Updating Winter: The Importance of Climate-Sensitive Urban Design for Winter Settlements

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This study explores urban design principles for winter settlements to identify climate-related conditions that affect soft mobility (walking and cycling) in these communities. Winter communities have evolved lifestyles and means suited to living and working with local conditions and seasonal variation. However, climate change will cause changes in weather that will require adaptation in such communities. These changes may present new risks and unexpected challenges to outdoor soft mobility in the community. Physical inactivity has emerged as a major focus of concern in public health policy. Winter weather has always limited outdoor soft mobility in winter settlements. In particular, outdoor activity in winter can be reduced by inclement weather and fear of accidents. People's understanding of the barriers to and enablers of soft mobility are also often based on experience and ability to detect environmental clues. To help winter communities maximise the opportunities for outdoor soft mobility and the associated wellbeing benefits, built environments must be designed with an understanding of climate change.

This study explores barriers to and enablers of soft mobility in winter and discusses them in light of climate change and human wellbeing. It is argued that established principles of urban design may require re-evaluation if we want to increase outdoor soft mobility in winter. Increases in physical activity could help reduce costs and pressures on health services by creating safer and more walkable communities. The paper concludes by suggesting that communities should focus on more context-based winter urban design principles that account for ongoing climate change.

Introduction

All over the world, the form of the built environment plays a key role as an enabler or inhibitor of urban outdoor activities such as soft mobility. The public realm can make it more attractive for people to be mobile outdoors and to participate in public life, or it can put people off venturing outside. A key urban design challenge in winter cities is to create environments that encourage outdoor activity in both the winter and the summer. A closely related challenge is to understand how changes in weather due to climate change will influence *people's soft mobility choices*.

The reason for studying this is the importance of understanding how the relationship between urban form, weather, seasonal variations, and climate change influences human outdoor activity.

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In this study, the focus on outdoor activity is problematised around the concern that people spend a low percentage of their time outdoors in winter conditions.

To explore this issue, the study focuses on the question: What is the current state of knowledge and practice relating to the urban design of winter cities? For the purposes of this work, winter settlements are defined as places with significant seasonal climate variation, temperatures that are normally below zero, precipitation that is mainly in the form of snow, and limited hours of sunshine & daylight (Pressman, 1989). Many of these settlements are sub-Arctic; notable examples include Luleå (Sweden), Tromsø (Norway), Arkhangelsk, (Russia), and Yellowknife (Canada).

Figure 1: Seasonal variation in Luleå, Sweden. Photographs taken at the same location in winter and summer.

The rationale for this study is the proposition that while urban design should support outdoor activity (Boverket, 2012; CABE, 2009; Carmona, Punter, & Chapman, 2002; Cowan, Adams, & Chapman, 2010; Eriksson, 2013), the urban design principles for Winter settlements may not account for evolving Winter barriers to outdoor soft mobility and the associated impacts on human wellbeing (Chapman & Larsson, 2018; Chapman, Nilsson, Larsson & Rizzo, 2017; Koivurova & Kähkönen, 2018).

While the study was not limited to any particular location or type or scale of winter city, most of the analysed guidance emanated from northern Europe and North America. The documentation also focused on places large enough to be settlements with some form of facilities, rather than groupings of individual buildings. As such, the research is primarily oriented towards more urban winter communities.

Climate Change

Global warming is changing sub-Arctic seasons and winter (Chen & Chen, 2013). Consequently, average temperatures and levels of precipitation in the sub-arctic are expected to rise between now and 2100.

In light of environmental concerns, the Intergovernmental Panel on Climate Change (IPCC) was set up in 1988 by the World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP). Reports issued by the IPCC in 1990, 1992 and 1995 highlighted the risks of substantially reduced snow cover with impacts on ecosystems and social & economic activity. Later assessments in 2001 (IPCC) concluded that the proportion of winter precipitation falling as rain will increase and that snow conditions will become less reliable, affecting tourism.

The IPCC's 2007 report continued this theme, highlighting the impact of snow and glacier melt runoff on drinking water and the likelihood of extensive species lose in mountainous areas. The latest *Climate Change 2014, Synthesis Report* reinforces these conclusions and presents climatic trajectories suggesting that the northern hemisphere's spring snow cover may have fallen by between 7 and 25% by the end of the 21st Century (IPCC).

At the national level, Finland's environmental administration has concluded that climate change may result in winters that are more humid and cloudier, with diminished snow cover and increased rainfall (Vaccia, 2014). The County Administration Board of Norrbotten, Sweden (Länsstyrelsen i Norrbottens län, 2012) concluded that by 2100, annual average temperatures will have increased by 4-6 °C, annual precipitation will have increased by 15-50%, snowfall will have declined, and the snow cover period will be more than a month shorter than it presently is across the country (Gustavsson, 2011).

Figure 2: The changing face of winter – the E4 motorway, Sweden, during a rainstorm in December 2017.

The Norwegian Environmental Agency, Miljødirektoratet, predicts that by 2100, annual temperatures will have increased by around 4.5 °C and precipitation by about 18%, with more frequent and intense rainfall (Hanssen-Bauer et al., 2017). The 2007 (Updated 2015) 'Final Report' from the Swedish Commission on Climate and Vulnerability notes that Sweden will be strongly affected by climate change, stressing the risks of flooding and adverse impacts on water (Swedish Commission on Climate and Vulnerability, 2007).

Research from international and national agencies sets out the environmental context of this study by illustrating that annual average temperatures are generally rising and precipitation as rain is increasing, while snowfall and snow cover are decreasing. Put simply, they suggest that winter settlements are getting warmer and will have more rain and less snow. This is important when discussing soft mobility in winter settlements because the weathers associated with warmer winters may influence people's choices and ability to be outdoors and active in winter. In this study, soft mobility is seen as a type of everyday physical activity and is defined as human-powered, non-motorized ways of getting around that have relatively little environmental impact, such as walking, cycling, rollerblading, or skiing.

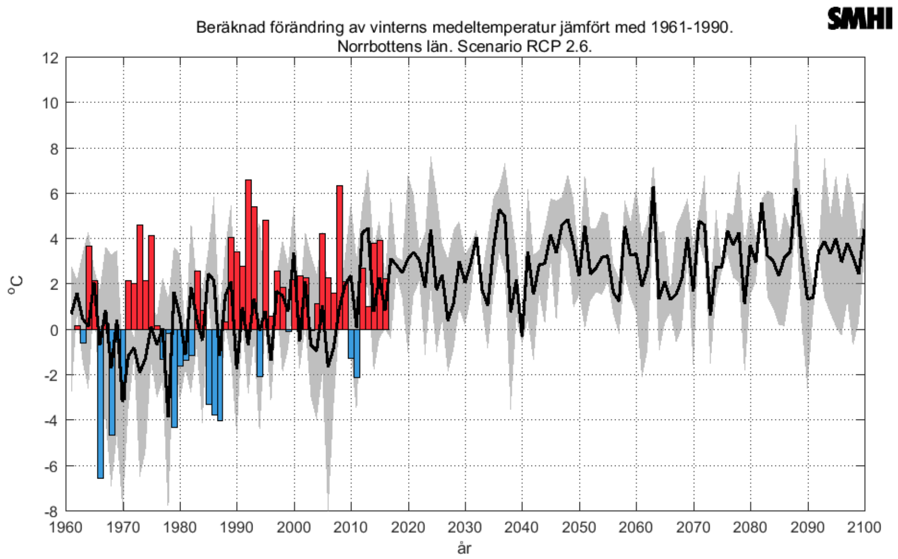

Figure 3: Historical and predicted mean winter temperatures in Norrbottens län, Sweden, under Scenario RCP2.6, showing that mean winter temperatures are projected to exceed 0 °C. Generated using SMHI's Climate scenarios tool: https://www.smhi.se/en/climate/climate-scenarios/haag_en.html

Urban Health

Koln et al (2012) cite physical inactivity as the fourth leading cause of death worldwide, and note that 31% of the world's population do not achieve the minimum recommended level of physical activity. Similarly, Murray et al (2013) identified physical inactivity and low physical activity as the risk factor with the fourth highest attributable burden of disease in the UK; together, diet and physical inactivity accounted for 14.3% of the UK's disability-adjusted life-years in 2010. The U.S. Surgeon General links health directly to activity, highlighting physical activity as one of the most important steps to improving health at all ages (U.S. Department of Health and Human Services, 2015).

The U.S. Center for Disease Control (1999) estimates that $1 invested in measures that encourage physical activity leads to medical cost savings of $3.20 (WHO, 2002). The WHO classifies measures to improve 'diet and physical activity' as 'best buys' - high impact, cost-effective programmes that can be delivered with constrained resources (WHO, 2014). In 2015, the WHO estimated that the additional healthcare costs attributable to physical inactivity in a population of

10 million people (roughly the population of Sweden) of whom 50% are insufficiently physically active would be 910 million EUR per annum (WHO, 2015).

Outdoor soft mobility in winter communities can be hindered by inclement weather. It has been estimated that people spend 90% of their lives indoors (Evans & McCoy, 1998), and Winter-related reductions in physical activity have been found in various countries (Chan & Ryan, 2009). In Finland, for example, population-based studies showed that people spend only 4% of their total time exposed to cold outdoor climates, with most of this exposure occurring during their leisure time (Mäkinen et al., 2006).

If this is even close to correct, it indicates that the winter can reduce outdoor activity in general, resulting in lower levels of physical activity. Therefore, actions to enable soft mobility and make it easier and more practical for people to regularly use soft mobility modes of transport could increase physical activity, energy expenditure (metabolic rate), and physical capacity. All of these are known to improve human health and reduce health care costs (U.S. Department of Health and Human Services, 2015; House of Lords, 2016; WHO, 2018).

To develop successful winter communities, it is important to facilitate year-round outdoor soft mobility in a way that accounts for and accommodates changing climatic conditions. Because around 100 million people live in sub-Arctic regions, this is an important focus for both winter settlement planning and public health policy.

Figure 4: Examples of outdoor winter activities.

Methods

The objective of this study is to explore winter settlement urban design principles to identify climate-related conditions that affect opportunities for soft mobility in winter communities.

A literature search was performed using the keywords 'winter cities', 'urban design', and 'health' in the Scopus and Web of Science databases. The number of hits obtained ranged from 233 (for searches using the keywords 'winter cities' and 'urban design' individually) to six when all keywords were used together. After an initial review of the 233 documents, 13 documents relevant to the urban design of winter settlements were identified. Further literature searches were undertaken using the reference lists included in these documents. This revealed 22 additional relevant documents. This review is thus based on a total of 35 documents (22 journal articles, 9 books, 2 citywide urban design guides and 2 academic theses) covering various aspects of Winter urban design.

A deductive content analysis (Patton, 2002) of the literature was performed (Fig. 9) to identify relevant knowledge and information on winter conditions in relation to the built environment. Winter settlement urban design considerations in the literature were then used to populate a matrix that juxtaposed aspects of urban form (siting & layout, height & massing, façade & interface, and public realm & landscape) with Winter conditions (solar access, wind, snow, rain, cold, darkness, and the presence of snow- and ice-covered surfaces). The literature coverage of each aspect of urban form in relation to each winter condition was then ranked using a traffic light system: green, orange, and red denoted combinations that were discussed extensively, to a limited degree, and very little or not at all, respectively. Once all relevant information had been sorted, the outcomes were analysed; this analysis is presented below. The discussion and conclusions sections compare the results of the analysis to the current discourse on climate change and human wellbeing.

Analysis

The architect Ralph Erskine famously said that in winter communities:

> houses and towns should open like flowers to the sun of spring and summer but, also like flowers, turn their backs on the shadows and the cold northern winds, offering sun warmth and wind-protection to their terraces, gardens and streets (Collymore, 1994: 26).

While Erskine can be seen as a leading figure in winter design and his 1959 *Grammar for High Latitude Architecture* is an early set of design principles for winter settlements, the Canadian planner Dr. Norman Pressman was one of the most prolific advocates of the concept of winter cities. Pressman was a founding member of the Winter Cities Association (the WCA; 1982 to 2005), which focused on ways of improving the environments of winter settlements. Over time, the WCA shifted from advocating glassing over cities (Pressman, 1985) to favouring more urban concepts such as compactness, higher density, streets for people, and mixed-use and transit-oriented-development (Pressman, 2004). The dominance of Pressman and the WCA's studies on winter settlements is reflected in their high number of publications on the subject. Of the 35 documents reviewed for this paper, 17 were produced either by the WCA or in Canada; the others came from North America, Norway and Sweden. The demise of the WCA in 2005 resulted in a near-complete cessation of research into the design of winter cities. Nevertheless, the work of Pressman and the WCA defined three key issues that are still prominent in Winter settlement urban design, namely design for solar access, wind defence, and snow management (Andbert, 1979; Bengtsson, 1980; Børve, 1982; Werier, 1983; Pihlak, 1983; Pressman, 1985; Pressman & Zepic, 1986; Gappert, 1987; Børve, 1987; Pressman & Mänty, 1988; Matus, 1988; Glaumann & Westerberg, 1988; Børve, 1988; Sterten, 1988; Zrudlo, 1988; Pressman, 1988; Pressman, 1989a; Pressman, 1989b; Pressman, 1989c; Westerberg & Glaumann, 1990; Pressman, 1991; Pressman, 1994a; Pressman, 1994b; Pressman, 1995; Pressman, 1996; Urban Systems, 2000; Bergström & Magnusson, 2003; Pressman, 2004; Eliasson, Knez, Westerberg, Thorsson, & Lindberg, 2007; Westerberg, 2009; Ebrahimabadi, 2012; Ebrahimabadi, 2015; Ebrahimabadi, Nilsson, & Johansson, 2015; Edmonton, 2016; Ebrahimabadi, Johansson, Rizzo, & Nilsson, 2018).

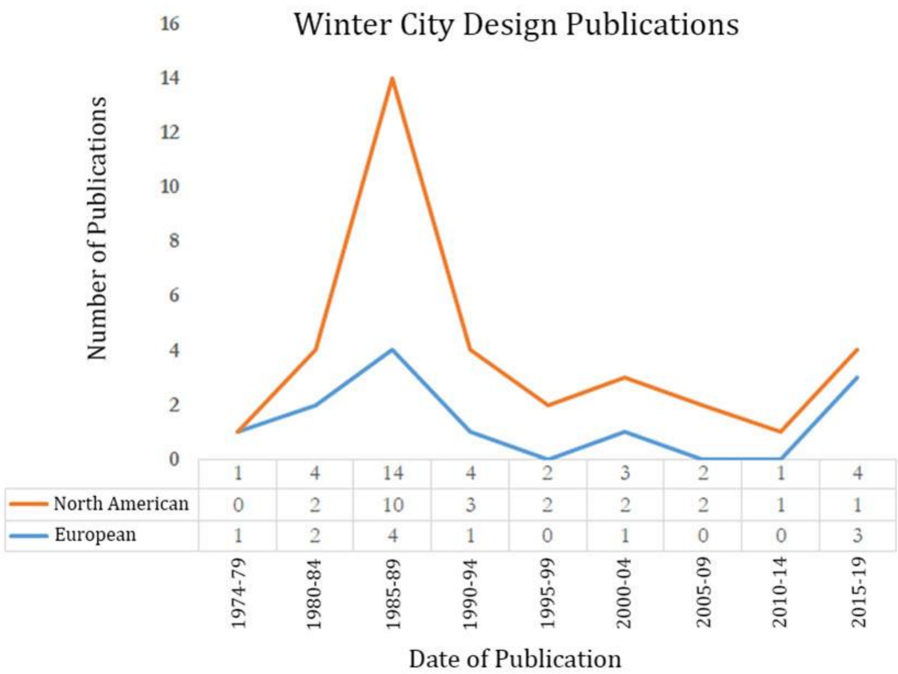

Figure 5: Years of publication of the 35 documents selected for inclusion in this review.

Maximising Solar Access

The review indicated that sunshine and solar access are mainly seen as positive factors, and urban designers commonly seek to capture their general benefits (Pressman, 1986, 1988; Pressman, 1988; Pressman, 1989a; Pressman, 1989b; Pressman, 1989c; Pressman, 1991; Pressman, 1995; Pressman, 1996; Urban Systems, 2000; Pressman, 2004; Ebrahimabadi, 2012; Ebrahimabadi, 2015; Ebrahimabadi et al, 2015; Edmonton, 2016; Ebrahimabadi et al, 2018). In the context of winter settlement design, two varieties of solar illumination are commonly considered: direct and reflected sunlight.

It has been noted that the case for maximizing direct solar access in high-latitude cities is complex because there can be significant issues of shadowing. Pressman & Zepic (1986) observe that in high-latitude winter settlements, the low angled winter sun can cast shadows whose length is up to 15 times an object's height. The large design distance between buildings suggested by Matus (1988) to overcome this issue is arguably too high a price to pay for the benefits of direct solar radiation. This was confirmed by Ebrahimabadi et al (2015) in a study on the New Kiruna settlement in Arctic Sweden, which concluded that the large open spaces needed to maximise solar access cannot be accommodated in central areas, making maximisation of solar access untenable as a major design objective.

Figure 6: A bright spring winter day making it attractive to be outdoors in sub-zero temperatures.

For winter settlements with low light levels and long winters, reflected light can bring significant benefits and should be considered in parallel with direct solar access. Andbert (1979) and Børve (1987) both suggest that snow reflects around 85% of directly incident solar radiation, whereas tarmac reflects only around 10% (Børve, 1987).

Other important features of nature light in high-latitude winter settlements are 'polar nights' and the 'midnight sun'. High-latitude settlements, and especially those above the Arctic Circle, can have extended periods of 'daylight' that may last for all 24 hours of the day in summer, and periods of almost continuous darkness during the winter.

Shelter from the Wind

Wind is commonly cited as one of the most uncomfortable outdoor weather conditions. However, Pressman's research (1995) suggested that improved outdoor microclimates can be achieved by good design, and that this could increase the number of comfortable outdoors days in winter settlements by as much as 30% in a year.

Of the three major issues in winter settlement urban design, wind is probably the most extensively studied. It is generally agreed that built forms and vegetation can either reduce or compound the effects of wind (Børve, 1982; Børve, 1987; Børve, 1988; Sterten, 1988; Glaumann, 1988; Zrudlo, Pressman, 1988; Pressman, 1989a; Pressman, 1989b; Pressman, 1989c; Pressman, 1991; Pressman, 1995; Pressman, 1996; Pressman, 2004; Ebrahimabadi, 2012; Ebrahimabadi, 2015; Ebrahimabadi et al, 2018). The literature and guidance on designing based on wind in winter settlements is often similar to that for more temperate climates, and suggests that it can be preferable to have low buildings that all have similar heights because they conduct wind over the buildings, reduce wind speed, and minimise turbulence at pedestrian level. Tall buildings (buildings that are at least twice the average height in a neighbourhood or area) should be avoided because they create their own microclimates and downdrafts, and increase wind speeds at pedestrian level (Ebrahimabadi et al, 2015; Edmonton, 2016).

Ebrahimabadi also suggests that wind intensity can be reduced by around 50% if buildings more than twice the average height in an area are avoided (2015). Other urban design solutions for mitigating the impact of wind include stepping or terracing buildings where taller buildings are needed (Pressman, 1995), adding podium levels to protect pedestrians from strong wind at ground level (Glaumann, 1988; Pressman, 1995; Edmonton, 2016), or using closed blocks to the north and east to block cold wind (Pressman, 1995).

Trees can be used as windbreaks and have the advantage that they filter the wind without stopping it entirely (Pressman, 1995). It has been suggested that coniferous trees are preferable in winter settlements because they buffer wind and provide colour during winter (Pressman & Zepic, 1986). They also reduce airborne pollution better than deciduous trees.

Designs for winter settlements can also exploit the beneficial effects of wind. Snow gathers where wind speeds are low, so it is possible to control where snow gathers by understanding how wind is affected by the orientation of buildings, streets, and spaces (Glaumann & Westerberg, 1988; Pressman, 1995; Sterten, 1988). For example, a main road aligned with the prevailing wind benefits from natural snow clearing.

Design for Snow

Snow is one of the most prominent features of winter. On the one hand, it brings beauty and light, by reflecting up to 85% of solar radiation (Andbert, 1979; Børve, 1987). On the other, it brings slippery surfaces and risks of injury from falling. Discussions of snow in urban design often focus on its design opportunities, issues of safety & management, and its storage and removal (Andbert, 1979; Børve, 1982; Børve, 1988; Sterten, 1988; Pressman, 1988; Pressman, 1989a; Pressman, 1989b; Pressman, 1989c; Pressman, 1991; Pressman, 1995; Pressman, 1996; Urban Systems, 2000; Pressman, 2004; Ebrahimabadi et al, 2015; Edmonton, 2016).

Figure 7: Snow cover in the public realm can create hazards, as illustrated by this outdoor staircase.

The literature indicates that it is better to have multiple snow storage areas distributed across a city than to have a single storage location, and that where possible, storage areas should be incorporated into street designs (Urbansystems, 2000; Ebrahimabadi et al, 2015; Edmonton, 2016). It has also been argued that snow should not be stored in shaded places where colder and more humid microclimates prevail (Glaumann, 1988). Small storage areas with solar access are preferable because they accelerate melting (Edmonton, 2016).

Standing snow and snow cover can also be problematic in the melting period because they cause streets to fill with water and slush, making it very unpleasant to be outdoors (Edmonton, 2016). This issue can be exacerbated because snow that has been standing for a long time tends to carry greater levels of pollution than stormwater (Bengtsson, 1980), which can be unpleasant to pedestrians and users of the public realm.

Figure 8: A residential street can be significantly affected by water-based barriers to soft mobility in winter. Here the street is covered by water, slush, snow and ice all at the same time.

While the literature often focuses on maintenance, the reviewed publications highlight several ways in which the urban form influence snow. The siting and layout of buildings, streets, and vegetation can be used to control snowdrift and where snow gathers (Børve, 1987; Børve, 1988; Sterten, 1988; Pressman, 1995). The design of façades and interfaces (including roofs) can also be critical because it can affect the throw or falling of snow off roofs and icicle formation. The literature suggests that building entrances and roofs should be designed to limit falling ice, snow and other discharges from above (Urbansystems, 2000; Edmonton, 2016). Transition zones such as canopies, arcades, and other overhead shelter systems should also be considered to provide weather protection for outdoor soft mobility (Pressman & Zepic, 1986; Pressman, 1995; Urbansystems, 2000; Edmonton, 2016).

At ground or pavement level, it is recommended to slightly raise pedestrian streets or grade them to eliminate curb-side accumulation of snowmelt or ice formation (Urbansystems, 2000; Edmonton, 2016). Street designs should also direct snowmelt away from building entries (towards roadways), and roads should be dished in the middle to collect slush.

Other Weather Concerns

The main weather considerations examined in the included literature were solar access, wind defence, and snow management; other aspects of winter weather received less attention. In particular, the literature only rarely touches on issues relating to rain, darkness, and ice. References to rain are limited and confined to issues such as pooling in streets and spaces, and the use of permeable surfaces to mitigate heavy rainfall (Urbansystems, 2000; Edmonton, 2016). Almost nothing is said about how urban form and the public realm can mitigate the effects of rain on outdoor soft mobility.

Similarly, very little is said about darkness beyond the observation that it is a prerequisite for creative lighting (Edmonton, 2016) and enables architectural lighting to create focal points in the urban form (Urbansystems, 2000). Finally, ice and ice cover are only mentioned as the basis for various Winter sports (Ebrahimabadi, 2012) and as factors that should be considered when designing streetscapes (Urbansystems, 2000; Edmonton, 2016).

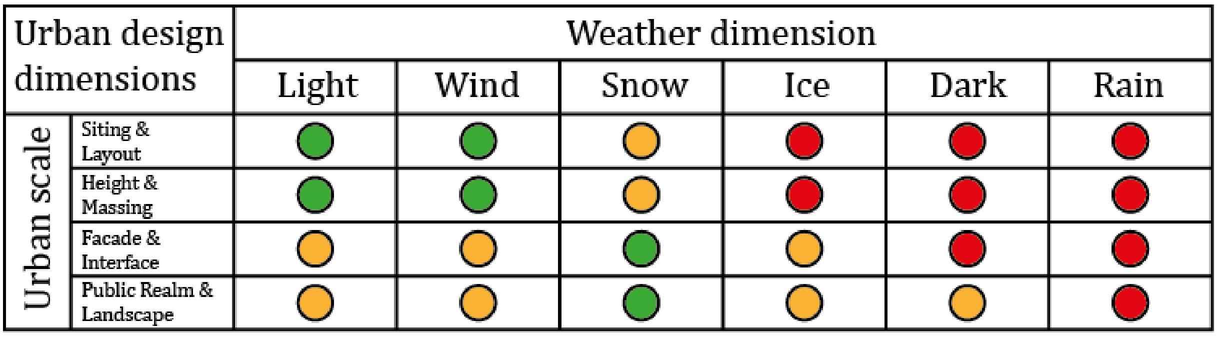

Figure 9: Matrix showing the treatment of different urban design issues and climate-sensitive aspects of winter weather in the urban design literature. Green, orange, and red dots indicate issues that have been covered extensively, to a limited degree, and little or not at all, respectively.

The results of the literature review are summarized in the above matrix, which shows how extensively the urban design literature discusses different aspects of winter weather in relation to various aspects of urban form. It is clear that the classical concerns of urban design for winter settlements – sun, wind, and snow - are well covered by research articles, books and policy, but issues relating to ice, darkness and rain are only lightly addressed.

Discussion

This study set out to explore winter settlement urban design principles and evaluate their fitness for purpose in light of climate change. The intention was to add to the discussion of how we can help communities maximise opportunities for outdoor soft mobility in winter and the physical wellbeing benefits this can bring.

The most striking result of this study is the age of the reviewed documents. Twenty-five of the 35 documents were published before the year 2000, and only one was published between 2010 and 2014. This is problematic for urban design and academia because new agendas emerged during these periods that have not been addressed in the literature. This is especially concerning because it means that many older (and possibly now outdated) books and articles continue to serve as cornerstones of urban design thinking for winter settlements.

Few of the reviewed publications mentioned the concept of sustainability even though it was introduced in 1987 by the report "Our common future" (WCED). They were also silent on the term climate change, which came onto the international agenda in 1988 with the establishment of the IPCC, as well as the issue of human health and wellbeing, which came to prominence in 1996 as a consequence of the U.S. Surgeon General's report on physical activity and health. The two notable exceptions were Pressman's article *Sustainable Winter cities: Future directions for planning, policy and design* (1996) and his book *Shaping Cities for Winter, Climate Comfort and Sustainable Design* (2004), which mention emerging agendas of reducing pollution, resource efficiency, sustainability, and human health.

Although Pressman references 'sustainable development' and 'human health' in these publications, knowledge about these issues has increased rapidly since they were written. Major climate frameworks have been developed since the 1990s under the aegis of the IPCC and are regularly updated with new information on climate change. The same is true for human health: although the 1996 Surgeon General's report was available when some of the included documents were being prepared, this issue has only really gained traction in the past decade. One of the key policy documents, *Step it up?*, which promotes walking and walkable communities and their health benefits (U.S. Department of Health and Human Services) was only published in 2015. Another important recently published policy document is the WHO's 2018 global action plan on physical activity, which places safe and enabling active outdoor environments at the heart of the WHO's mission. The recent publication of these two policy statements highlights the rapidly developing nature of this field.

While it can be argued that the reviewed urban design publications are dated, the more recent publications did focus more on creating compact settlements with higher densities, streets for people, and public transit-oriented development. This was likely done on the basis of contemporary policy concerns relating to resource efficiency and pollution (Gordon, 1997; Jenks et al, 1996) rather than human wellbeing. Nevertheless, such approaches also increase the walkability and cycle-ability of communities, which is beneficial for human wellbeing.

The reviewed publications largely focused on the three traditional urban design considerations for winter settlements – solar access, shelter from the wind, and design for snow storage and removal. These issues can be discussed individually in terms of their impact on outdoor soft mobility.

Almost all the reviewed publications highlight solar radiation as a positive contributor and facilitator of outdoor human activity (Andbert, 1979; Urbansystems, 2000; Ebrahimabadi et al, 2015; Edmonton, 2016). While many discussions are based on experience, such as the warmth created by direct sunlight, some focus on design considerations. Discussions around solar penetration and urban form highlight the difficulty of maintaining solar penetration in winter settlements. It is argued that the low sun angles experienced at high latitudes can create extensive shadowing over long distances (Matus, 1988).

This review does not indicate that these arguments conflict with efforts to address issues relating to climate change. Direct solar access is likely to remain as important in the future as it was when the principles of winter urban design were first established. However, the discussion about indirect lighting is likely to evolve. Light reflected from snow accounts for an appreciable proportion of the ambient light in winter, so reductions in snowfall and cover due to warming may mean that communities benefit less from this indirect light. Consequently, climate change may necessitate better outdoor lighting in winter settlements.

Unlike sun and wind, snow is seen as both a positive and a negative (Andbert, 1979; Børve, 1987; Berggård & Johansson, 2010; Gard, Berggård, Rosander, & Larsson, 2018). Its beauty is noted, but various authors highlight its potential to inhibit the functioning of people and communities. Analyses of its beauty and leisure benefits are often limited to common sense discussions whereas information on its maintenance and management are often quite technical. Climate change is likely to significantly alter the impact of snow on winter settlements. As temperatures rise, potentially above 0 °C, some winter cities are likely to experience more rain and less snow, which could have a major effect on outdoor soft mobility in winter. Rain in winter settlements is highlighted as a major barrier to soft mobility in winter (Chapman et al, 2017), so this issue may become increasingly important for urban design.

Climate change is not expected to significantly change wind patterns. Therefore, protecting against and minimising the effects of wind will probably continue to be important in winter settlement design (Erell, 2011).

Overall, the results of the review indicate that climate change will probably alter the balance between snow and water in winter. This effect is relatively straightforward: in general (although not inevitably), if the temperature is below 0 °C, precipitation will fall as snow. However, above 0 °C, it is likely to fall as rain. As winter cities warm, water is likely to become a bigger barrier to soft mobility in winter and the positive effects of physical activity on wellbeing. This issue may not be limited to the occurrence of precipitation as rain; it may cause a range of problems including the build-up of standing water, the accumulation of ice if the temperature fluctuates around 0 °C, and the formation of slush. All of these could be barriers to soft mobility and increase the risk of being outdoors in winter.

Method Discussion

A unique aspect of this review is that it considers the treatment of urban design considerations in relation to individual weather conditions. This allowed the discussion of focus on the relationships between urban form and specific weather types, and to identify gaps in the research literature.

Whilst literature was systematically searched using appropriate keywords to identify publications with relevant content, the search protocol could only retrieve publications listed in research databases (namely Web of Science or Scopus) or cited in a relevant document listed in such a database. Consequently, relevant works may have been overlooked if they were not listed in the databases, not cited by listed documents, or not published in English.

While the climate data and trajectories considered in this work are drawn from IPCC documents, the implications of these trajectories were primarily considered in terms of their effects on Finland, Norway and Sweden. Consequently, the analysis is primarily relevant to the Nordic context.

Conclusions

This review indicates that most of the publications that serve as cornerstones in the field of urban design for Winter settlements do not account for current knowledge of climate change (including climate adaptation and climate resilience) or the impact of outdoor soft mobility on human wellbeing. This is simply because most of the relevant publications were written either before or very shortly after these issues first came to prominence.

While the design principles of solar access, wind, and snow management remain important for modern winter settlements, winter warming due to climate change is significantly affecting snowfall and snow cover. Many winter settlements are likely to experience more rainfall and more fluctuations around 0°C because of warming; while this change may be minor in numerical terms, it will have profound implications for outdoor soft mobility because 0°C is the point at which snow (commonly seen as a positive attribute of the environment) becomes rain, water, and slush, all of which are commonly seen as negative attributes that create barriers to soft mobility.

We suggest that to facilitate outdoor soft mobility in winter and reduce risk under these changing conditions, the urban design principles for winter settlements may need to be widened in scope to encompass new winter conditions associated with climate change.

Warmer winter cities with temperatures that are often around 0°C and fluctuate more rapidly than they do at present will compel designers to consider how these conditions affect outdoor environments. Both present risks for outdoor activity because fluctuations around 0°C can rapidly change the nature of water in the public realm, transforming snow into ice, water, or slush. Designers must consider how the qualities of the 'built' public realm can be retained when streets and pathways are covered by winter precipitation. This may necessitate creating larger pedestrian areas within the public realm that can successfully accommodate both soft mobility and the build-ups associated with winter. Alternatively, designs could be created that exploit the sun and wind to help clear snow, ice, water and slush.

Figure 10: The Great Park Development, UK has green natural spaces that are designed flood with excessive storm water.

We may also consider how buildings and the public realm can be designed to help manage more rain in winter. Buildings and the public realm can be designed to provide temporary water storage when needed without affecting the usability of streets and pathways. Future building designs for winter cities may also include more features such as roof overhangs, arcades, and colonnades to provide street-level protection from rain and wind.

Urban designers working on high-latitude winter settlements will also need to consider how increasing levels of rain and lower levels of snow cover are likely to affect ambient light in winter. Ensuring adequate ambient outdoor lighting in winter may become an increasingly important design challenge. While rising outdoor temperatures are expected in winter, these changes are unlikely to change the natural seasonal lighting patterns of high-latitude settlements. Traditionally, light levels in winter are increased by reflection from snow, which mitigates against the impact of limited daylight hours and 'polar' nights. Reduced snow cover will therefore reduce the ambient lighting of the outdoor environment. This effect will be compounded because while snow is highly reflective, water is light absorbing and makes places visually darker. The reduction of outdoor ambient lighting in winter will present a fairly unique design challenge and will require an increased focus on making the outdoor environment attractive in winter.

These changes could all affect levels of outdoor soft mobility in winter and thus the wellbeing benefits associated with physical activity. However, because climate change will affect different winter settlements in different ways, designers should seek to understand its impact in the local context, and avoid generic 'one size fits all' approaches to climate mitigation, adaptation or resilience for winter settlements.

Designers will also benefit from looking at places whose present environmental conditions resembles those predicted for their settlement in future. For example, northern Scandinavian settlements that are expecting more rain could look to southerly settlements such as Bergen, Norway, which are designed to accommodate high levels of rain.

By taking such approaches and designing in context, urban designers of winter settlements may be better able to enable soft mobility in winter, reduce the risks of being outdoors in this season, and increase opportunities for residents to gain the associated physical wellbeing benefits.

Source Documents: Winter City Urban Design

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