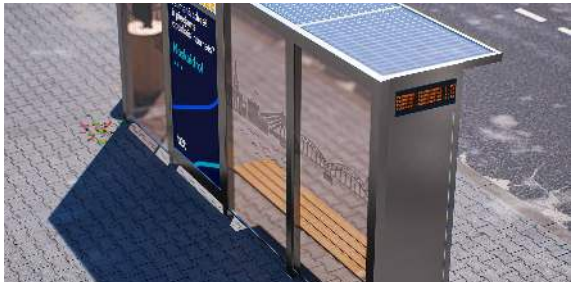
1 Cold



Walkability
Cold surfaces uncomfortable for sitting/resting

Bikeability
Cold handlebars uncomfortable to grip

Spatial Design
Inadequate thermal comfort discourages use

Heated waiting areas and shelters

Oslo: intelligent bus shelter networks

Oslo's smart city strategy includes initiatives like solar-powered infrastructure, connectivity for public transport users through the Ruter app, and a focus on sustainability.

4 Cold

Walkability
Doorways become icy from repeated melting/freezing events at threshold

Bikeability
Bike parking pads have icy patches from building heat lost at base wall

Spatial Design
Thermal bridges near entrances create condensation, slipperiness

Insulation at threshold areas

Oslo: targeted anti-slip matting for entrances and racks

Oslo has implemented various winter safety measures including installing anti-slip materials, such as mats and textured coverings, in high-traffic pedestrian areas and around public transport stops, entrances to public buildings, and bike parking zones to prevent accidents during the winter season.

2 Cold

Walkability
Thermal discomfort reduces outdoor activity

Bikeability
Thermal discomfort reduces cycling duration

Spatial Design
Cold surfaces create uncomfortable microclimates

Public space thermal confort design

Copenhagen: thermal comfort public space design

Copenhagen's public space design for thermal comfort emphasizes a "people-first" approach by integrating green infrastructure, water features, and urban morphology to mitigate heat and enhance well-being. Key strategies include optimizing the ratio of green to hard surfaces, utilizing strategic tree planting, ensuring continuity of green networks, and incorporating urban water elements to create more pleasant and functional public spaces, even in the face of a changing climate.

2 Cold

Walkability
Thermal discomfort reduces outdoor activity

Bikeability
Thermal discomfort reduces cycling duration

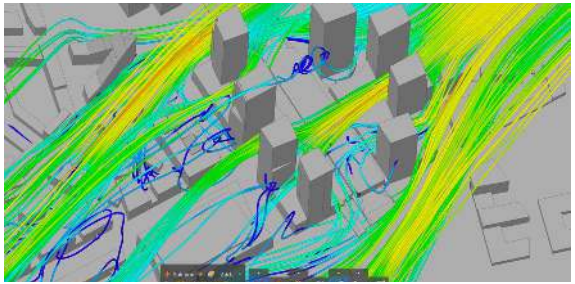
Spatial Design
Cold surfaces create uncomfortable microclimates

Public space thermal confort design

Stockholm: microclimate management

Stockholm has embedded the principles of green and blue infrastructure into its urban planning fabric. This is evident in the city's "Environment Programme 2030" and "Climate Action Plan 2030," which outline concrete measures to create a more resilient and sustainable urban environment.

3 Cold



Walkability
Wind chill affects exposed skin

Bikeability
Wind chill creates dangerous exposure

Spatial Design
Wind chill reduces usable outdoor spaces

Wind protection microclimate design

Helsinki: comprehensive wind protection urban planning

The city's strategic documents, such as the Helsinki City Strategy and various climate adaptation plans, explicitly recognize strong winds as an extreme weather event that requires proactive mitigation measures. A key principle embedded in these plans is the "control of increased wind pressure" in all new developments.

3 Cold

Walkability
Wind chill affects exposed skin

Bikeability
Wind chill creates dangerous exposure

Spatial Design
Wind chill reduces usable outdoor spaces

Wind protection microclimate design

Oulu: integrated comfort strategies

The city is a prominent member of the Winter Design Cities network, a global platform for cities to share best practices in creating livable winter environments. Oulu's approach is a blend of practical solutions and a cultural embrace of the season.

5 Darkness

Walkability
Reduced visibility increases accident risk

Bikeability
Reduced visibility to/from other road users

Spatial Design
Reduced visibility in public spaces

Enhanced LED street lighting

Stockholm: LED lighting upgrades

Stockholm has been actively upgrading its urban lighting infrastructure with LED technology as part of its sustainability and energy efficiency initiatives. Key projects include replacing conventional streetlights with LED luminaires equipped with advanced presence control sensors that adjust the light intensity based on pedestrian or cyclist presence

5 Darkness

Walkability
Reduced visibility increases accident risk

Bikeability
Reduced visibility to/from other road users

Spatial Design
Reduced visibility in public spaces

Enhanced LED street lighting

Helsinki: comprehensive street illumination

Helsinki has implemented a comprehensive and smart street illumination system that integrates advanced LED technology and intelligent control to enhance energy efficiency, safety, and urban quality. With approximately 100,000 luminaires under dynamic control by partners like C2 SmartLight, Helsinki's lighting adapts to real-time conditions such as pedestrian presence and events, optimizing light levels by location and usage.

6 Darkness

Walkability
Fear of walking in dark areas

Bikeability
Inadequate lighting on bike infrastructure

Spatial Design
Poor lighting creates unsafe areas

Smart lighting systems with sensors

Copenhagen: smart lighting with motion sensors

Copenhagen has implemented a city-wide smart lighting upgrade featuring LED streetlights integrated with motion sensors and adaptive control systems. Over 18,800 streetlights, representing about half the city's lighting fleet, have been replaced with energy-efficient LED luminaires equipped with presence/absence detection to automatically adjust brightness based on pedestrian, cyclist, or vehicle movement.

6 Darkness

Walkability
Fear of walking in dark areas

Bikeability
Inadequate lighting on bike infrastructure

Spatial Design
Poor lighting creates unsafe areas

Smart lighting systems with sensors

Malmö: adaptive brightness systems

Malmö has implemented advanced adaptive brightness street lighting systems as part of its smart city initiatives to optimize energy consumption and enhance road safety. A prominent example is the installation of over 600 IZYLUM luminaires with integrated adaptive color temperature technology, allowing the LEDs to adjust their brightness and color temperature dynamically from 3,000K to 2,000K depending on the time of night and traffic density. This ensures optimal visibility during busy periods while significantly reducing light pollution and energy use during low-traffic hours.

8 Darkness

Walkability
Difficulty identifying hazards in low light

Bikeability
Difficulty seeing road hazards at night

Spatial Design
Inadequate lighting infrastructure coverage

Comprehensive lighting master plans

Stockholm: comprehensive pedestrian lighting master plan

Stockholm has a comprehensive pedestrian lighting plan that is part of its broader Pedestrian Plan and urban mobility strategies. This plan prioritizes pedestrian safety, comfort, and accessibility by implementing smart LED lighting systems along pedestrian routes.

8 Darkness

Walkability
Difficulty identifying hazards in low light

Bikeability
Difficulty seeing road hazards at night

Spatial Design
Inadequate lighting infrastructure coverage

Comprehensive lighting master plans

Gothenburg: integrated lighting design

Gothenburg has a well-developed integrated lighting design approach that plays a crucial role in the city's urban planning and sustainability strategies. One hallmark project is the extensive lighting design for the "World of Volvo" building, which combines advanced indoor and outdoor lighting solutions to highlight the building's unique wooden architecture while adapting to seasonal changes in natural light.

9 Darkness

Walkability
Difficulty being seen by traffic

Bikeability
Difficulty being seen by traffic

Spatial Design
No significant issues

Increase lighting near major roads

Stockholm: highway lighting upgrades

Stockholm is undergoing significant highway lighting upgrades as part of the E4 Förbifart Stockholm (Stockholm Bypass) project, one of Europe's largest infrastructure developments. The project involves constructing a new 21-kilometer highway bypass west of Stockholm, with around 18 kilometers built underground in tunnels. This lighting system includes LED strips and floodlights designed to enhance safety, visibility, and energy efficiency within the tunnels.

9 Darkness

Walkability
Difficulty being seen by traffic

Bikeability
Difficulty being seen by traffic

Spatial Design
No significant issues

Increase lighting near major roads

Helsinki: pedestrian overpass illumination

Helsinki features several pedestrian overpass illumination projects that prioritize safety, aesthetics, and sustainability. Notably, the Kruunuvuori Bridge, which is part of the city's Crown Bridges tram and pedestrian network, incorporates integrated lighting designed to maintain comfort and safety throughout the year despite long winter darkness. This includes lighting that shields pedestrians from harsh weather while providing clear visibility and an open atmosphere.

11 Extreme Cold

Walkability
No significant issues

Bikeability
No significant issues

Spatial Design
Extreme cold damages electronic systems

Cold-weather electronic protection

Moscow: cold-weather electronic protection protocols

Moscow employs extensive cold-weather electronic protection protocols designed to ensure the reliable operation and longevity of critical electronic equipment during the extreme winter conditions the city faces. These protocols include the use of specially engineered enclosures, heating elements, and insulation materials that maintain optimal operating temperatures for electronics even when ambient temperatures plunge below -30°C.

11 Extreme Cold

Walkability
No significant issues

Bikeability
No significant issues

Spatial Design
Extreme cold damages electronic systems

Cold-weather electronic protection

St. Petersburg: system winterization

these protocols include preventative maintenance and upgrades to heating, insulation, and anti-freezing systems used across municipal utilities, transportation networks, and public services. For example, water and sewage systems are winterized by replacing liquids with antifreeze compounds and insulating pipes to prevent freezing and damage.

12

Extreme Cold

Walkability
Cold reduces manual dexterity

Bikeability
Cold reduces brake effectiveness

Spatial Design
Cold reduces infrastructure flexibility

Flexible infrastructure design

Copenhagen: adaptive construction standards

Copenhagen's adaptive construction standards emphasize resilience, sustainability, and flexibility to meet future urban challenges. The standards incorporate principles such as design for disassembly and adaptability (DfD and DfA), which enable buildings and infrastructure to be easily modified, expanded, or repurposed over time. These approaches promote the reuse and recycling of materials, reducing environmental impact and extending the lifespan of structures.

14 Extreme Cold

Walkability
No significant issues

Bikeability
Cold temperatures drain e-bike batteries faster, metal components become brittle in cold

Spatial Design
Extreme temperatures affect material properties

Cold-resistant material specifications

Anchorage: extreme cold material specifications

For Anchorage's extreme cold, construction material specifications prioritize frost protection, such as requiring concrete to be free of ice and using heated water and aggregates for masonry, while structures require durable, cold-resistant materials like concrete, wood, brick, stone, and metal.

14 Extreme Cold

Walkability
No significant issues

Bikeability
Cold temperatures drain e-bike batteries faster, metal components become brittle in cold

Spatial Design
Extreme temperatures affect material properties

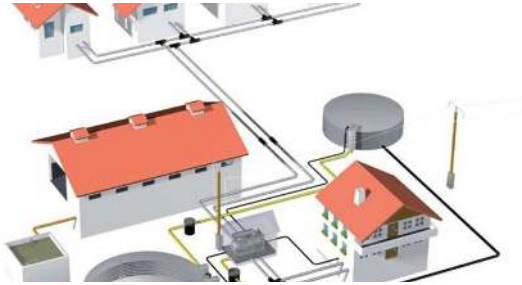
Cold-resistant material specifications

Fairbanks: arctic construction standards

Fairbanks adheres to the Alaska Building Code, which is based on the International Building Code but includes specific amendments for permafrost and cold climates, mandating a minimum footing depth of 42 inches below grade to prevent frost heave.

15

Extreme Cold



Walkability
Cold weather limits time outdoors

Bikeability
No significant issues

Spatial Design
Cold weather increases energy demands

Energy-efficient heating systems

Reykjavik: geothermal district heating integration

Since the 1930s, the city has developed one of the largest and most sophisticated geothermal district heating networks globally, which now supplies around 90% of the city's buildings with hot water for heating. This system harnesses geothermal wells and power plants, such as those at Hellisheidi and Nesjavellir, to produce renewable hot water that is distributed through an extensive pipeline network.

15

Extreme Cold

Walkability
Cold weather limits time outdoors

Bikeability
No significant issues

Spatial Design
Cold weather increases energy demands

Energy-efficient heating systems

Akureyri: renewable energy systems

All heating in Akureyri arrives from geothermal hot water that is extracted from boreholes (100% renewable) and all electricity is produced with either hydropower or geothermal power (100% renewable).

16

Extreme Cold

Walkability
Condensation and surface frost at thermal bridges on walks

Bikeability
Sudden traction changes at expansion joints and cold spots

Spatial Design
Thermal bridges in pavement cause hidden localized ice

Insulated pavement and joint retrofits

Berlin: integrated insulation in reconstructed sidewalks/pavement

Reconstruction projects often include layers of thermal insulation beneath pavement to reduce heat loss from underlying soils and infrastructure, thereby mitigating frost damage and prolonging pavement life. Materials such as expanded polystyrene (EPS) are commonly used for their durability and insulating properties. In some cases, systems include drainage and waterproofing membranes to prevent moisture ingress, which combined with insulation helps control freeze-thaw cycles and associated pavement cracking.

16

Extreme Cold

Walkability
Condensation and surface frost at thermal bridges on walks

Bikeability
Sudden traction changes at expansion joints and cold spots

Spatial Design
Thermal bridges in pavement cause hidden localized ice

Insulated pavement and joint retrofits

Montreal: expansion joint retrofits

A flagship example is the custom expansion joint system developed for the Samuel-De Champlain Bridge, which supports the Réseau express métropolitain (REM) rapid transit network. This system provides a wide expansion range of 24 to 27 inches (60 to 70 cm), far exceeding standard joints, allowing the bridge deck to accommodate substantial thermal movement from summer heat to harsh winter cold.

17 Freeze-Thaw Cycles

Walkability
Uneven surfaces create trip hazards

Bikeability
Surface damage creates cycling hazards

Spatial Design
Repeated freeze-thaw creates potholes

Pavement management

Calgary: comprehensive pothole prevention programs

Calgary's comprehensive pothole programs include preventative measures like the Annual Paving Program for road rehabilitation and responsive maintenance like cold patch and hot asphalt repairs throughout the year. Residents contribute by reporting potholes via 311, and the city uses pothole maps and service requests to track and address repairs, aiming to balance timely fixes with long-term road health.

17 Freeze-Thaw Cycles

Walkability
Uneven surfaces create trip hazards

Bikeability
Surface damage creates cycling hazards

Spatial Design
Repeated freeze-thaw creates potholes

Pavement management

Edmonton: proactive road management

The city's Safe Mobility Strategy (2021-2025) emphasizes data-driven decision-making to identify high-risk areas and deploy timely interventions such as road repairs, pothole fillings, and resurfacing before major damage occurs. Edmonton uses advanced infrastructure management tools that monitor road conditions in real time and optimize resource allocation.

18 Freeze-Thaw Cycles

Walkability
Damaged pavements unsafe for wheelchairs

Bikeability
Pothole damage to wheels and frames

Spatial Design
Frost action loosens pavement materials

High-quality base layer construction

Germany: high-performance pavement base

German concrete pavement construction often features stabilized bases, such as lean concrete, and emphasizes drainage through granular blanket layers and edge drains to ensure strong support and manage moisture under the pavement. Specifications for high-performance permeable bases, when used, typically require a high void content (over 20%) and a compressive strength above 15 MPa, with a low permeability coefficient.

24 Ice

Walkability
Ice makes assistive devices ineffective

Bikeability
Ice makes bike handling unpredictable

Spatial Design
Ice blocks drainage and water systems

Heated infrastructure elements

Wageningen: heated cycling infrastructure pilots

In Wageningen, a 50-meter stretch of cycle path is heated by underground pipes. This energy-efficient system maintains the bike lane surface temperature above freezing to prevent ice formation and snow accumulation. The system uses stored thermal energy collected in summer and may also use waste heat from nearby industrial sources, controlled automatically by sensors measuring temperature and moisture.

19 Freeze-Thaw Cycles

Walkability
Surface instability affects balance

Bikeability
Uneven surfaces affect bike stability

Spatial Design
Thermal cycling weakens infrastructure joints

Expansion joint maintenance

Amsterdam: thermal expansion management systems

These systems include expansion joints, sliding bearings, and flexible connection elements designed to absorb thermal expansion and contraction without causing damage or deformation to the structures.

19 Freeze-Thaw Cycles

Walkability
Surface instability affects balance

Bikeability
Uneven surfaces affect bike stability

Spatial Design
Thermal cycling weakens infrastructure joints

Expansion joint maintenance

Rotterdam: joint predictive maintenance

Rotterdam employs predictive maintenance aided by sensors and digital twins to monitor the condition of expansion joints and pavement surfaces in real time, enabling timely interventions before severe deterioration occurs.

20 Freeze-Thaw Cycles

Walkability
Trip hazards at ramps and crosswalks after midwinter thaw

Bikeability
Bike lanes become rough with heaved asphalt sections

Spatial Design
Frost heave causes unleveled pedestrian crossings

Annual crosswalk re-leveling programs

Calgary: seasonal crosswalk grinding and repair

The City of Calgary's pavement marking program, which runs from May to October, includes repainting and maintenance of over 8,500 crosswalks annually, with locations near schools receiving twice-yearly attention. While the program mainly focuses on repainting, grinding and minor repairs are performed to smooth uneven or damaged surfaces that cause hazards for pedestrians and cyclists.

20 Freeze-Thaw Cycles

Walkability
Trip hazards at ramps and crosswalks after midwinter thaw

Bikeability
Bike lanes become rough with heaved asphalt sections

Spatial Design
Frost heave causes unleveled pedestrian crossings

Annual crosswalk re-leveling programs

Helsinki: annual pavement inspections post-thaw

Visual road condition measurements are performed at low speeds by inspectors using vehicles equipped for detailed assessments. The evaluations focus on identifying frost heave damage, cracks, and unevenness caused by water infiltration and freezing under the pavement surface during winter.

22 Ice

Walkability
Invisible hazards cause unexpected falls

Bikeability
Unexpected sliding and crashes

Spatial Design
Black ice invisible on roads/sidewalks

Heated pavement systems

Oulu: heated downtown pedestrian zone

Oulu, Finland, utilizes an innovative system of heating some of its downtown pedestrian and cycling paths to melt snow and ice, making the area safer and more accessible for pedestrians and cyclists in its harsh winters. This experimental system uses excess steam from other energy sources to warm the pavement, a testament to the city's commitment to being a global leader in winter cycling infrastructure.

22 Ice

Walkability
Invisible hazards cause unexpected falls

Bikeability
Unexpected sliding and crashes

Spatial Design
Black ice invisible on roads/sidewalks

Heated pavement systems

Reykjavik: Geothermal pavement heating

This geothermal heating system melts snow and ice on outdoor surfaces, significantly enhancing snow removal efficiency and safety for pedestrians and vehicles. The availability of abundant geothermal resources allows the city to implement these heated pavements sustainably and cost-effectively compared to traditional methods.

23 Ice

Walkability
Senior pedestrians especially vulnerable

Bikeability
Studded tires required for safety

Spatial Design
Ice expansion cracks infrastructure

Regular ice removal and gritting

Helsinki: sand/grit cleared annually before May 1st

In Helsinki, sand and grit used for winter road and sidewalk traction are systematically cleared annually before May 1st as part of the city's spring street cleaning program. This removal process typically begins in March and continues through April when the winter maintenance season ends, and the thawing renders sand and grit unnecessary and potentially damaging to the environment.

23 Ice

Walkability
Senior pedestrians especially vulnerable

Bikeability
Studded tires required for safety

Spatial Design
Ice expansion cracks infrastructure

Regular ice removal and gritting

Tampere: comprehensive cleaning

The removal of sand and grit used during the winter season is part of the city's spring maintenance tasks. The cleaning of the biggest and busiest streets, as well as main pedestrian and cycling routes, is expected to be completed by early May

25 Ice

Walkability
Ice creates psychological fear of walking

Bikeability
Icy conditions prevent safe stopping

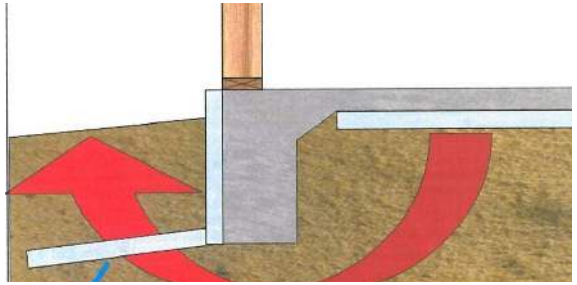
Spatial Design
Frost heave damages pavement structures

Frost-resistant pavement design

Anchorage: permafrost-adapted pavement design

Anchorage adapts its pavement designs to permafrost conditions by using thick insulating gravel layers, thermal insulation materials, and staged construction methods to minimize thawing of the underlying permafrost. The designs also focus on avoiding sensitive areas, controlling heat transfer, and accommodating ground movement through flexible pavement structures, ensuring long-term stability and durability.

25 Ice



Walkability
Ice creates psychological fear of walking

Bikeability
Icy conditions prevent safe stopping

Spatial Design
Frost heave damages pavement structures

Frost-resistant pavement design

Fairbanks: frost-resistant construction

Fairbanks utilizes frost-resistant construction to protect buildings from permafrost thaw and frost heave by using methods such as insulating foundations, placing buildings on gavel pads, installing post foundations, or using piles with refrigeration coils to keep the ground frozen.

26 Ice

Walkability
No significant issues

Bikeability
No significant issues

Spatial Design
Ice accumulation on transit infrastructure

Proactive ice prevention protocols

Reykjavik: geothermal heated bus stops

Bus stop platforms in Reykjavik often feature geothermal heating, a system implemented across the city's downtown to keep pedestrians warm during the cold Icelandic winters by using the abundant natural geothermal energy available.

21 Ice

Walkability
Extremely high fall risk on icy surfaces

Bikeability
Complete loss of traction possible

Spatial Design
Ice forms on surfaces creating hazards

Anti-icing chemical application

Minneapolis: proactive de-icing 2 hours before storms

Minneapolis employs a proactive de-icing strategy that involves applying anti-icing chemicals, such as liquid brine, to road surfaces approximately 2 hours before an anticipated storm. This pre-treatment prevents snow and ice from bonding to the pavement, making it easier to remove accumulation during the storm and reducing the need for large amounts of deicing chemicals afterward.

27

Ice

Walkability
Curb ramp puddles freeze, blocking strollers and wheelchairs

Bikeability
Icy gutter accumulations create dangerous merging zones

Spatial Design
Icy curb ramps and street crossings block inclusive access

Targeted de-icing

Toronto: curb ramp auditing/retrofit

Toronto has a structured curb ramp auditing and retrofit program guided by the Toronto Accessibility Design Guidelines (TADG), which ensure all curb ramps meet accessibility adn safety standards. The city prioritizes the installation and retrofitting of curb ramps at all pedestrian crossings and transit stops to provide safe and barrier-free access.

27

Ice

Walkability
Curb ramp puddles freeze, blocking strollers and wheelchairs

Bikeability
Icy gutter accumulations create dangerous merging zones

Spatial Design
Icy curb ramps and street crossings block inclusive access

Targeted de-icing

Minneapolis: winter street crossing design upgrades

These upgrades include the installation of clearly marked crosswalks with high-visibility pavement markings, curb extensions to shorten crossing distances, pedestrian safety islands, and improved ADA-compliant curb ramps.

28

Ice

Walkability
Limited traction for people with mobility aids and canes

Bikeability
Few riders equip studded or winter tires for icy/snowy days

Spatial Design
Absence of citywide studded tire programs leaves icy routes unsafe

Tire subsidy or distribution programs

Edmonton: free studded tire program

Edmonton offers a free studded tire program for winter cycling. The program provides eligible participants with free studded winter tires to promote safe year-round cycling and lower car dependence during the winter months.

28

Ice

Walkability
Limited traction for people with mobility aids and canes

Bikeability
Few riders equip studded or winter tires for icy/snowy days

Spatial Design
Absence of citywide studded tire programs leaves icy routes unsafe

Tire subsidy or distribution programs

British Columbia: community tire swap events

The province regularly encourage drivers to swap winter tires after April 30 or install them from October 1, hosting various garages and regional campaigns for tire changes

30 Ice

Walkability
No significant issues

Bikeability
Gravel dangerous for cyclists

Spatial Design
City puts gravel to prevent slipping

Timely gravel removal in spring

Helsinki: gravel removal program

Helsinki, like other Finnish cities, uses a spring street sweeping program to remove the anti-skid gravel and grit used during winter.

30 Ice

Walkability
No significant issues

Bikeability
Gravel dangerous for cyclists

Spatial Design
City puts gravel to prevent slipping

Timely gravel removal in spring

Oulu: use of non-slip surfacing

Oulu extensively uses anti-skid treatments including gritting on packed snow surfaces for bike lanes. The city maintains bike paths with anti-skid treatment rather than bare pavement, creating safer packed snow surfaces.

32 Ice

Walkability
No significant issues

Bikeability
Ice accumulation affects bike parking

Spatial Design
No significant issues

Proactive icicle removal

St. Petersburg: icicle removal brigades

St. Petersburg has dedicated municipal services to remove large, dangerous icicles and snow from buildings to prevent them from falling on pedestrians and vehicles during winter.

32 Ice

Walkability
No significant issues

Bikeability
Ice accumulation affects bike parking

Spatial Design
No significant issues

Proactive icicle removal

Montreal: heated gutter systems

Heated roof systems in Montreal are primarily used for de-icing to prevent ice dams, icicles, and subsequent water damage, which are major concerns due to the city's winter climate.

33 Rain/Freezing Rain

Walkability
Pedestrians soaked by splashes

Bikeability
Reduced visibility for cyclists

Spatial Design
Splashing water from passing cars

Splash guards on vehicles

Massachussets: mandatory splash guards

In Massachusetts, splash guards are mandatory for all motor vehicles and trailers except for passenger motor vehicles. Any passenger vehicle with tires that extend beyond the fenders or body must also be equipped with flaps or guards

33 Rain/Freezing Rain

Walkability
Pedestrians soaked by splashes

Bikeability
Reduced visibility for cyclists

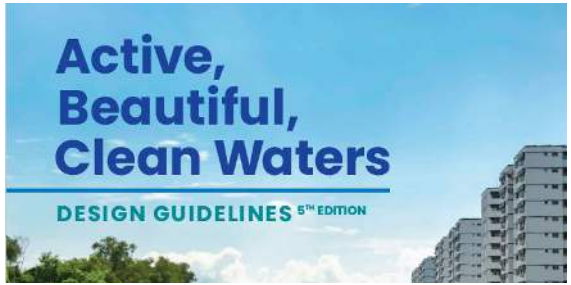
Spatial Design
Splashing water from passing cars

Splash guards on vehicles

London: curbside splash protection

Known for pioneering permeable paving slabs and roadside pollutant capture trials to reduce splash and urban runoff pollution.

34 Rain/Freezing Rain



Walkability
Wet conditions increase slip risk

Bikeability
Wet brakes less effective

Spatial Design
Water pooling leads to flooding

Improved drainage and SUDS

Singapore: ABC Waters program

The Active, Beautiful, Clean Waters (ABC Waters) Programme aims to create inviting waterscapes for all to enjoy. It offers both residents and visitors many features like lookout decks and pedestrian bridges, and attracts walking, jogging and cycling enthusiasts too.

34 Rain/Freezing Rain

Walkability
Wet conditions increase slip risk

Bikeability
Wet brakes less effective

Spatial Design
Water pooling leads to flooding

Improved drainage and SUDS

Copenhagen: comprehensive green infrastructure

Copenhagen has implemented a comprehensive and advanced green infrastructure system, including Sustainable Urban Drainage Systems (SUDS). The city is internationally recognized for its integrated approach to climate adaptation, resilience, and sustainable urban living.

35 Rain/Freezing Rain

Walkability
Flooding blocks pedestrian routes

Bikeability
Visibility reduced in rain

Spatial Design
Drainage systems overwhelmed

Permeable surfaces and bioswales

Amsterdam: permeable pavements

Amsterdam and other Dutch municipalities use permeable pavements to manage stormwater by allowing water to infiltrate through the surface and into underlying layers, which helps recharge groundwater and reduce urban flooding

35 Rain/Freezing Rain

Walkability
Flooding blocks pedestrian routes

Bikeability
Visibility reduced in rain

Spatial Design
Drainage systems overwhelmed

Permeable surfaces and bioswales

Rotterdam: integrated rain gardens

Rotterdam has been developing integrated rain garden projects, such as the "Regentuin" (rain garden) at the Hofbogen to manage stormwater and create green spaces, as part of its broader strategy to adapt to climate change and prevent flooding.

36 Rain/Freezing Rain

Walkability
Puddles and wet surfaces dangerous

Bikeability
Road spray affects cyclist comfort

Spatial Design
Freeze-thaw cycles damage pavement

Proactive drainage maintenance

Montreal: comprehensive neighborhood snow removal

Montreal clears snow from roads, sidewalks, bike paths, and public spaces with a fleet of around 1,000 vehicles and about 3,000 workers, managing approximately 10,000 kilometers of streets annually.

38 Rain/Freezing Rain

Walkability
Wet weather discourages outdoor activity

Bikeability
Wet conditions cause mechanical issues

Spatial Design
Wet surfaces become slippery danger zones

Non-slip surface treatments

Berlin: anti-slip pathway systems

Berlin has strict snow clearance regulations with designated clearing widths (1-1.5 meters) and anti-slip requirements. Property owners must clear and grit sidewalks; failure to comply constitutes an administrative offence with fines up to √¢‚Äö¬¨10,000.

37 Rain/Freezing Rain

Walkability
Ice rain creates extremely hazardous conditions

Bikeability
Freezing rain makes cycling impossible

Spatial Design
Ice dams form on infrastructure

Ice dam prevention systems

Oslo: advanced ice dam prevention

Norway has regulations regarding roof snow protection to prevent avalanches from roofs, and roof snow guards are part of standard building practices in Norwegian winter cities. These systems help prevent ice dams by controlling snow accumulation and preventing sudden releases

37 Rain/Freezing Rain

Walkability
Ice rain creates extremely hazardous conditions

Bikeability
Freezing rain makes cycling impossible

Spatial Design
Ice dams form on infrastructure

Ice dam prevention systems

Bergen: roof system management

Bergen has snow sensor-activated heating systems for sidewalks and plazas. Property owners are required to remove snow and ice with fines for non-compliance, creating comprehensive roof management responsibilities.

40 Rain/Freezing Rain

Walkability
Unexpected ice patches at sheltered entrances

Bikeability
Abrupt ice near intersections, approaching traffic signals

Spatial Design
Refreezing runoff forms isolated hazardous ice patches

Thermal cameras

Black ice sensor pilot program

These systems use infrared temperature sensors to measure road surface temperature in real-time, providing early warning when conditions approach freezing. Similar systems have been implemented in vehicles and infrastructure projects globally.

40 Rain/Freezing Rain

Walkability
Unexpected ice patches at sheltered entrances

Bikeability
Abrupt ice near intersections, approaching traffic signals

Spatial Design
Refreezing runoff forms isolated hazardous ice patches

Thermal cameras

Helsinki: gritting mapped to collision data

Helsinki maintains comprehensive traffic accident data since 2000 and has sophisticated winter maintenance protocols. The city uses data-driven approaches for traffic safety.

41

Slush

Walkability
Slush soaks through footwear

Bikeability
Slush creates unpredictable handling

Spatial Design
Slush pools block pedestrian paths

Rapid slush removal systems

Minneapolis: real-time slush removal response teams

Minneapolis has substantial snow removal operations with over 300 workers responding to weather events and maintains extensive public works operations with dedicated winter maintenance crews.

41

Slush

Walkability
Slush soaks through footwear

Bikeability
Slush creates unpredictable handling

Spatial Design
Slush pools block pedestrian paths

Rapid slush removal systems

St. Paul: rapid response protocols

St. Paul has 96-hour Snow Emergency protocols with three distinct phases. More than 70 plow crews clear over 1,800 lane miles in less than 24 hours during Night and Day Plow Route Phases. The city provides multilingual alerts and dedicated snow emergency apps.

42 Slush

Walkability
Splashing slush creates uncomfortable walking

Bikeability
Slush spray reduces visibility

Spatial Design
Slush splash from vehicles creates mess

Vehicle splash guards installation

Maine: mandatory vehicle splash guards in winter zones

Maine requires splash guards for trucks and commercial vehicles.

42 Slush

Walkability
Splashing slush creates uncomfortable walking

Bikeability
Slush spray reduces visibility

Spatial Design
Slush splash from vehicles creates mess

Vehicle splash guards installation

Cambridge: vehicle compliance programs

Cambridge (Ontario, Canada) has snow event parking enforcement and compliance monitoring. The city actively tickets and tows vehicles during snow events.

43 Slush

Walkability
Slush provides unpredictable traction

Bikeability
Slush provides unpredictable traction

Spatial Design
Slush infiltrates building entrances

Heated entrance mats and systems

Zurich: heated building systems

Zurich's extensive district heating network and heat interface units for buildings build sophisticated thermal energy distribution.

51 Snow

Walkability
Snow obstructs navigation landmarks

Bikeability
Snow reduces visibility of road markings

Spatial Design
Snow creates visual barriers and sight line issues

Clear sight line maintenance protocols

Helsinki: snow visibility management protocols

The city has detailed protocols for snow clearing with different priority levels and timing requirements to maintain visibility and safety.

44

Slush

Walkability
No significant issues

Bikeability
Slush makes stopping distances longer

Spatial Design
Slush damages street surface materials

Durable surface materials selection

Toronto: winter-grade pavement material standards

Toronto's pavement design guidelines include material specifications using Superpave asphalt mix designs and consideration of freeze-thaw cycles. Toronto's guidelines address resilient modulus for subgrade soils and design parameters that account for Ontario's climate conditions, including frost susceptibility.

44

Slush

Walkability
No significant issues

Bikeability
Slush makes stopping distances longer

Spatial Design
Slush damages street surface materials

Durable surface materials selection

Ottawa: cold-weather specifications

Ottawa has detailed cold weather standards including minimum heat requirements: not less than 16.67C (62F) at night and not less than 20C (68F) during daytime. The city maintains extensive winter maintenance quality standards and operates an Extreme Heat, Cold and Smog Planning Committee.

45 Snow

Walkability
Slippery packed snow surfaces

Bikeability
Reduced traction and steering control

Spatial Design
Streets accumulate snow, narrowing lanes

Snow plowing of bike lanes first

Oulu: maintain white packed snow surface

The city implements a specific strategy where packed snow surfaces are preferred over bare asphalt for bike lanes. Oulu maintains a thin layer of packed snow and applies anti-skid treatment through gritting.

45 Snow

Walkability
Slippery packed snow surfaces

Bikeability
Reduced traction and steering control

Spatial Design
Streets accumulate snow, narrowing lanes

Snow plowing of bike lanes first

Copenhagen: clear bike lanes by 8 AM

Copenhagen has an official policy that all bicycle infrastructure is cleared of snow by 08:00 AM. The cities of Copenhagen and Frederiksberg salt before snow falls and, after snow is on the ground, bike lanes are cleared before streets.

46 Snow

Walkability
Difficulty walking through deep snow

Bikeability
Bike lanes blocked by snow piles

Spatial Design
Snow blocks bike lanes and sidewalks

Small plows for narrow paths

Montreal: specialized small plows

Montreal uses compact specialized plows and pickup trucks with mounted snow blades for bike paths. The city explained: Most of the time we're using pickups, four by fours, equipped with a shovel on the front. These smaller vehicles are specifically chosen because bike paths are too narrow for large street plows but wider than sidewalks

46 Snow

Walkability
Difficulty walking through deep snow

Bikeability
Bike lanes blocked by snow piles

Spatial Design
Snow blocks bike lanes and sidewalks

Small plows for narrow paths

Stockholm: cargo bike maintenance teams

Stockholm has cycling maintenance workers (cykeljouren) equipped with cargo bikes who use them with tools to clear debris, fill potholes, and remove ice and snow.

Walkability
Reduced walking speeds and comfort

Bikeability
Difficulty maintaining balance

Spatial Design
Snow storage takes up valuable urban space

Strategic snow storage areas in design

Toronto: designated snow storage space

Toronto has a network of five snow storage sites throughout the city. The city's snow removal operations involve transporting snow to these designated facilities.

47 Snow

Walkability
Reduced walking speeds and comfort

Bikeability
Difficulty maintaining balance

Spatial Design
Snow storage takes up valuable urban space

Strategic snow storage areas in design

Montreal: designated snow storage space

Montreal operates 28 snow disposal sites managing over 13 million cubic meters of snow annually. The city has strict regulations requiring snow to be taken to authorized disposal sites, including both snow dumps and snow melters.

48 Snow

Walkability
Fall risk increases 32x in snowy conditions

Bikeability
Cannot use standard tires effectively

Spatial Design
Packed snow becomes slippery when compressed

Maintain packed snow vs. bare asphalt

Oulu: packed snow preferred over bare asphalt

The city implements a specific strategy where packed snow surfaces are preferred over bare asphalt for bike lanes. Oulu maintains a thin layer of packed snow and applies anti-skid treatment through gritting.

48 Snow

Walkability
Fall risk increases 32x in snowy conditions

Bikeability
Cannot use standard tires effectively

Spatial Design
Packed snow becomes slippery when compressed

Maintain packed snow vs. bare asphalt

Helsinki: quality corridor standards

Finland introduced "quality corridors" for pedestrian and cycling routes with higher maintenance standards than regular categories. Quality corridors may have night-time quality requirements with Maintenance category K1 providing the highest service level. Cities including Helsinki have implemented these corridors.

49 Snow

Walkability
No significant issues

Bikeability
No significant issues

Spatial Design
Snow accumulation blocks drainage systems

Improved drainage design

Minneapolis: integrated sidewalk drainage systems

Minneapolis maintains an extensive Surface Water & Sewers Division that oversees integrated stormwater management systems. The city has implemented comprehensive drainage solutions including features designed to handle snowmelt and prevent flooding, with programs like Adopt-A-Drain to maintain storm drain functionality.

49 Snow

Walkability
No significant issues

Bikeability
No significant issues

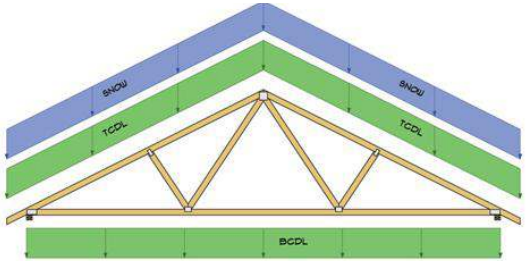
Spatial Design
Snow accumulation blocks drainage systems

Improved drainage design

Ottawa: priority network drainage

Ottawa maintains priority-based winter maintenance including drainage management. Roads are designed to drain based on sewer capacity, and roadside ditches are cleared to provide drainage for spring melt. The city operates Rain Ready Ottawa programs for stormwater management.

50 Snow



Walkability
Snow blocks wheelchair accessibility

Bikeability
Snow clogs derailleurs and brakes

Spatial Design
Heavy snow loads damage infrastructure

Structural design for snow load

Winnipeg: structural snow load standards exceed 150 kg/m²

Winnipeg's structural design guidelines specify a ground snow load (Ss) of 1.9 kPa.

50 Snow

Walkability
Snow blocks wheelchair accessibility

Bikeability
Snow clogs derailleurs and brakes

Spatial Design
Heavy snow loads damage infrastructure

Structural design for snow load

Calgary: infrastructure capacity planning

Calgary has comprehensive snow and ice control capacity planning with a $54 million annual budget. The city plans for snow storage site development, with recommendations to rehabilitate existing sites at $16 million and develop new sites at $36 million.

52 Snow

Walkability
Wheelchair users and caregivers cannot reach public transit

Bikeability
Bike racks and docking stations inaccessible due to snow

Spatial Design
Snow piles at transit stops hinder wheelchair and stroller access

Clear transit stops and mobility corridors

Ottawa: accessibility audits for snow removal

Ottawa conducts extensive accessibility audits through the "Snow Mole" campaign organized by the Council on Aging. These citizen-led audits specifically assess winter walkability for seniors and people with mobility concerns, examining inaccessible crosswalks, pedestrian walk buttons and bus stops, impassable intersections.

52 Snow

Walkability
Wheelchair users and caregivers cannot reach public transit

Bikeability
Bike racks and docking stations inaccessible due to snow

Spatial Design
Snow piles at transit stops hinder wheelchair and stroller access

Clear transit stops and mobility corridors

Montreal: dedicated sidewalk plow teams for transit access

Montreal operates specialized sidewalk plowing with mechanical equipment across the city using dedicated "sidewalk plow" machines. There have been calls to create more specialized teams specifically for accessibility zones including transit access.

53 Snow

Walkability
Long waits at unsheltered stops in extreme cold

Bikeability
Bike/transit hubs blocked by snow reduce mode shift options

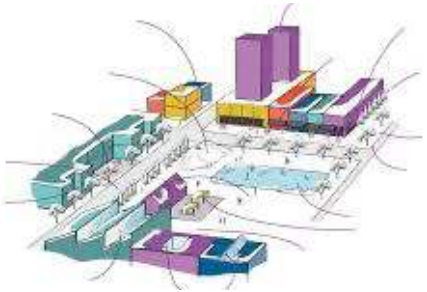
Spatial Design
Bus shelters fill with snow and become impassable

Heated/snow-free mobility hubs

Reykjavik: geothermal heated stops

Reykjavik has extensive geothermal heating infrastructure for streets and sidewalks, and uses geothermal energy extensively throughout the city.

53 Snow



Walkability
Long waits at unsheltered stops in extreme cold

Bikeability
Bike/transit hubs blocked by snow reduce mode shift options

Spatial Design
Bus shelters fill with snow and become impassable

Heated/snow-free mobility hubs

Edmonton: pilot snow-free mobility hub design

Edmonton has piloted heated transit shelters and explored enhanced transit facilities, with studies examining heated and/or wind-protected transit shelters. The Assisted Snow Removal Pilot Program supports accessibility.

54 Snow

Walkability
Hazard for pedestrians near buildings

Bikeability
Snow piles at entrances block cyclists

Spatial Design
Falling snow from roofs

Snow guards and heated roof systems

Oslo: mandatory roof snow guards

Norwegian building codes include requirements for roof construction to handle snow loads and prevent dangerous snow slides, with snow guard systems being standard practice in Nordic countries.

54 Snow

Walkability
Hazard for pedestrians near buildings

Bikeability
Snow piles at entrances block cyclists

Spatial Design
Falling snow from roofs

Snow guards and heated roof systems

Helsinki: heated roof pilots

Helsinki and Helen Ltd conduct pilot projects using AI technology to optimize district heating in schools and sports facilities (Systemic Heat Shift pilot). Helsinki Airport uses sub-surface heating for aircraft parking areas.

55 Snow

Walkability
Signs unreadable for drivers and pedestrians

Bikeability
Hidden cycling wayfinding signs

Spatial Design
Snow covers traffic signs

Project traffic signs digitally on snow

Liila: Snow-sign projection pilots

The challenge for cycling and pedestrian paths in the winter is the darkness, snow and sanding that may make the signs painted on the road hard to see. Liila projected traffic sign marks pedestrian and cyclist lanes by reflecting traffic signs on them.

55 Snow

Walkability
Signs unreadable for drivers and pedestrians

Bikeability
Hidden cycling wayfinding signs

Spatial Design
Snow covers traffic signs

Project traffic signs digitally on snow

Tampere: raised, illuminated signposts

Tampere is piloting illuminated road markings that project light onto snow when regular markings are covered. When regular road markings are concealed by snow, pedestrians and cyclists are guided by light-generated markings resembling traffic signs on the road surface. This innovation received the highest votes from residents.

56 Snow

Walkability
No significant issues

Bikeability
No significant issues

Spatial Design
Space for storing snow after removed

Dedicated snow storage

Tallinn: narrow corridors next to sidewalks for snow storage

Tallinn has specific winter maintenance protocols that include snow storage considerations in urban design. The city expanded sidewalk snow clearing operations, particularly in the Kesklinn and Põhja-Tallinn districts, where "narrow, winding sidewalks" are characteristic. Municipal regulations require that "when snow is piled on the sidewalk, there must be at least 1.20 meters of clear walking space", indicating planned accommodation for snow storage alongside pathways.

56 Snow

Walkability
No significant issues

Bikeability
No significant issues

Spatial Design
Space for storing snow after removed

Dedicated snow storage

Tallinn: three-stage snow storage system

Tallinn operates multiple snow storage sites (eight sites documented) with staged capacity management. The city removed more than 595,000 cubic meters of snow during the snowiest winter in a decade. Tallinn Airport has dedicated snow collection areas with seasonal separation and meltwater channelling.

57 Snow

Walkability
Slippery roads cause traffic hazards

Bikeability
No significant issues

Spatial Design
Lack of knowledge about surface conditions on roads

IoT road sensors

Estonia: national road info services

Estonia operates "Tark Tee" (Smart Road), a comprehensive traffic information system providing real-time road conditions. The system uses IoT sensors and weather stations to monitor road conditions and provides forecasted road conditions up to 48 hours in advance. The system includes mobile and in-road sensors that gather the necessary information and can communicate with each other and forward information.

57 Snow

Walkability
Slippery roads cause traffic hazards

Bikeability
No significant issues

Spatial Design
Lack of knowledge about surface conditions on roads

IoT road sensors

Tallinn: road weather sensor deployment

Estonia operates "Tark Tee" (Smart Road), a comprehensive traffic information system using IoT sensors and weather stations nationwide. Mobile and in-road sensors gather information and communicate with each other, providing forecasted road conditions up to 48 hours in advance.

58 Snow

Walkability
No significant issues

Bikeability
No significant issues

Spatial Design
Lack of knowledge about which streets have been cleaned

Snowplow GPS tracking

Helsinki: open snowplow tracking map

Helsinki provides real-time GPS tracking of snowplows through an open data API. The system was introduced in 2012 when Stara introduced an electronic production control system that produces GPS location data. The public can access live maps showing snowplow locations and activities incl. snow removal, spreading sand, de-icing with salt.

58 Snow

Walkability
No significant issues

Bikeability
No significant issues

Spatial Design
Lack of knowledge about which streets have been cleaned

Snowplow GPS tracking

Stockholm: live plow GPS dashboard

Stockholm has GPS tracking infrastructure and a traffic app "Trafiken.nu i Stockholm" with real-time information. The app provides traffic cameras and real-time road condition information.

60 Wind

Walkability
Strong winds can knock pedestrians off balance

Bikeability
Crosswinds affect bike stability

Spatial Design
Cold wind increases fall risk

Wind barriers, protective street design

Copenhagen: evergreen windbreaks

Copenhagen has extensive tree planting initiatives and a tree protection policy, with goals to plant 100,000 additional trees.

60 Wind

Walkability
Strong winds can knock pedestrians off balance

Bikeability
Crosswinds affect bike stability

Spatial Design
Cold wind increases fall risk

Wind barriers, protective street design

Oslo: strategic building orientation

Norwegian buildings incorporate climate-responsive design including orientation for snow load management and wind considerations. Research examines how different orientations affect energy performance in Norwegian climates. Oslo experiences significantly calmer winds compared to many other locations due to surrounding mountains.

61 Wind

Walkability
Difficulty navigating with reduced visibility

Bikeability
Loss of balance, damage for collision with debris

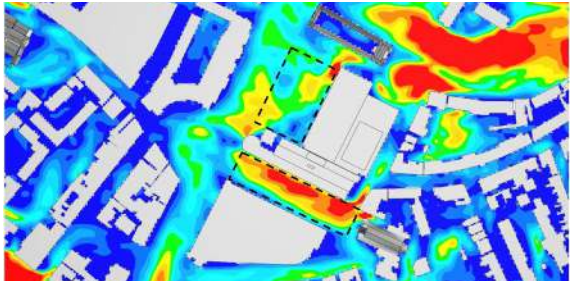
Spatial Design
Debris and snow blown into walkways

Regular debris clearing

Calgary: pathway maintenance teams

Calgary has dedicated pathway management teams that maintain approximately 800 km of pathways and provides regular maintenance incl. debris clearing. Calgary also hosts annual Pathway and River Cleanup events with thousands of volunteers.

62 Wind



Walkability
Wind reduces effectiveness of winter clothing

Bikeability
Wind reduces battery life of e-bikes

Spatial Design
Wind reduces effectiveness of heating systems

Sheltered heating systems design

Toronto: wind comfort assessment for developments

Toronto requires Pedestrian Level Wind Studies for all new developments taller than 20 meters. These comprehensive studies use computational fluid dynamics (CFD) to assess wind comfort and safety, with specific criteria for different pedestrian activitie.

64 **Wind**

Walkability
Sudden snow drifts obscure tactile surfaces for the visually impaired

Bikeability
No significant issues

Spatial Design
Windblown snow creates drifts blocking midblock crossings

Snow fencing, directional wind breaks

Winnipeg: urban snow fencing program

Winnipeg is working on expanding snow fences throughout the city, to install them on an annual basis, to mitigate the amount of drifting snow.

64 **Wind**

Walkability
Sudden snow drifts obscure tactile surfaces for the visually impaired

Bikeability
No significant issues

Spatial Design
Windblown snow creates drifts blocking midblock crossings

Snow fencing, directional wind breaks

Chicago: targeted windbreak planting at crossings

Chicago has a major tree planting initiative with $46 million investment to plant 75,000 trees, prioritizing underserved neighborhoods on South and West sides. Windbreak principles are documented in general landscaping guidance.

65 **Wind**

Walkability
Risk of falling branches for walkers

Bikeability
Obstacles and hazards from debris

Spatial Design
Tree branches fall or obstruct space

Regular tree maintenance and pruning

Copenhagen: urban tree trimming policy

Copenhagen has a comprehensive **tree protection policy passed in 2016 that addresses tree maintenance and protection.

65 **Wind**

Walkability
Risk of falling branches for walkers

Bikeability
Obstacles and hazards from debris

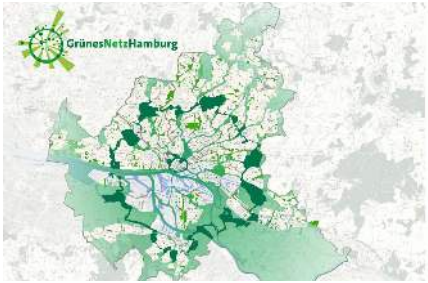
Spatial Design
Tree branches fall or obstruct space

Regular tree maintenance and pruning

Stockholm: safety checks during storms

Sweden and Stockholm have comprehensive winter weather warning systems and safety protocols. When weather is particularly severe, authorities may advise the public not to drive and public transport might be cancelled. SMHI issues weather warnings in three levels (yellow, orange, red).

66 **Wind**



Walkability
No significant issues

Bikeability
No significant issues

Spatial Design
Wind tunnels and gusts create discomfort

Green to disperse and redirect wind

Hamburg: wind-break tree corridors

Hamburg has the "GrünesNetzHamburg" (Green Network Hamburg), an extensive urban planning scheme featuring green corridors that connect the city to countryside. The system includes "landscape axes" and "green rings" with tree-lined streets. This network was designed to provide recreational access and environmental benefits, incl. wind mitigation effects.

66 **Wind**

Walkability
No significant issues

Bikeability
No significant issues

Spatial Design
Wind tunnels and gusts create discomfort

Green to disperse and redirect wind

Malmö: vegetation buffers in open squares

Malmö's development incorporates vegetation buffers and wind management through strategic planning. The variations in the grid shield use areas from the weather, and suggested measures to improve wind control include adding vegetation and wind barriers. Research shows trees moderate wind speed; large trees with lower shrubberies significantly reduce wind movement.