Shading the Whole Journey: A Review of Outdoor Heat, Ground Surfaces and Climate-Specific Cooling for Sustainable Mega-Event Precincts in Saudi Arabia

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Abstract

Saudi Arabia will host World Expo 2030 in Riyadh and the FIFA World Cup 2034 in five cities. Visitors to both events will spend much of their time outdoors: walking from transit stations, standing in security and ticket queues, and gathering in plazas and fan zones at fixed times that cannot move with the weather. Anyone who has walked across an open plaza in a Saudi summer, or even in October, knows that the problem is not only hot air. The sun strikes from above, and a hot, bright pavement sends heat and glare back from below. This review brings together published evidence on outdoor thermal comfort in hot climates and reads it from the point of view of an architect designing the visitor's route. The main findings are four. First, daytime heat stress in hot-dry cities comes mainly from direct and reflected sun. Continuous shade along the whole visitor journey therefore matters more than any other single measure, and artificial shade can work as well as tree shade. Second, light and highly reflective paving in open sun can lower surface temperature while raising the radiant load on people; reflective surfaces belong under shade, not in exposed plazas. Third, fine water mist works well in dry Riyadh but adds discomfort in humid coastal hosts such as Jeddah and Al Khobar, where cooled and dehumidified refuges and breeze-aware layouts are needed instead. Fourth, standing still in a queue under the midday sun is a heavier burden than walking, and clear information about remaining time and distance helps people tolerate the route. The paper proposes three checks to be passed before an event precinct is approved: shade continuity at the peak hour, maximum exposure time between refuges, and a city-specific assessment of cooling measures using the Universal Thermal Climate Index. Sustainability links include solar canopies that shade and generate power, irrigation with treated wastewater, and targeted rather than blanket active cooling. A short research agenda closes the paper.

Keywords: outdoor thermal comfort; mega-events; Expo 2030; FIFA World Cup 2034; shade; mean radiant temperature; UTCI; evaporative cooling; hot-arid climate; Saudi Arabia; sustainable urban design

1. Introduction

In Saudi Arabia, most of us have walked through an open plaza or a festival ground in the full heat of summer, or at the start of the season in October. The first thing you notice when you leave an air-

conditioned space for an exposed plaza is that the problem is not only "hot air". The heat seems to come from two directions: the sun hits your head from above, and the hot paving answers back from below with heat and glare. People change their behaviour at once. Everyone walks quickly, keeps close to the walls of buildings and follows any narrow strip of shadow, or jumps from under a canopy to the shade of a tree. The wide, impressive plaza stays almost empty in the middle while people crowd into any shaded corner.

This everyday observation is the starting point of this paper, because the Kingdom is about to place very large numbers of visitors in exactly such spaces. World Expo 2030 will run in Riyadh from 1 October 2030 to 31 March 2031 on a site of about 6 km², and more than 40 million visits are expected over the six months [1]. On 11 December 2024, FIFA confirmed Saudi Arabia as host of the 2034 World Cup, with 15 stadiums in five host cities: Riyadh, Jeddah, Al Khobar, Abha and NEOM. FIFA has said it will work with stakeholders to set the optimal timing of the tournament because of the hot climate [2]. Even if the main events are placed in the cooler months, October in Riyadh still falls within the season of outdoor heat stress [3]. Over the longer term, climate projections place parts of the Gulf region among the places where heat may approach the limits of human adaptability by the end of the century [4].

Mega-events are not held only inside air-conditioned buildings. Millions of people will walk long distances from transit stations, stand in queues for security checks and tickets, and gather in plazas and fan zones at times fixed long in advance, which cannot be changed because of the weather. With five host cities in different climates, the control of heat in outdoor space becomes a matter of human safety and operational success, not a luxury.

Research on outdoor thermal comfort has grown quickly, and several reviews summarise mitigation strategies at a global level [5–9]. Saudi studies have also increased, covering school playgrounds and parks in Riyadh [3,10] and street orientation in Jeddah [11]. Still, the existing work leaves three problems open. First, the literature studies spaces, while event visitors experience a journey: a sequence of walking, waiting and gathering. Second, guidance seldom separates the dry interior from the humid coast, although both climates exist among the 2034 host cities. Third, a common design habit works against comfort. In many public spaces in our cities, the plaza is designed for the aerial shot or the 3D rendering. It is very large and fully open, so the façade looks good in pictures. It is paved with light tiles or polished granite and decorated with small shrubs spaced far apart. The result is a plaza that stays empty all day from May to October and comes to life only after sunset.

The aim of this review is to bring the published evidence together around the visitor's journey and to turn it into a small number of design checks for Saudi event precincts. Section 3 explains why radiation, not air temperature, is the main enemy of comfort outdoors. Sections 4 to 6 review shade, ground surfaces and water-based cooling, and show where the host cities need different answers. Section 7 looks at queues, refuges and information along the route, and Section 8 proposes three checks before a precinct is approved.

2. Review Method

This is a narrative review. A narrative design was chosen because the sources mix field measurements, numerical simulations, surveys and official announcements, which cannot be pooled statistically.

Scoping search. The open bibliographic index OpenAlex was searched through its public API for the phrase "outdoor thermal comfort" in titles and abstracts. The search returned 2,737 records. A second query combined the same phrase with Saudi OR Riyadh OR Jeddah and returned 35 records. Both counts were retrieved on 11 November 2026 (Figure 1).

Selection. The review then followed three routes: recent review articles on outdoor comfort and heat mitigation; studies on the specific measures discussed in this paper (urban geometry, shade, vegetation, reflective surfaces and water mist); and Saudi and mega-event studies. Backward citation tracking was used from the key reviews. Peer-reviewed sources were included when they had a registered DOI, and each DOI was checked against its Crossref record. Facts on the two events were taken from the Bureau International des Expositions and from news reports of the FIFA decision. Searching for and checking references was assisted by a generative AI tool, as stated in the Declarations; the author checked every source used.

Limitations. Only one bibliographic index was searched systematically, and the review is not exhaustive. The paper reports no new measurements. Personal observations are clearly marked as such and are used to frame the questions, not as evidence.

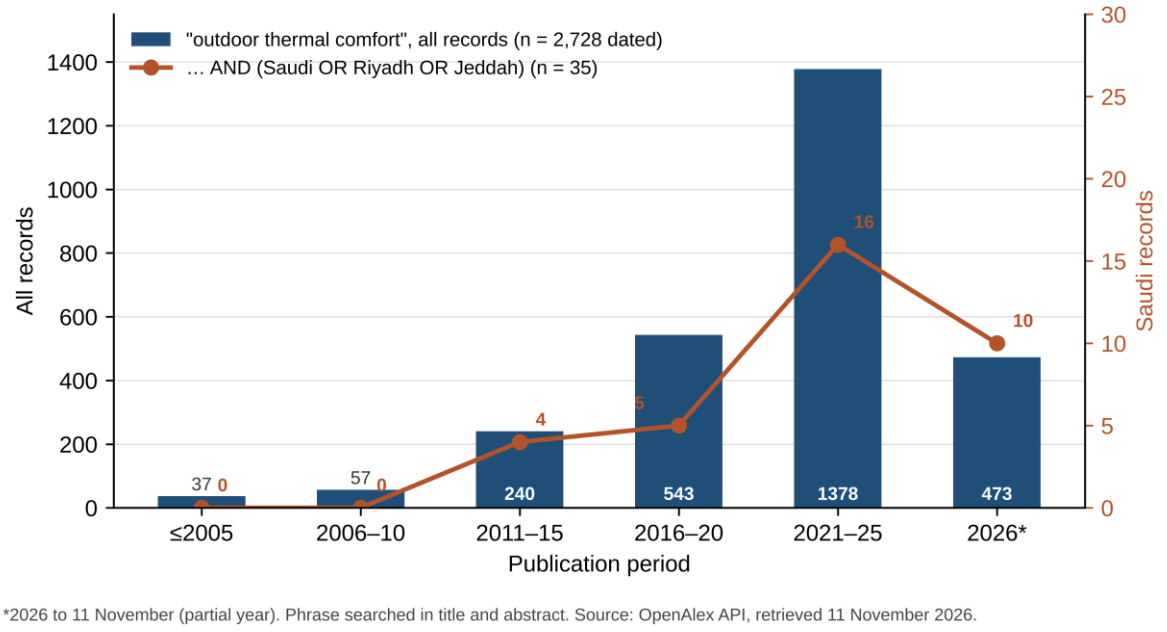


Figure 1. OpenAlex records with "outdoor thermal comfort" in the title or abstract, by publication period, for all records and for records that also mention Saudi Arabia, Riyadh or Jeddah. Retrieved 11 November 2026; 2026 is a partial year.

The field has grown fast: 1,378 of the 2,728 dated records appeared in 2021–2025. Saudi studies are also increasing, but they remain a very small share of the whole, about 1.3%. The evidence base for the Saudi host cities is therefore thin compared with the scale of the events.

3. Radiation, Not Air Temperature

The weather forecast reports air temperature. People outdoors feel something else: the total heat load on their bodies. In a hot-dry city at midday, most of that load is radiation. It comes from the direct sun, the bright sky, and the heat and sunlight sent back by hot ground and walls. Comfort research captures this through the mean radiant temperature (MRT), which combines all radiant fluxes reaching a person, and through indices that combine MRT with air temperature, humidity and wind. The two indices most used in hot-climate studies are the Physiological Equivalent Temperature (PET) [12] and the Universal Thermal Climate Index (UTCI) [13,14]. UTCI has the advantage of a fixed scale of heat-stress categories: moderate (26–32 °C), strong (32–38 °C), very strong (38–46 °C) and extreme (above 46 °C) [14]. Comparative work shows that UTCI responds well to changes in radiation and wind [15].

Saudi evidence shows how large the radiant load can be. In a park in Riyadh, simulated MRT reached 81.3 °C and UTCI 53.5 °C during the hottest week, while summer daytime air temperature averaged about 43 °C with a relative humidity near 19% [10]. The radiant environment was almost 40 degrees hotter than the air. A field study in an arid urban setting by researchers in Riyadh found that people would face strong heat stress for most of the summer daytime, and that long sun exposure combined with physical activity would cause heat fatigue [16]. A seasonal study in Tempe, Arizona, also a hot-dry city, found that globe temperature, which captures radiation from all directions, tracked people's comfort better than air temperature [17].

For designers, this changes the question. By day, pedestrians suffer mostly from direct and reflected sun, and much less from the temperature of the air. Measures that only cool the air by a degree or two will do little for a person standing in the sun, while measures that block or reduce radiation can change the experience completely. This also explains why the comfort indices, not air temperature, should be used to judge an event space. Field and simulation methods for these indices still vary between studies, and calls for standard instruments and procedures remain relevant [18].

A further nuance concerns the "heat island". Remote-sensing studies of Riyadh show that the city can be cooler than its desert surroundings at the surface by day and warmer at night [19], and that land surface temperature has risen across land-use types over recent decades [20,21]. So for a pedestrian in an event plaza, the daytime problem lies at street level, in the radiant load, more than in the city as a whole.

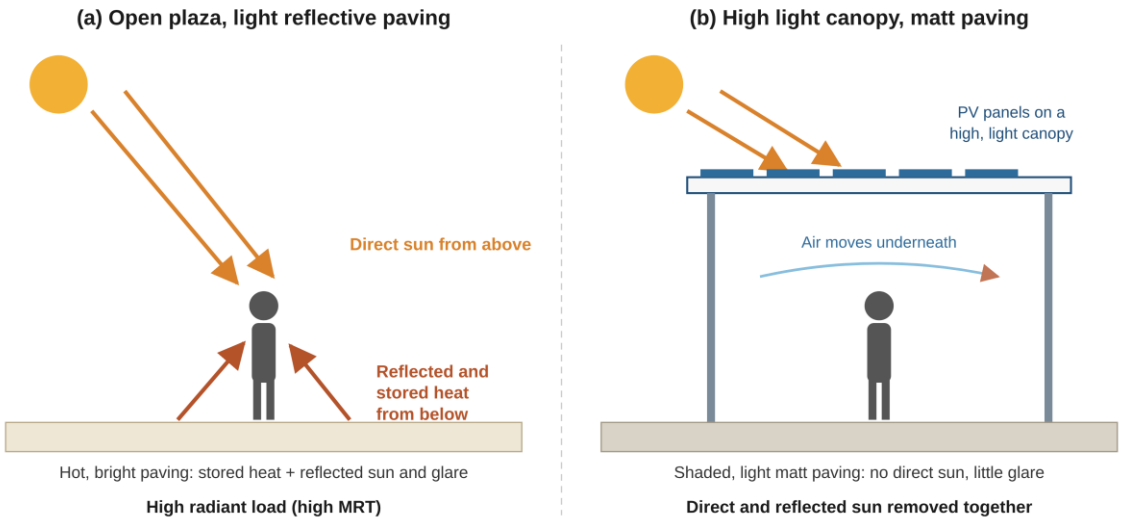


Figure 2. Heat from two directions: in an open plaza the pedestrian receives direct solar radiation from above and reflected radiation and heat from the paving below. A high, light canopy removes the direct sun and the reflected component at the same time.

4. Shade: The Backbone of Comfort

4.1 What the evidence shows

Shade is the most effective single measure because it removes direct radiation at once. In Tempe, tree shade and an artificial solar canopy were about equally effective in improving perceived thermal comfort [17]. In Riyadh, trees with large canopies reduced UTCI by up to 11.26 K at 11:00 in a park, and the best combination of 15 m trees with full photovoltaic (PV) shading reduced UTCI by 9.8 K at 14:00 [10]. In four Riyadh school playgrounds, optimised shading with small openings combined with trees reduced UTCI by about 4.2–4.8 °C in the hottest months [3]. Combinations clearly do better than single measures. Even so, the best passive packages still leave strong heat stress at summer midday in Riyadh.

Urban geometry provides shade at no running cost. In the hot-dry city of Fez, a deep street canyon was on average about 6 K, and up to 10 K, cooler by day than a shallow one [22]. Simulations for a hot-dry climate found that wide streets with a height-to-width ratio of 0.5 are highly stressful in any orientation, while narrower north–south streets perform much better [23]. In humid Jeddah, street orientation also changed comfort levels clearly [11].

4.2 The author's preference

As an architect, I prefer to combine two kinds of shade: the shade of the built masses themselves, and high canopies combined with trees. The shade of buildings, when the passages are well proportioned and correctly oriented, gives deep and cool shade with no maintenance cost. High, light-coloured canopies, especially those carrying solar panels on top, are very practical. They give shade from the opening day of the project, without waiting ten years for trees to grow. They let the air move underneath, and they produce electricity that can run the lighting or cooling of the space.

When trees are planted under or beside them, the result is a natural, restful scene with real protection from the sun.

Two conditions apply. The canopy should be high and light in colour, so that it does not store heat and radiate it back onto people's heads. And the arrangement of trees and panels must be planned together: in the Riyadh park study, very large tree canopies shaded the PV panels and reduced their output [10]. Trees also bring benefits beyond shade. Street greenery affects comfort through the mind as well as the body [24]. A systematic review found that green areas tend to be cooler than non-green areas, although the evidence was not enough to say exactly how greening should be integrated into a city [25]. In Riyadh, the main limit is water. The Green Riyadh programme irrigates with treated wastewater through a network of about 1,350 km sized for about 7.5 million trees [10], which shows how event landscapes can be linked to non-potable water from the start.

4.3 Shade must be continuous

A common mistake is to place separate canopies as isolated islands. The visitor then has to leave and re-enter the sun again and again between one station and the next. For an event route, the important measure is not the shaded area of the site but the share of the actual walking and waiting route that is shaded at the peak hour. A Tokyo study of the 2020 Olympic marathon course showed how strongly heat stress varied along a single route with street geometry and shading [26], which supports assessing routes segment by segment rather than as an average.

5. Ground Surfaces, Glare and Seating

Dark or rubber surfaces exposed to the sun store heat, burn the feet and raise the temperature of the space. What many people overlook is that very light, highly reflective paving (high albedo) in a sunny plaza is not a solution for pedestrians either. It may lower the surface temperature and the air temperature slightly, but it reflects sunlight and glare back towards people's bodies and faces and so increases their heat stress. The evidence supports this. In Los Angeles, a reflective coating made the road surface up to 6 °C cooler in the afternoon, but the air only about 0.5 °C cooler. Meanwhile, pedestrians on the coated streets received a mean radiant temperature about 4 °C higher than on uncoated ones [27]. Earlier work in street canyons in a hot-dry climate showed that high-albedo materials can increase pedestrian heat stress through reflected radiation [28].

The rule I follow is simple: do not use reflective paving in an open, unshaded plaza; use light, matt colours under shade. On exposed routes, a paving that does not reflect glare and does not store much heat is the better choice. Glare also matters for comfort on its own. On light, shiny floors people narrow their eyes the whole time they are outside.

Seating also matters. Stone or metal benches in the sun become too hot to sit on, even in the late afternoon, because they have stored the heat of the whole day. Seats on event routes should be shaded during the hours of use, or made of materials that stay touchable in the sun. This is the author's observation and a gap in the reviewed literature, which focuses on air, surface and radiant temperature rather than on contact with surfaces.

6. Water and Evaporative Cooling: One Recipe Does Not Fit All

Fine water mist is widely used at events and in hot cities. A systematic review of twenty years of studies, from 12 countries and 7 climate zones, summarises the technologies, methods and effects of water mist systems [29]. Field measurements with surveys show that misting can improve comfort, with results depending on droplet size, nozzle position, wind and, above all, the humidity of the air [30]. At the Shanghai World Expo 2010, spray cooling was applied in outdoor spaces, including waiting areas, which makes it a direct precedent for Expo queues [31].

I have tried misting in both climates, and the difference is like night and day. In Riyadh, when you walk along a passage or sit in an outdoor café with the fine mist running, you feel fresh at once, as if cool air touches your face. The air is dry, so the water evaporates before it wets you and takes heat with it. When I tried the same idea on the coast in Jeddah, it was very unpleasant. The air is already close to saturation, so the mist does not evaporate. It turns into closeness and dampness that makes clothes stick to the body and increases the feeling of heat and discomfort.

This is exactly what the physics of evaporation predicts. Evaporation needs dry air; where relative humidity is near 19% in summer, as in Riyadh [10], each litre of water can absorb much more heat from the air than on a humid coast. In humid hosts, misting adds moisture and can make the very heat stress it aims to relieve worse, because it also slows the evaporation of sweat from the skin. In Jeddah and Al Khobar the better options are layouts that open paths for the sea breeze [11] and enclosed, cooled and dehumidified waiting points. The lesson from the Qatar 2022 World Cup points the same way: the climatic challenge of a Gulf tournament was handled with a mix of venue cooling and timing, and with attention to what the facilities would leave behind [32].

7. The Visitor Journey: Queues, Refuges and Information

7.1 Standing is worse than walking

Forced standing under the sun is what tires people most. Walking in the heat is one thing; standing in a security or ticket queue that does not move under the midday sun is something else entirely. The reviewed studies, however, mostly assess spaces when they are empty and do not measure the time people spend waiting in them. Field studies confirm that prolonged sun exposure combined with activity leads to heat fatigue [16], and the psychological literature shows that exposure time, expectation and perceived control all shape how people judge outdoor conditions [33]. A person who knows that a queue will take five minutes, and who can see the shaded gate ahead, is in a different position from a person waiting with no information.

7.2 Designing the route from the metro to the stadium

If I were to design the route from a metro station to a stadium, I would put three things first.

First, continuous shade without gaps. The fan should leave the metro door and reach the stadium gate under a continuous shaded cover, without crossing “sun gaps” that raise body heat every few metres.

Second, cooled places to catch one’s breath. Along the route and at the security points, I would place cooled rest points (cooled refuges) and drinking water at short intervals. Nobody should walk more

than two or three minutes in the heat without finding a place to cool down. This interval is a design intention, not a tested threshold; Section 8 proposes it as a measure to be tested.

Third, a comfortable floor that does not reflect the sun. I would choose paving that does not reflect glare and does not store heat, with clear signs that tell the fan how many minutes remain to the gate. When people know how much is left, they tolerate the route psychologically much better than those who walk into the unknown.

Older people and children deserve special attention in the spacing of refuges and water points, because they are less able to cope with heat exposure and slower on long routes.

8. Three Checks Before a Precinct Is Approved

The evidence and the observations above lead to three checks that an event precinct should pass before its design is approved (Table 1). They are proposals for practice and for future testing, not validated standards.

Table 1. Proposed heat checks for event precincts.

Check	What is verified	How it can be assessed	Notes and sources
1. Shade continuity at the peak hour	The actual path of people, including every queue and long walkway, is shaded at midday	Share of the route length and of each queue area in shade at the design hour, from a solar or microclimate model	Shade is the most effective single measure [10,17]; routes vary segment by segment [26]
2. Maximum exposure time	Minutes a visitor spends between the transit stop and the entrance, and the distance to the nearest refuge and drinking water	Longest continuous time in strong heat stress (UTCI above 32 °C) between two refuges; safe spacing for older people and children	Exposure time shapes perceived comfort [33]; the target interval needs testing
3. Cooling suited to the city	Riyadh solutions, such as misting fans, are not copied to Jeddah or Al Khobar; cooling is checked against each city's weather and humidity	UTCI assessment at the design hour with local weather data; misting only where the air is dry	Misting depends on humidity [29,30]; UTCI categories [14]

For checks 1 and 3, microclimate models such as ENVI-met allow the designer to test alternative layouts of canopies and trees before construction. A review of the model's performance shows that results should be validated against field measurements, especially for radiation and surface temperatures [34]. For check 2, the measure is new. To the author's knowledge, no study has yet set a safe exposure interval for event crowds in Saudi climates, and the two-to-three-minute interval suggested in Section 7 should be tested in pilot events before 2030.

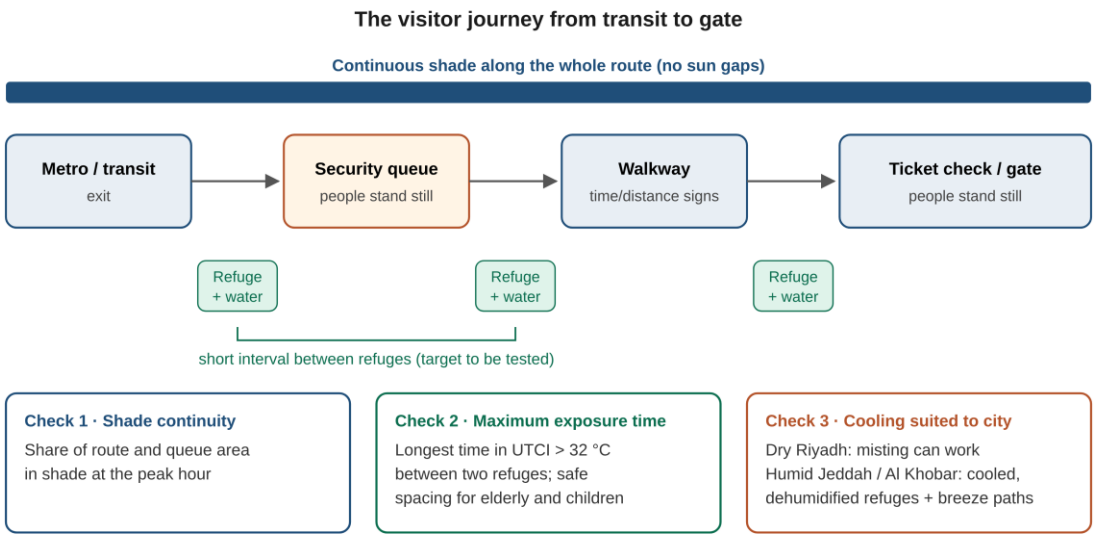


Figure 3. The visitor journey from transit to gate with continuous shade, cooled refuges and water points, and the three checks applied along it.

9. Sustainability Links

Heat measures for mega-events must not trade one problem for another. Energy, water and legacy need the most care.

Energy. PV canopies combine shade with power generation [10], so the main shading layer of a route can also feed its lighting, signs and cooled refuges. Active cooling should be targeted. Cooled refuges at the points where crowds wait use much less energy than attempts to cool whole plazas.

Water. Trees and misting both use water. Linking event landscapes to treated wastewater, as in the Green Riyadh network [10], and limiting misting to the dry interior where it actually works, avoid wasting water where it brings little benefit.

Legacy. Event precincts last longer than the events. A shaded route from a metro station, built for a few weeks of football, can serve the city's daily life for decades. The Qatar 2022 experience shows that legacy should be planned from the start [32]. The plaza that stays empty from May to October is a waste of land and materials, whatever its appearance in the renderings.

10. Research Gaps

The reviewed literature leaves at least four questions open.

1. **Few Saudi field measurements during real crowds.** Most Saudi studies use simulations of parks or schools. Pilot events before 2030 and 2034 offer a chance to measure real conditions on real routes.
2. **Queues and waiting time.** Studies assess empty spaces, not the minutes people spend standing in them. Exposure-time measures need field testing.
3. **The humid host cities and the highlands.** The Saudi evidence found is concentrated in Riyadh and Jeddah. Little was found for Al Khobar, Abha or NEOM.

4. **Contact with hot surfaces.** The temperature of seats, handrails and other surfaces that people touch has received little attention compared with air and radiant temperature.

11. Conclusions

What tires people outdoors is the direct sun and the heat reflected from the ground, not just the air temperature in the weather report. For this reason, continuous shade is the greatest service a designer can give a visitor, along the whole route from the transit stop to the seat. The five host cities of the 2034 World Cup are not one climate: what refreshes people in dry Riyadh can suffocate them in humid Jeddah and Al Khobar. Reflective paving belongs under shade, not in the open sun. Finally, good plaza design is not complete with concrete and trees alone. It must work together with smart management of crowd movement, waiting times, drinking water and safe refuges. If these points are respected, the precincts of Expo 2030 and the World Cup 2034 can become a lasting urban legacy for Saudi streets and cities.

Declarations

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Use of generative AI: Generative AI was used to translate the author's Arabic notes into English, to search for references, and for language editing. The author provided the observations and arguments, reviewed and edited the full text.

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