transport access methodology [5,6]; local operational analysis [8].
Dust and heat shelter standards for streets and stops (shade targets, windbreak orientation)	Reduced exposure during walking and waiting; improved walkability; more	Aral Sea health and dust evidence [1,10]; restoration benefits and dust reduction pathways [2,3].

	stable street life in summer.	
Water-sensitive public space design (drought-tolerant planting, efficient irrigation, permeable surfaces where feasible)	Lower maintenance and irrigation demand; reduced heat load; improved resilience under water scarcity.	Local arid climate context [9]; restoration and drought adaptation priorities [2,3].

4. Discussion

The comparison highlights a planning lesson that is particularly relevant to Nukus: sectoral projects deliver partial benefits unless the public realm is designed around exposure constraints. In practice, transport investments are most effective when the walking and waiting environment is comfortable and safe. This is consistent with the SDG 11.2.1 emphasis on convenient access as a function of the street network and stop location, not only the existence of vehicles [5,6].

Regional land restoration programs (for example, afforestation of the dried Aral seabed) are necessary to reduce dust at source, but they do not eliminate the need for urban-scale shelter design. Evidence from the Aral Sea region indicates that dust exposure is persistent and has measurable health impacts [1], supporting the inclusion of dust and heat shelter as a first-order planning indicator rather than a secondary aesthetic choice.

Limitations. The framework is designed for municipal screening and is intentionally conservative about data needs. The scenario values in Figure 2 are illustrative, and citywide application would require local surveys or geospatial analysis (for example, stop inventories, canopy mapping and maintenance records). Nevertheless, the structure of the indicator set and the reliance on recognized definitions allow the city to

progressively replace assumptions with measured data without changing the evaluation logic.

5. Conclusion

For Nukus, climate and dust constraints should be treated as core planning inputs. This paper proposed a compact indicator-based evaluation method grounded in international frameworks and regional evidence. A scenario comparison showed that an integrated package combining mobility improvements with water-resilient, salt-tolerant green infrastructure and shelter standards is the most robust option. Future work should focus on building a municipal data pipeline for SDG-aligned transport access assessment, mapping of shaded routes and maintenance indicators, so that the scorecard becomes a living tool for annual budgeting and program updates.

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