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RETHINKING NORDIC URBAN HARBOUR DEVELOPMENT – A SUSTAINABLE PERSPECTIVE

ELIZABETH DONOVAN, SOFIE PELSMAKERS AND URSZULA KOZMINSKA

Abstract

With the continuous growth of urban environments, space for new residential developments is in continuous demand. Subsequently, the recent transformation and reclamation of waterfronts are becoming increasingly desirable. However, this is often at the expense of social, environmental and architectural quality where affordability, good urban design, human scale, citizen wellbeing, as well as quality outdoor spaces and ecology are often set aside. Moreover, given that housing is expected to last 50 years or more in cities meant to last for centuries, it raises questions about protection from future predicted climate change, which is often jeopardised in favour of exploiting land values. Equally, the buildings' lifespans and demanding environmental conditions of the harbour context are often compromised in the formal and material choices. A "Sustainable Residential Waterfront Development Framework" was developed based on extensive literature of key criteria for sustainable residential harbour (re)development and combined with three main environmental themes. The framework and its criteria and themes are demonstrated through an exemplifying case study. By using analysis photographs, maps and section diagrams, this article also illustrates the above-described tensions. Finally, the framework helps to unfold how these issues can be overcome to create more sustainable living environments now and in the future.

Keywords:
sustainable development, waterfront redevelopment, Aarhus Ø, harbour development, sustainable urban design, climate change

Introduction

How we design and live in our urban environments becomes progressively more crucial because of the increasing global population, reduction of resources and biodiversity, combined with the global climate emergency. In recent years, there has been a renewed interest in the design, (re)development and study of urban coastal areas, and how these perform in a changing climate and in increasingly extreme weather events. Since the 1960s, there has been a global trend for post-industrial cities to transform physically and conceptually (Giovinazzi & Moretti, 2010) from once large industrial spaces of ports and harbours into new urban waterfront neighbourhoods (Meyer, 2003). Europe has the longest coastline of all continents (Codato et al., 2012), with many coastal centres affected by rising sea levels caused by increased global heating (Oppenheimer et al., 2019). Thus, harbour transformations are part of the EU's sustainable development approach (Codato et al., 2012) because they have a significant impact on cities and residents' lives and on the overall sustainability the region.

Yet, many recent urban waterfront zones appear indistinguishable from conventional urban developments elsewhere. They result in mixed-use developments in best cases, but typically are predominantly residential areas with minimal public spaces, or freely accessible and non-consumer activities (Small, 2017). Additionally, large waterfront redevelopments can be insular, dismissing the context in which they exist, or as Marshall (2001, p. 6) states, "They reside in a self-imposed vacuum". Waterfronts are also often treated as "clean slates" or tabula rasa (Braae & Diedrich, 2012), resulting in a loss of collective memory, urban identity and thus, culture (Pugliano et al., 2019; Braae & Diedrich, 2012).

However, the waterfront is not an isolated and insular space (Jacobs, 1961). As a space in the city, it offers many opportunities if designed well, and can fail miserably if not considered and designed as the complex system it is. Waterfronts and urban coastal areas are unique edge environments, transitioning between the water and the city, while also overlapping different communities and zones. They are dynamic and complex interfaces between human and non-human environments (Urban Land Institute, 2004). These new developments can be seen as unique opportunities to have a significant influence on the economy and community – changing the face and pride of a city (Marshall, 2001) – while at the same time conflicting with other environmental, social and cultural factors (Pugliano et al., 2019). Further, Marshall (2001, p. 4) identifies the unique visibility of these sites, using the metaphor of a stage upon which life is set, and elaborates that "the waterfront is an expression of what we are as a culture". However, many waterfront developments reflect the twenty-first century's neoliberal capitalist culture rather than a rich and diverse culture observed in other parts of a city (Shaw, 2001).

There are apparent overlaps and endless opportunities to merge and integrate sustainability with the (re)development of harbour areas; however, thus far, trends in the Nordic region leave much room for improvement. In the Nordics and worldwide, the development of coastal areas is often copied and pasted designs that disregard the local context and environmental, social and cultural factors (Yıldıza et al., 2015).

This article aims to explore gaps and opportunities in residential waterfront developments, specifically from the perspective of sustainability. The research questions are: what are the key sustainability criteria for residential waterfront development, and how can they be assessed? To do so, a "Sustainable Residential Waterfront Development Framework" was developed, identifying 20 waterfront sustainability parameters with a suggested scale for assessment (ranging from poor to outstanding), illustrated through a case study. Thus, this article commences with a short overview of the history of waterfront development, background to the climate emergency, the literature review that defines the methods and forms the framework's basis, demonstrated through the case study (Aarhus Ø). To conclude, a synthesised discussion of sustainable waterfront development considerations is outlined to envision more sustainable living environments now and in the future.

Background: Innovations in housing and waterfront development

History of waterfront development in a Nordic context

Waterfronts are dynamic environments with a long history of changing functions to meet human needs, including travel, trade, labour and more recently, recreation. Historically they have thrived as the location of martime commerce, before suffering from patterns of neglect, which have led to redevelopment (Werf et al., 2009). While these areas indicate a time of growth and wealth based on industrial production, they also speak "to a time when environmental degradation was an unacknowledged by-product of growth and profit" (Marshall, 2001, p. 5).

Urban waterfront regeneration started with the transformation of industrial buildings in Baltimore, Boston and San Francisco in the 1960s (Smith et al., 2012. Meyer, 2003). Shaw (2001) identifies four generations of post-industrial developments, with these first examples as part of the "functionalist traditions" (2001, p. 15). Later, in the second generation, these were scaled up and enriched by public-private partnerships in the 1980s, such as Sydney, Toronto, Cape Town, London Docklands, Barcelona and Rotterdam (Shaw, 2001). The third-generation popularised former redevelopment strategies in, for example, Liverpool, Vancouver or Shanghai, while the fourth, dated to the beginning of the 21st century, focused more on the use of resources, and provided a diverse functional set-up, often mixing housing and leisure (Shaw, 2001).

An analysis of the new developments in harbour areas in the Nordic cities shows the diversity and favourable potential of urban waterfront regeneration approaches. Copenhagen serves as an interesting example of the change in the waterfront regeneration strategies after the critical perception of first development in the 1990s (Smith et al., 2012). The public promenade's design showed the necessity to focus on the relations between privately owned buildings and public spaces, to create inviting harbour areas. Later, the lively harbour redevelopment of Sluseholmen embraced the concept of canal-living and high-quality design. The strategies, which focus on high-density and promote mixed-use typologies, are visible in the ongoing development of Nordhavn, one of Scandinavia's largest urban development projects.

Attention to the public space was also addressed in the redevelopment of the Oslo waterfront ("Fjordcity"). Here, diverse planning methods, including participatory processes, were used to create accessible public space, with exemplary use of the Opera House roof as a public square. High-quality public spaces define a strong visual identity of a mixed-used area of Aker Brygge (1985, 1998). This approach was later continued in the Sørenga district, the redevelopment of an old container dock located in the fjord of Bjørvika providing apartments and workplaces, surrounded by a park, several channels, a bathing complex and a harbour promenade with services. Sørenga is criticised for the lack of particular architectural character, but it is also praised for accessible, inclusive and human-scale public space.

Another inspiring example of urban waterfront regeneration is the B001 district in Malmö, constructed on land reclaimed from the sea and the former dock. The project started with a mixed-use development for the European Housing Expo in 2001 by K. Tham. It included 1000 housing units as well as commercial, educational and service buildings distributed among recreational areas, which promote biodiversity and incorporate storm-water management strategies in infrastructure and public space with a strong place identity. B001 is one of the few districts that explicitly tests sustainability strategies such as water, waste recycling, passive resilience and renewable energy sources, and it favours cyclists and pedestrians above cars.

Finally, the innovative approach to urban waterfront regeneration is also visible in the Arabia district in Helsinki. The area was developed in the 2000s to regenerate a wasteland by the Vanhankaupunginlahti bay, and since 2007 has been developed as a laboratory for housing, connecting gardens and neighbourhood buildings (Helsinki Living Lab). It is clear that with their transformation, harbourfronts offer a moment for cities to reconnect with the water's edge, which has been obstructed for many decades. Furthermore, these examples present an alternative to the anonymity and environmental degradation, which are often consequences of fast and cheap, neoliberal, consumer-based urban development.

Harbour developments in a changing climate

Our harbours and coastal areas are buffer zones between harsh and extreme weather, sea-level rise, sea spray and waves. They are governed by climate and the sea, along with human-made progress (Allan et al., 2007). The effects of climate change are being felt globally, and the North is no exception. Current and future trends indicate that this will materialise as more extreme weather, loss of animal habitat and biodiversity, and the changing natural conditions will impact culture and the economy (Reijonen, n.d.). Three factors that affect all areas in the northern regions, but especially in waterfront settlements, are rising sea levels, increased extreme weather with subsequent flooding and changing temperatures (Climate Change Post, 2020).

Increasing temperatures, heavier snow melts and glacial retreats are especially evident in the northern regions (Naylor, 2019). Since the mid-nineteenth century, an average temperature increase of 0.6 °C (IPPC, 2007) has been observed; however, in the Nordic countries for the same period, this was above 1 °C. This is due to its location in the northern hemisphere (Mäkelä et al., 2016). Specifically, Denmark has experienced a 1.5 °C increase (Nordiska Ministerrådet, 2009) and 2.3 °C in Finland since the industrial revolution, well above the current global average temperature increase (Mikkonen et al., 2015).

As a result of Arctic ice loss, between 1850 and 2006, the global sea level has risen on average by 24 centimetres (Box and Colgan, n.d.). The Arctic reports (Arctic Monitoring and Assessment Programme – AMAP, 2017) indicate that even if we reduce emissions in accordance with the Paris agreement (RCP4.5) by 2100, globally, we will experience an additional sea-level rise of 54 centimetres and 74 centimetres under "business-as-usual" (RCP8.5) within the same time frame (Colgan et al., 2018). Interestingly, this will not be evenly distributed amongst the Nordic region; for example, projections indicate that Oslo and Copenhagen will have different experiences. Colgan et al. (2018) explain that in a "business-as-usual" climate scenario, in Oslo, there is a 50% chance sea-level rise locally will exceed 22 centimetres, while in the same scenario, Copenhagen is projected to experience 68 centimetres. While at the extreme end of the projections with a lower probability of 5%, Oslo will experience 112 cm and Copenhagen 161 cm by 2100 (Colgan et al., 2018). The drastic variances within these projections highlight how essential designing for a changing climate and future scenario is. For example, Copenhagen's flood protection is based on a water level of 150 cm above sea level, which will not withstand these projections (Hallegatte et al., 2011). Clearly, we are in a climate emergency, and thus have to start designing for it – especially in coastal areas.

Methods and theoretical framework

Key sustainability parameters

The methods employed in this article are based on both qualitative and quantitative data, starting with an initial literature review. From this preliminary literature study, sets of criteria were synthesised to form an initial set of principles to develop general parameters for waterfront (re)developments by creating a “Sustainable Residential Waterfront Development Framework”, to be tested on the presented case study. The primary literature included the set of nine parameters for a “soft city” (Sim, 2019), the 12 Design Quality Criteria by the Gehl Institute (n.d.), “Toronto design submission criteria” (City of Toronto, 2019) and “criteria for ‘healthy homes’” (Steemers & Baker, 2019) – see figure 1. These four key sources were selected based on their relevance to contemporary harbour front developments and sustainable housing – covering both the site (neighbourhood) and building scale. These 20 parameters formed the basis of the evaluation framework for this study. When evaluating a case study, a ranking of “poor”, “average”, “good” or “outstanding” is assigned based on quantitative and qualitative data for each of the 20 parameters, which are evaluated through case study analysis (see further below); no ranking is given if the parameter was not present or if there was insufficient available data.

Furthermore, three main themes (see below) were devised from the literature to categorise the 20 parameters to analyse and exemplify certain aspects through a waterfront case study analysis.

The three themes can be described as:

- **Climate and social adaptation** – understanding the waterfront in the broader context, especially concerning water issues and social and community spaces.
- **Climate, materiality and ageing** – exploring the different material properties at both housing and urban scale, outlining how they relate to form, ageing and the idea of public space and residential atmospheres.
- **Climate and comfort** – focusing on the building and neighbourhood scale, especially concerning solar and daylight conditions and how that impacts heating, thermal comfort and the health and wellbeing of spaces.

Theoretical site analysis approach

The article “Site specificity in contemporary large-scale harbour transformation projects” by Ellen Braae & Lisa Diedrich (2012) outlines parameters for “examining site-specificity” and general “reading” of a site from a designer’s perspective. This framework was chosen as it combines the physical and immaterial factors and the fluid aspects of a site, thus forming a well-rounded approach to our analysis to encapsulate the complexity of harbour developments, following the 20 sustainability parameters and three themes (fig. 1). This framework is based on three pairs of parameters described further below. While this analysis is initially considered by Braae and Diedrich (2012) as a method or approach for examining a site for transformation, in the case of this paper, it will be used as an analysis and reflection tool for the development of the existing waterfront and how it may transform to address future climatic challenges and resource scarcity. The three parameters are:

- **Physical** – includes the physical parameters of *structure* and *materials*, ranging in scale and physical space. Within this theme, both formal and subjective methods are employed (Braae & Diedrich, 2012).
- **Flux** – refers to both the natural process and use or function (practices) of a site, including factual aspects such as water cycles, or solar studies and subjective concerns, such as aesthetics or weathering (Braae & Diedrich, 2012). Building on this theme, flux will also refer to future flux and transformative capacities within this paper, especially concerning climate change.
- **Immaterial** – includes *memory* and *atmosphere*, two elusive, complex and sometimes contested parameters. While both themes are outlined in Braae and Diedrich's article, and the use of both are relevant for this article, the atmosphere will be the primary focus due to the limitations of the study. The atmosphere is considered a temporal phenomenon experienced between the subject and the object, such as light or weather conditions (Braae & Diedrich, 2012)

These three parameters of the study are utilised in combination with the three previously described climate-related themes because the physical, flux and immaterial are present and crucial for understanding the case study, both quantitatively and qualitatively.

Case study analysis

The developed framework is demonstrated through Aarhus Ø in Denmark, combined with the authors' expertise, information collected and objective observation, analysis and evaluation. The harbour area Aarhus Ø, Denmark's second-largest city facing the Baltic Sea, was chosen as the case study site to illustrate many of the literature's findings. Aarhus Ø is a recent and ongoing development with many principles. It faces similar challenges, which are relatable to other Nordic waterfronts presented in this historical overview and upcoming developments. Moreover, it was the main Nordic harbour familiar to all authors and physically accessible during the COVID 19 period.

Within this case study analysis, quantitative methods such as solar studies, site sections, material mapping and environmental mapping were combined with more qualitative and subjective experience and observation analysis inspired by the theoretical approach of Braae & Diedrich (2012) – discussed above.

Sustainable residential waterfront (re)development: key sustainability criteria

A waterfront, just like any other urban space, requires careful and well-considered planning and design. Globally, the development of waterfronts is often part of the city's densification as opposed to suburban sprawl (Stevens, 2006). Ultimately, the waterfront is "a symbol for living quality and an exceptional location within the city context" and should combine ecological, economic and social goals (Niemann & Werner, 2016, p. 433). It can often be considered a space free of constraints as a brown or grey-field site, sometimes with minimal physical context or value. However, the complexity of parameters required for a successful waterfront design exceed a regular development (Marshall, 2001) as reclaimed land is not usually designed structurally for large building projects as well as the challenges of sea-level rise, infrastructure, connections to the city and forming social and public spaces from scratch during extensive construction periods. Nevertheless, some fundamental principles can be utilised to ensure the success of a project.

Considerable research indicates that specific characteristics repeatedly emerge relating to the design of neighbourhoods combined with health and wellbeing. This includes high-density, mixed-use, pedestrian-oriented, availability of diverse public open space, high-quality green space, providing local facilities, biodiverse environments, the importance of the threshold between the home and neighbourhood, views of nature and the neighbourhood (Steemers & Baker, 2019). Similarly, the Gehl Institute (n.d.) in its "12 Quality Criteria" highlights the human scale and a pleasant micro-climate, as David Sim (2019) also highlighted in "Nine Criteria for Liveable Urban Density". Indeed, sunlit and sheltered public spaces are essential to encourage and attract residents to spend time outdoors throughout the year (Codato et al., 2012; City of Toronto, 2019). In addition to the previous characteristics, diversity of built form and smaller carbon footprint are noted by Sim (2019), while the Gehl Institute (n.d.) emphasises the importance of spaces for sitting, lingering, play and different activities. Moreover, the visual quality of materials, construction detailing, and fenestration are also considered essential. They contribute to the area's aesthetic character and can create a sense of identity (City of Toronto, 2019; Steemers & Baker, 2019; Sim, 2019).

It is clear from the literature that social and cultural concerns are crucial in a design's success. As Steemers & Baker (2019, p. 31) explain, "the provision of local 'everyday public spaces' creates opportunities for people to connect and is a meaningful resource of wellbeing for individuals or the wider community". This is significant in developments where an overall master plan of the public spaces is not well articulated, and the building considered the design object, rather than the entire plot and how it connects to its neighbours. For instance, despite the waterfront being public, topographical and hydrological considerations and equal access and views to the waterfront are often compromised for the benefit of private interests (Codato et al., 2012; Stevens, 2006). As often in these scenarios, the everyday public spaces are forgotten, especially on the ground floor, which is essential to activate (City of Toronto, 2019).

While the public space, connection to the city and environment play crucial roles in waterfront developments, so do the spaces we reside in. As we spend nearly 90% of our time indoors, of which 70% is in our homes (Steemers & Baker, 2019), it is crucial that these spaces positively affect our health and wellbeing. Essential aspects of housing design at an often-hostile waterfront environment include aspects such as good thermal performance and solar access to provide free heating in the heating season, good daylight, views of the sky and views and physical connections to outside and nature, providing seasonal awareness in support of residents' health and wellbeing (Steemers & Baker 2019; Pelsmakers, 2015; City of Toronto, 2019; Drexler & El Khouli, 2012).

Another main principle for harbour development is that buildings should step down in height towards the water (Codato et al., 2012; Stevens, 2006). Doing so maximises views and enables good daylight and sunlight of internal living areas and external public spaces, all criteria for a pleasant waterfront microclimate both for the public and residents living there. This is important, given that the waterfront area is a finite available space and enables equal access to water views.

To support long-term sustainability, flexible and adaptable spaces are also needed to accommodate residents' changing needs over time – for example, increased working from home, changes in family composition and demographic shifts, etc. (City of Toronto, 2019; Sim, 2019; Saarimaa & Pelsmakers, 2020). Such housing adaptability means residents do not have to move home if their situation changes, supporting stability and diversity and reducing the impact of fluctuating communities (Jusan & Sulaiman, 2005; Femenias & Geromel, 2019). If developments cannot support societal change, they can become obsolete and are demolished (Huuhka & Vestergaard, 2019), further exacerbating the climate crisis. Adaptability and diversity principles also extend to the neighbourhood scale (Sim, 2019). For example, the need for different activities at different times to attract and support a diversity of users over time. This is why new housing typologies should include mixed-use 'hybrid' buildings (Pelsmakers et al., 2020), different housing types and tenures (e.g., student and intergenerational housing and affordable ownership options) and new ways of living and sharing (e.g., collective living, sharing of spaces). Furthermore, the use of collaborative processes can help to create inclusive, diverse living options and environments.

In waterfront developments, durable, long-lasting materials with low maintenance are favoured to resist corrosion due to salt exposure. Therefore, concrete, steel, aluminium, masonry and stone are often encountered in harbour areas. Organic and unstable building materials that absorb water, dissolve, deteriorate or change properties due to wetting and drying are best avoided (FEMA, 2008). Exposure to high wind speeds requires intact foundations, a structurally sound envelope with durable connections, reinforced windows and doors and a tight outer skin to minimise penetration of wind, rain, debris and microorganisms.

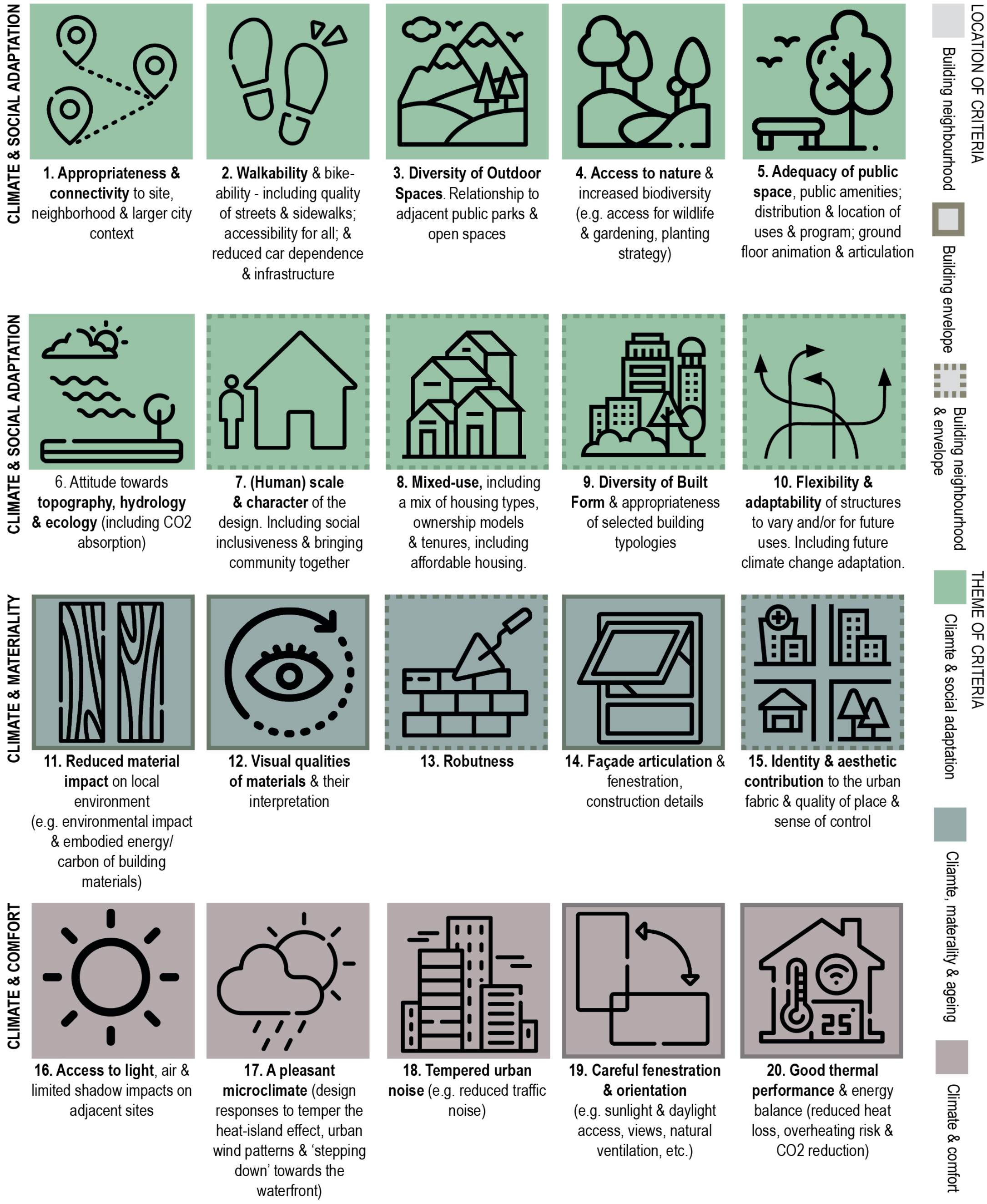
However, this approach to urban development, which focuses on robustness and performance efficiency of materials, contradicts nature's natural fluxes, negatively affecting the seabed and disconnects land and underwater ecosystems. It also impacts the quality of public space, access to water, diversity of functions and usability. Thorough investigations of the lifecycle of buildings and surrounding areas reveal long-term effects of selected material solutions, their environmental impacts, ageing, weathering, decay, as well as maintenance patterns and reuse or recycling possibilities. This knowledge creates an opportunity to rethink the current approach to durable but often generic housing harbour design. Maintenance, repair, replacement and reuse strategies may indicate new design possibilities that introduce local, organic materials to reconnect with nature and the socio-cultural context. Weathering, decay, embedded traces of passing time can uncover buildings' environmental and cultural meaning over time. They add age-value in architecture (Cairns & Jacobs, 2014) and the experience of the continuum (Hosey, 2012). These immaterial elements may become evidence of usage and history. They create a unique atmosphere, authentic "character and liveliness" (Jacobs, 1961) and a long-lasting identity of sustainable housing developments.

Many of these criteria are also overlapping in their consequences; for instance, the overall planning and layout of a development affects multiple considerations from orientation, daylight, natural ventilation, microclimate, wayfinding, form creation and building typology. In turn, these principles impact the quality of space. For example, the grouping of blocks and the creation of courtyards can improve the climate of the entire development and subsequent public spaces. This is especially beneficial when combined with lower building heights which protect from the wind but allow sun penetration (Codato et al., 2012; Stevens, 2006). Further, an asymmetrical layout – similar to those of medieval towns or cities – can improve the microclimate by blocking the wind and prioritising smaller, more protected outdoor spaces with the flexibility of use.

Designing suitable public spaces, which moderate weather to foster use in various weather conditions, is fundamental, especially in Nordic countries where much time is spent outside regardless of the often-harsh climate (Sim, 2019). This is even more relevant in waterfront developments, which are completely exposed to all of the natural elements.

Clearly, there is a massive potential for innovative housing to explore new typologies, foster community and social spaces, and to ensure a healthy built environment.

Figure 1
The "Sustainable Residential Waterfront Development Framework" summarises 20 key parameters for sustainable housing and waterfront developments from literature, along with three themes: climate and social adaptation, climate and materiality and climate and comfort. Note that there is little explicit mention of future climate change adaptability at any scale in most literature.
SOURCE: AUTHORS OWN INTERPRETATION BASED ON LITERATURE FROM SIM (2019); GEHL INSTITUTE (N.D.); CITY OF TORONTO (2019); STEEMERS & BAKER (2019).



A case study – Aarhus Ø

Aarhus Ø is an old, disused container terminal in Aarhus, Denmark. In 1997, Aarhus Municipality adopted a masterplan to define the physical development of the area. Within this framework, it was set out that the district would be redeveloped for housing with some offices and public functions. In 2007, the municipality took over the 100,000m2 of the port area, beginning the construction of Pier 4 (Aarhus Kommune, 2018). This redevelopment has occurred in stages, with the first building breaking ground in 2010 after delays from the financial crisis, while new projects are still being constructed today. The masterplan intends to accommodate 7,000 inhabitants and workplaces (Aarhus Kommune, 2018). At the time of writing, 11 of the 18 proposed apartment buildings were complete, with a further six under construction. When completed, the area will hold around 800,000 m2 of floor space (State of Green, 2016.). As such, the evaluation and discussion of Aarhus Ø is based on a snapshot of the preliminary construction phase and use at the time of writing and will change as the development is completed.

The district borders the sea, and in the past, the harbour was crucial to the city's economic development. As one of the largest container ports in the region, the Port of Aarhus has flourished and acted as a barrier between the city and the sea. Therefore, this has been a relevant factor in the redevelopment of this area. Specifically, pier 4, situated at the top of Aarhus Ø and connected to the Kattegat (sea) with extensive expanses of deep water, is extremely vulnerable to sea-level rise and sea spray (Nielsen, 2012). Subsequently, as part of the redevelopment, the area has been raised an additional 0.5 metres to an elevation of 2.5 metres, responding to (at the time of design) the 100-year projection of sea-level rise (Nielsen, 2012). This protection was achieved by a 1.2 km promenade with exterior coastal protection, including a ten-metre-wide belt of rocks at 0.5 meters below the water's surface, acting as a breakwater reducing sea spray (Nielsen, 2012). Due to the increase in elevation, the water can only be accessed at a small number of points throughout the development.

The analysis of architectural solutions in the housing development in Aarhus Ø creates an opportunity to discuss the materiality of newly constructed residential spaces in harbour areas. Most buildings are built with standard slab-wall or slab-column structural systems with underground parking levels and five to seventeen floors above ground, dedicated mainly to residencies, some offices and accompanying services. The buildings on the Southern edge of the neighbourhood and a dominant tower – the Lighthouse – are still under construction at the time of writing, and the spaces between buildings were also still being developed. However, it is possible to draft some preliminary conclusions on the built substance and future development plans. The following section will describe the case study of Aarhus Ø through the three different themes with some overlaps between them; each parameter is referred to by Fig. 1 followed by the parameter number, e.g., Fig. 1 – 1.

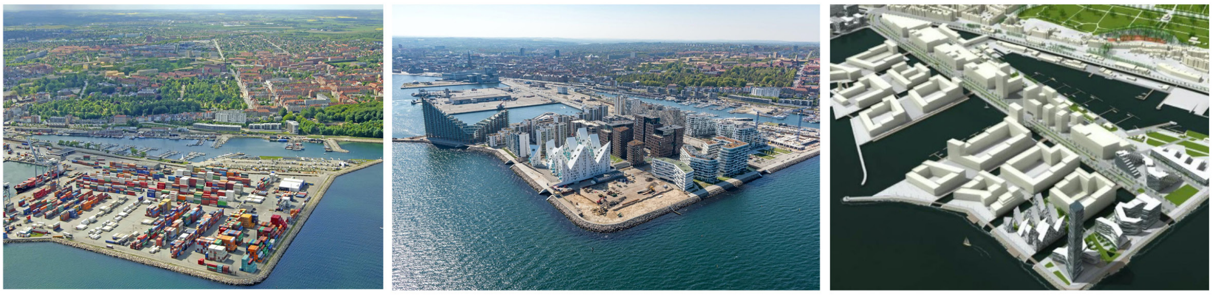


Figure 2
Photos indicate the transformation of Aarhus Ø, from a container terminal to the current phase of development in the middle and the projected design proposal to the far right.
IMAGE SOURCE: MIDDLE PHOTO: LUFTFOTO – JESPER LARSEN; RIGHT – AARHUS KOMMUNE

Theme 1:
Climate and Social Adaptation (parameters 1-10)

In Aarhus Ø little was pre-existing, providing the opportunity to optimise the environmental design to mitigate climate change but also be adaptable to face a changing climate (Gething, 2013; Pelsmakers et al., 2020). However, while low-energy buildings were included, and the ground floor elevation was physically raised by 0.5 meters, the development missed many other opportunities for holistic, social and climate-resilient spaces (Fig. 1 – 6 and 10). This could lead to a "longevity paradox" (Pelsmakers et al., 2020), whereby the main focus of "long life" only (e.g., future climate adaptation efforts) will not avoid building obsolescence if shorter to medium-term "loose fit" needs are neglected (e.g. social reasons for adaptation).

The increased ground elevation partially addresses sea-level rise but introduces new challenges such as public access to the water, one of the driving factors of waterfront developments (Fig. 1 – 5). Codato et al. (2012) explain that public access and good connections to the water are needed, with good daylight and sunlight and areas for leisure and recreation that are free to use and supported by a mix of (public and commercial) activities. Aarhus Ø has few public open or non-residential spaces to encourage 24/7 activities and significantly few lively edges enabling a mix of public and commercial use. Apart from the summer bathing facilities, primary activities to draw people in are missing (Fig. 1 – 8). Limiting residential uses could have encouraged other public and commercial activities throughout the day with active ground floors (Fig. 1 – 9) (Project for Public Spaces, 2009; City of Toronto, 2019; Stevens, 2006).

There are only two main points where the public can freely reach the water, at the swimming basin designed by BIG architects and at a small pier on the northwest boulevard (Fig. 1 – 3 and 5). Despite the materiality of the waterfront connection to the pier being the concrete boulevard with minimal seating, people still gather on the edge of the seawall to socialise and swim (see Fig. 3). Interestingly, these spaces neighbour the small park, which is rarely used, with people choosing the concrete's warmth, which avoids the building shadows slightly longer over the very shadowed grass (Fig. 1 – 4, 16, 17). Before the pier construction, this part of the development with a hostile microclimate and no 'purpose' was often used only for transit rather than stopping and socialising, reducing the desire to use the space by those who are less physically mobile (Fig. 1 – 1, 2, 7). The small addition of the pier has facilitated the flux of this portion of Aarhus Ø, giving purpose and creating a destination at the end of the long straight road. However, the weather influences this space, with strong cold winds blowing onshore and offshore from the west (Fig. 1 – 17). While the natural process' flux is a barrier for public outdoor space, it does create an opportunity to reconnect with the ever-changing forces of nature and the changing tidal sea level (Fig. 1 – 19, 20). This is one example of how to reconnect with the water, but it raises social inclusiveness issues of accessibility with only the young and able being capable of touching the water physically (Fig. 1 – 2 and 7). If designed to belong to the public, there should be a diversity of recreation areas: socialising and leisure can create a high-value, open space in the city (Codato et al., 2012).

Figure 3
Images of how the development meets the sea, illustrating the 2.5 m rise from sea level to the iceberg (left) and the pier along the boulevard, offers one of the few public accesses to the water (right).
SOURCE: K. WIBERG, U. KOZMINSKA

Critically, the increased ground elevation of 0.5m will not be enough to withstand the future projected sea-level rise (Fig. 1 – 10). For example, a sea-level rise of 40cm would lead to a storm surge of 1.63 meters, which is statistically the current 100-year event, and an 8-year event by 2050 (Aarhus Kommune, 2020 a). Figure 4 indicates the flood risk of a sea-level rise at 1.6 meters (Southern parts of Denmark already experienced this in 2017) and 2.5 meters. While it is not expected that the sea will rise permanently by 1.6 meters, the flood risk with storm surges easily exceeds 1.6 meters, painting a stark picture of the adaptability to a changing climate. Nielsen (2015) indicates that the existing reclaimed land was not stable enough to take an increased load from additional soil, making further ground elevation impossible. This brings into question the site's appropriateness for the design proposals, especially for thousands of homes (Fig. 1 – 6). This is further highlighted when considering that the new lighthouse project (142 meters tall) requires two piles with a diameter of two meters at almost 70 meters deep (Andersen, 2019) to be structurally stable in these ground conditions. There are clear limits to the flood mitigation approach of elevating the site. While a sea break has also been included in the project, other adaptable strategies could have been combined, reducing pressure from the water and at the same time having social and health benefits. These could have included reduced building mass, using softer or permeable surfaces rather than the excessive amount of concrete (Fig. 5) in nearly all public spaces (Fig. 1 – 6, 10, 11). A larger permeable greenery strip could have also supported biodiversity and wellbeing, offered social space and acted as a green buffer to storm surges (Fig. 1 – 3, 4). This has been done successfully in other Nordic harbour redevelopments – see Figure 17.

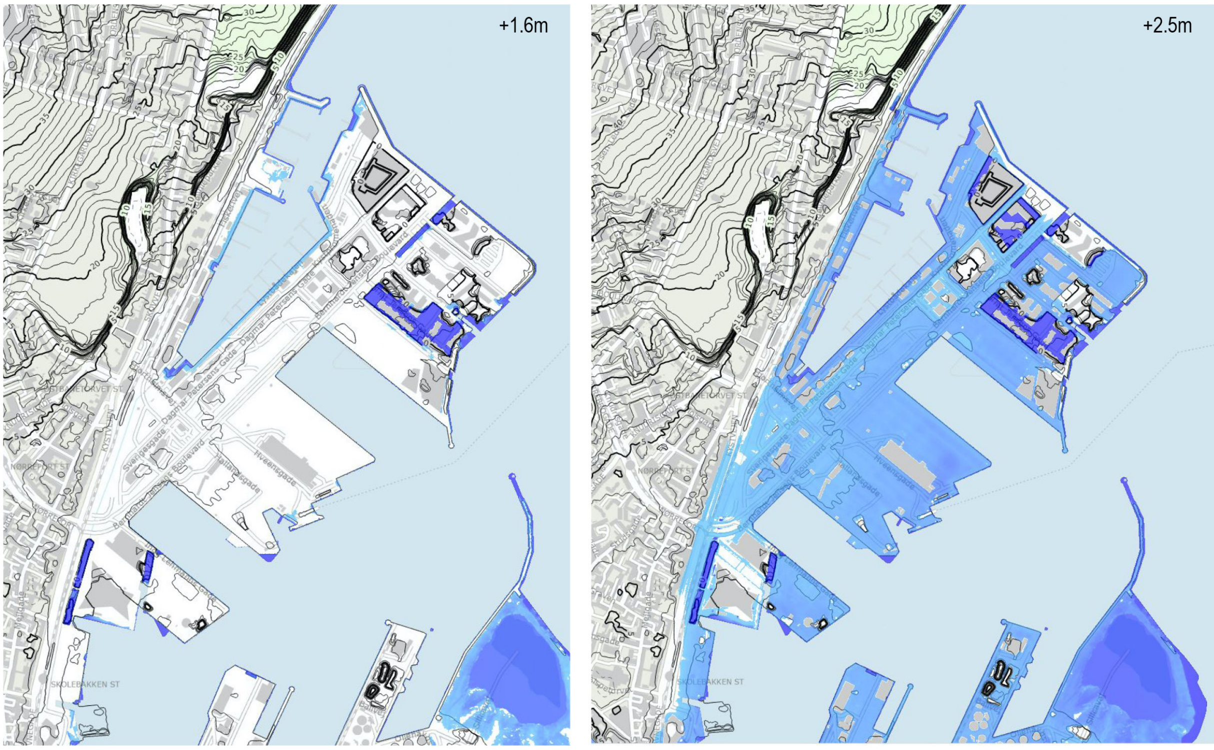


Figure 4
GIS flood risk maps of the Aarhus harbour area. Left indicating +1.6m and right +2.5m
SOURCE: K. WIBERG

As mentioned previously, strength in sustainable design comes from the holistic nature and considering the complexity of a project or site as a whole. This offers benefits as many factors influence each other; however, there are several missed opportunities for Aarhus Ø. For example, increasing the green spaces (Fig. 1 – 4) would have required a change in layout to increase light conditions, which would also have reduced the risk of flooding and improve the health and wellbeing of residents (Leporelli & Santi, 2019). However, there is little greenery at street level for residents or the public (Fig. 1 – 3, 4). Some private courtyards have greenery and some room for plants to grow (see Fig. 5), but plants are not thriving due to wind and shading. Street greenery and vegetation are typically absent or sparse, yet could help buffer some wind exposure (Pelsmakers, 2015), while improving resident health and wellbeing (Leporelli & Santi, 2019). Sheltered spaces with access to sunshine and views can also

Figure 5
Image from the pedestrian path along with the main access indicating walkability and paved surfaces. A portion of the main park and green space at dusk. Moreover, public hard-surface spaces between the Iceberg buildings with plans growing up the building on the left.
SOURCE: U. KOZMINSKA AND E. DONOVAN

support social activities (Fig. 1 – 16). The absence of suitably designed green and public spaces (see Fig. 5 for an example of the central green space) is a missed opportunity to provide a connection for city dwellers to the waterfront (Fig. 1 – 1) (Project for Public Spaces, 2009). For example, the AARHus courtyard by BIG architects is private.

However, during the construction phases of the development, small temporary public spaces developed, which not only added to the character of the waterfront but offered a more human scale connection to nature (Fig. 1 – 7) and offering other benefits, see Fig. 6. An additional example was the community gardens on the Lighthouse site while it remained a car park (Fig. 6). This created a small-scale urban farming intervention, fostering community and social interactions between those gardening and visiting the area. While quirky, these small connections to nature encouraged social life, but they have not been replaced or made permanent. Instead of healthy city design, cars are brought into narrow streets and courtyards for parking spaces, further reducing usability. Overall, the development missed an opportunity to enhance relations across scales (connectivity) or use of the site (appropriation) due to the elevated water edge and excessive hard surface with few moments for social activity or public engagement that provides year-round shelter and use (Fig. 1 – 7).

Figure 6
Temporary spaces previously on Aarhus Ø. Left, Skovbadet by SLA architects and right, urban farming outside the iceberg. Skovbadet placed 600 different species of trees along the Boulevard, reducing pollution from the cars and absorbing CO_2 while creating a pleasant microclimate, strengthening the social and community aspects and creating a diverse and interesting atmosphere.
SOURCE: E. DONOVAN

Theme 2:
Climate, Materiality and Aging (parameters 11–15)

In addition to the risk of flooding, waterfront developments' physical substances are affected by harsh weather conditions with high moisture levels, strong winds, sun exposure, salt crystallisation and surface algae growth. These factors require that the buildings in coastal areas are designed for robustness.

The predominant design strategy shaping the physical substance and material choices in Aarhus Ø address the need to withstand harsh weather conditions and mitigate related risks (Fig. 1 – 13). Floorings are covered with impermeable but long-lasting surfaces: asphalt in car and bicycle routes and concrete pedestrian pavements (e.g., Bernhardt Jensens Boulevard). Prevailing concrete paving of streets and shores protect from flooding risk and extensive usage. Safe and more organic materials are encountered in playgrounds, courts and wooden decks in a few places around bridges and canals (Fig. 1 – 12). Green, permeable surfaces are only visible in the Ø-line in the Eastern part of the development and to a limited extent by the Northern embankment. The envelopes of residential buildings are also designed for durability. The façades are covered with concrete panels, aluminium cladding and roofing, bricks and stone elements. A significant part of elevations and balustrades are glazed to ensure daylight access and undisturbed views (Fig. 1 – 14). Timber appears in The Harbour Bath's decks, as wall finishing of the canal promenade, in the façade cladding and soffit panels on balconies of The AARhus and as structure and cladding of The Aarhus Bath Houses.

Figure 7
Aarhus Ø materials mapping.
(Note: North is top of the page)
SOURCE: U. KOZMINSKA.

The material mapping and analysis (Fig. 7) show that façade materials were predominantly chosen to create tight and durable building envelopes that can resist winds, rains, moisture and salt crystallisation. Robust horizontal and vertical elevations will withstand harsh weather conditions, but they also influence the atmosphere of the space between buildings and the way it is used (Fig. 1 – 12, 15). Daily activities happen mainly around the main boulevard connecting the buildings with the centre and the greenery in the Ø-line. In summer, crowds gather in The Harbour Bath and the swimming spot in the North. The rest of the spaces between buildings act more as transition corridors than places to hang out.

The disconnection between buildings is often emphasised by their iconic form and unique aesthetic language. The formal dissonance is even more apparent when the floors and elevations of Aarhus Ø are affected by adverse weather conditions. The slick, white façades require regular maintenance to remain in favourable aesthetic and technical condition (e.g., The Harbour Islet), to protect from algae or moisture (e.g., The Lighthouse, The Iceberg).

Figure 8
Aarhus Ø materials – performance and weathering: The Lighthouse, The Iceberg, The Harbour Islet.
SOURCE: U. KOZMINSKA, E. DONOVAN

These challenges can be addressed when considering atmosphere and memory in relation to the material fluxes. A life cycle analysis creates the possibility to rethink the approach to harbour development design and suitable material choices. Understanding material fluxes and natural cycles help to evaluate which building elements should be robust and maintained, replaced, reused or recycled (Fig. 1 – 12), diverse solutions that accommodate various functional and aesthetic needs. What is more, they construct spaces where "authenticity refers to the look and feel of a place as well as the social connectedness that place inspires" (Zukin, 2010, p. 220). One can find glimpses of this approach in Aarhus Ø. They appear in the green Ø-line, which may become an active public space and unfold its full potential over time.

Similarly, the timber-clad Harbour Bath and the timber structure and claddings of The AARhus and adjacent bathing houses contribute to the character of new harbour housing. Nevertheless, they also may remain unnoticed in between predominant, closed walls. A more inclusive approach investigating life cycles of materials could help situate the new development within Aarhus harbour's functional, environmental, and socio-cultural context.

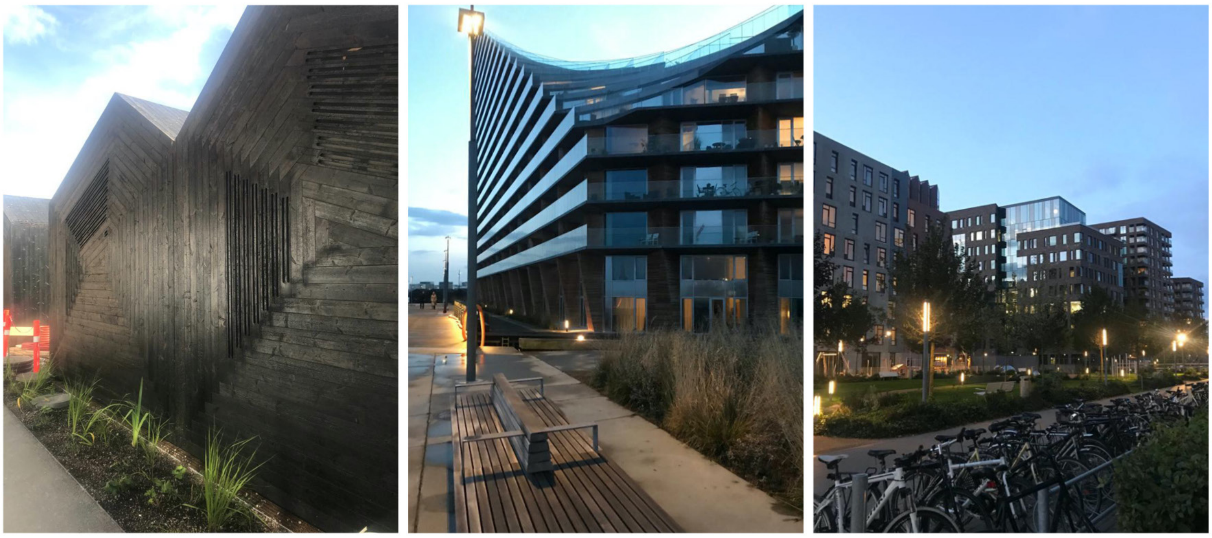


Figure 9
Aarhus Ø – glimpses of material identity: The Aarhus, Bath Houses, Q-line.
SOURCE: U. KOZMINSKA

Theme 3: Climate and Comfort (parameters 16–20)

The site is exposed to harsh environmental elements, especially in winter, though it can create a desirable micro-climate in the summertime. The urban plan and housing block design significantly impact the individual's general environmental performance and common living environments in Aarhus Ø. For example, instead of stepping down towards the waterfront, the reverse happens in almost all cases (Fig. 1 – 16), see Fig. 10 – 11. This creates unequal access to the waterfront views, and significantly overshadows the public promenade along the waterfront (See Fig. 12).

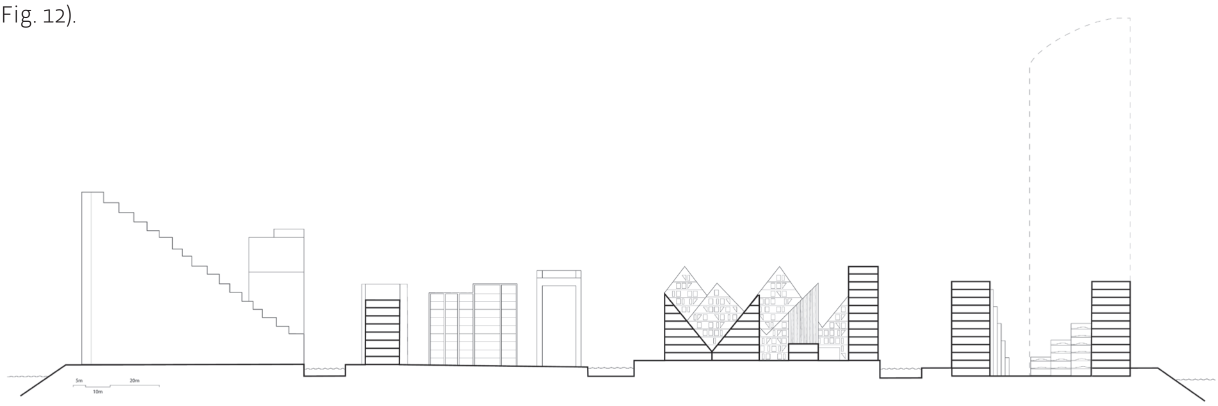


Figure 10
Indicates stepping up instead of stepping down to the water edges. The section drawing (along the southeast side) is constructed based on planning drawings, renderings and photographs.
The dotted line to the right is the Lighthouse tower currently under construction (AARhus – number 11 in fig. 7, is the large mass on the left).

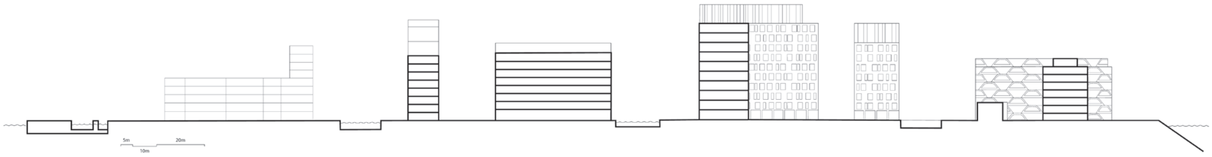


Figure 11
This indicates an exceptional stepping down of two blocks towards the water edges. The section drawing is constructed based on planning drawings, renderings and photographs.

Only two buildings step down exceptionally towards the water's edge, north-east and southwest (see Fig. 11). Not only do the out-of-scale, tall buildings block views, but they also cast long shadows on neighbouring areas. The city's latitude is at 54 degrees North, allowing low sun angles to bring free heat deep into interior spaces and in between buildings (Fig. 1 – 16, 20). However, tight courtyards and generally narrow streets are significantly overshadowed due to the close proximity of buildings to each other (relative to the building height). For example, the north-east side of the waterfront is almost always in the shade, and the largest tower in Denmark currently under construction at 142 meters will only worsen this situation. Extensive shading, along with wind exposure, affects external community spaces and waterfront walkways, and discourages spending time there outside of the summer season (Fig. 1 – 16, 17). The building shading also creates internal living spaces with fewer hours of daily sunlight than desirable, few external views and compromised privacy, apart from top floor units or those apartments directly facing the waterfront (Fig. 1 – 19). Some of the light-coloured facades help reflect light inside streets and spaces; however, they have weathered poorly, and need ongoing maintenance as previously described. Some of the stepped terraces (e.g., The AARhus) create better solar access and daylight within the apartments and enable generous private outdoor spaces, but their scale and depth overshadow the surroundings (Fig. 1 – 16, 19).

In winter, buildings are so tall that by midday, they cast shadows as long as 150–160 meters (and worse at other times on a winter day), see Fig. 12 (top). Even in spring and autumn, 40 to 60-meter-deep shadows plunge large parts of the facades, courtyards and spaces between buildings in the shade, though upper floor units benefit from more solar gain. The breaks in the skyline from the Iceberg help create some gaps in shadows. However, from the afternoon until sunset, the southeast and northeast public water edge and water itself are almost continuously shaded, see Fig. 12 (middle), discouraging social activities and affecting marine biodiversity (Dyson & Yocom, 2015).

As expected, there is less shading in summer and most courtyards and south and southeast facing facades receive solar gain (except for the tight Lighthouse courtyard), see Fig. 12 (bottom) and Fig. 13. However, there may be a significant risk of overheating in summer in the upper floor units, especially if they are single aspect with no cross-ventilation to benefit from fresh sea breezes (Fig. 1 – 19, 20). The southwest of the waterfront remains unshaded and creates a desirable location for the public bathing facilities (which are only shaded in early mornings in summer). The Youth Housing and Harbour Housing blocks cast long shadows of 100–200 meters on their southern neighbours due to the northern solar angle in summer evenings.

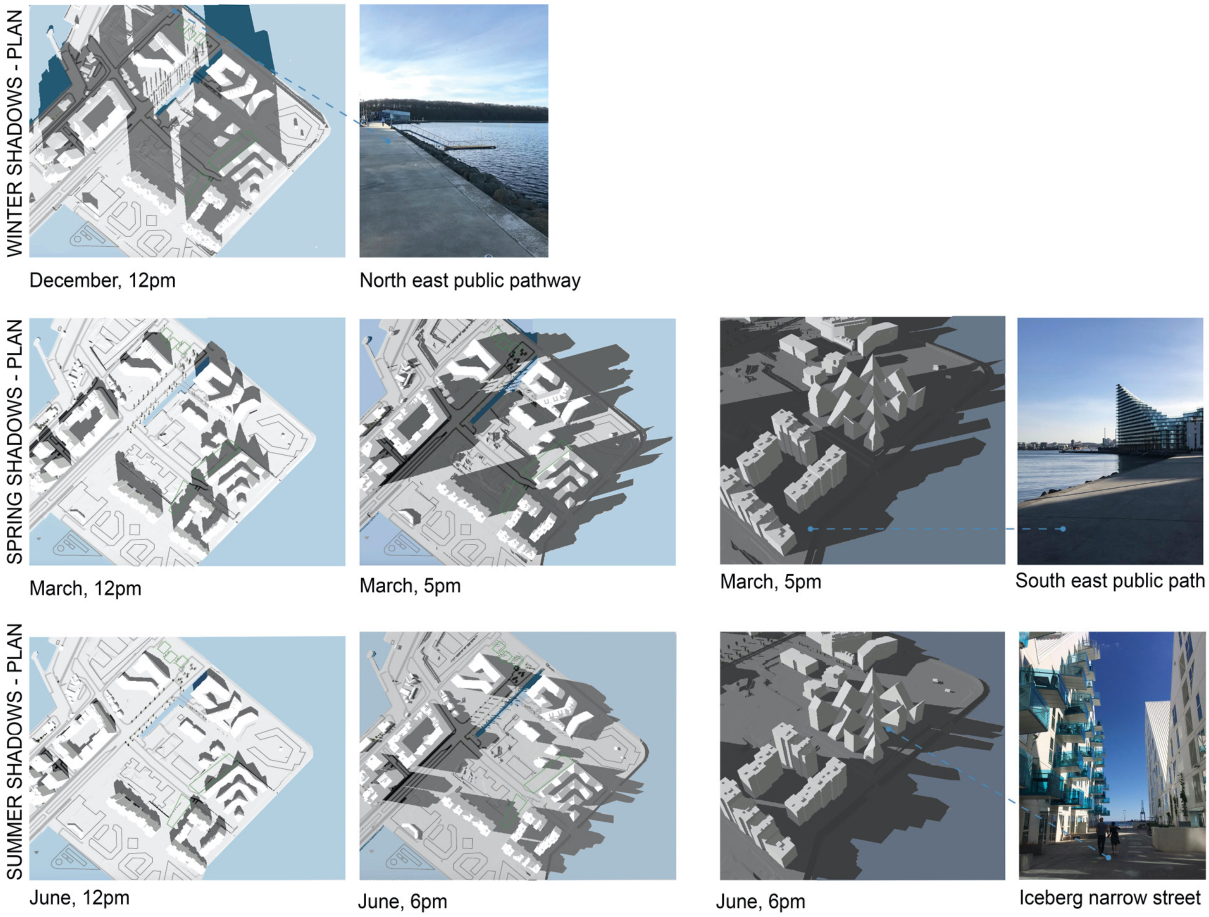


Figure 12
Shading in December (top), March (middle) and June (bottom), showing the depth of the shadows at midday and early evening, and extent of shading in some of the courtyards, streets and on lower facades. The model represents the most recent development phase, without all buildings that have recently been constructed or are still under construction.

Optimised solar access facades are 10 to 30 degrees from the south. In Aarhus Ø, they are angled at about 45 degrees due to streets being planned parallel to the 45-degree site shape. This street pattern is also not ideal for the prevailing winds, channelling them into the streets instead of providing shelter (Fig. 1 – 17), see Fig. 14. Preferably, buildings should have been skewed by 30 degrees to the prevailing wind direction, also benefiting from the winter sun (Pelsmakers, 2015).

Figure 13
Private courtyard of "the AARhus" June (pm), and public walkway (July, afternoon).
SOURCE: U. KOZMINSKA

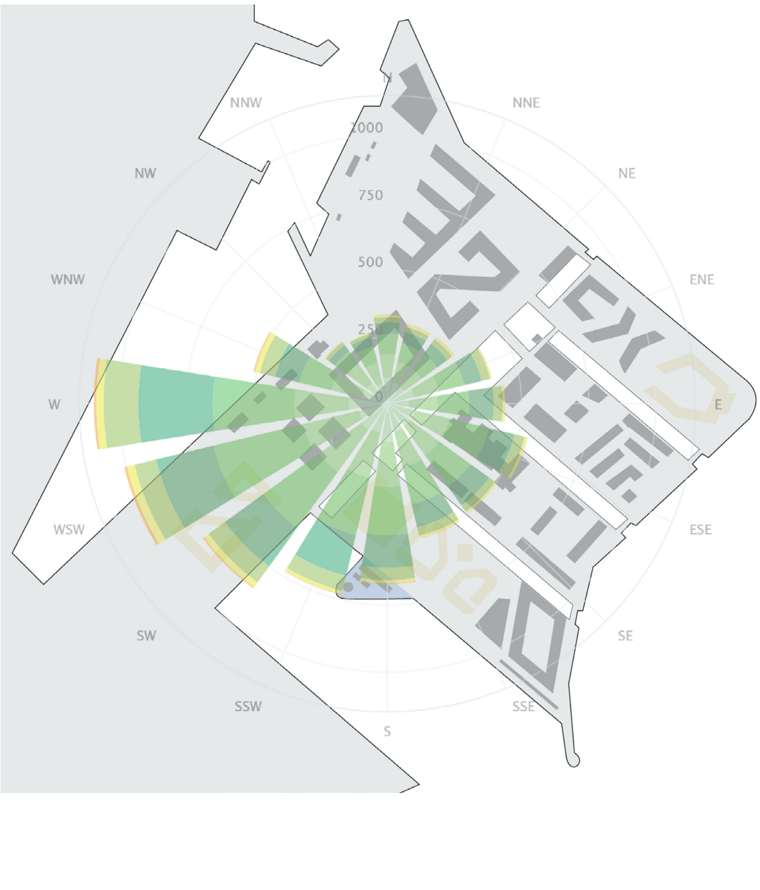


Figure 14
The wind rose overlaid to Aarhus Ø development, showing prevailing winds from West to South. Especially south-western winds are funnelled into the development due to the street pattern.

In summary, the overshadowing of spaces between housing blocks and their windy exposure does not create a pleasant microclimate, discouraging outdoor space use. There is also little integration of seasonal activities that provide shelter at different times of the year. The out-of-scale housing blocks also significantly compromise the quality and sustainability of individual apartments. The majority of parameters identified earlier (Fig. 1) are not met, affecting residents' wellbeing, see Fig. 15.

Discussion and conclusion

Most design parameters for sustainable waterfront development are not met in Aarhus Ø (Fig. 15), with most parameters scoring poorly or zero. Average parameters are access to nature (parameter 4), public parks and open spaces (5), diversity of built form (9), façade articulation (14), identity and aesthetic contribution (15), access to light and air (16); good parameters are material robustness (13) and good thermal performance (20). The current construction does not make it possible to easily rectify these issues without significant future demolition – in itself unsustainable given that the development was still under construction in 2021.

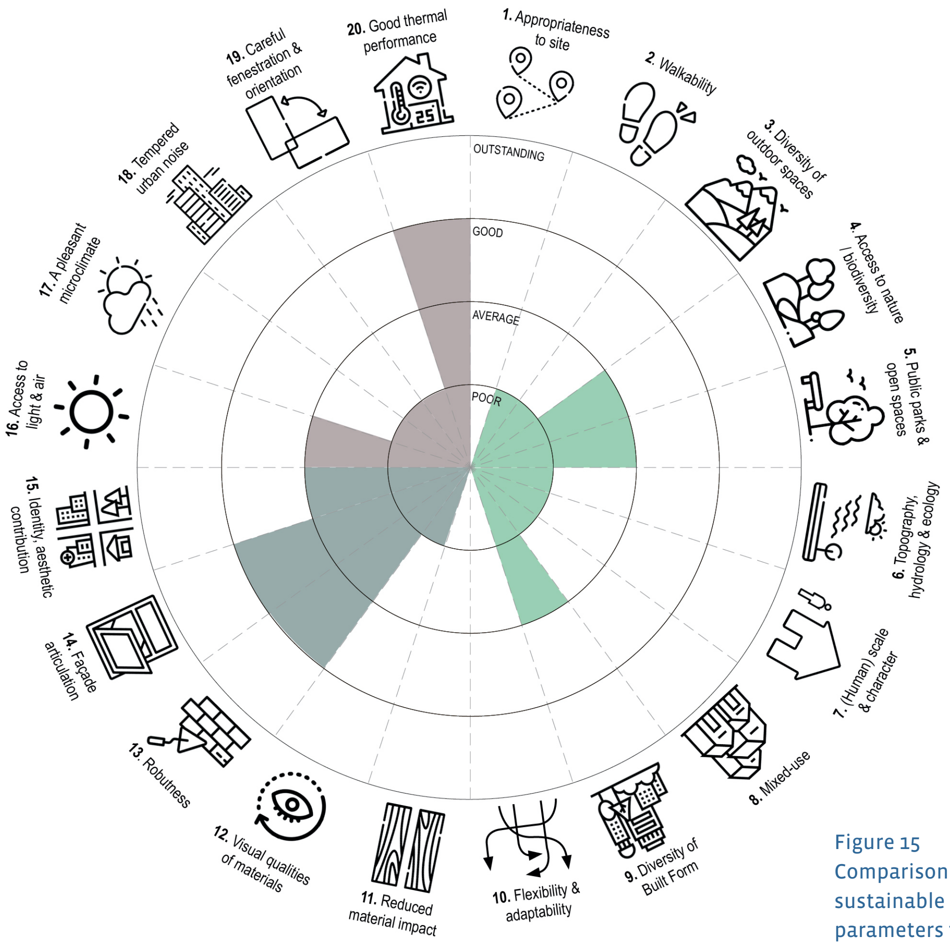


Figure 15
Comparison diagram of the 20-key sustainable harbour waterfront design parameters for Aarhus Ø.

Clearly, Aarhus Ø can be significantly improved, benefiting from some of the approaches in the new harbour developments in Copenhagen, Oslo, Stavanger, Malmo or Helsinki. For instance, the built substance would gain liveliness and autarky from more functional diversity (social adaptation), following the example of Copenhagen's Nordhavn (see Fig. 16). Further, investigating local traditions, building techniques and available materials (climate and materiality) could strengthen the link with the city. A more considerate design of the physical would also help develop the identity of space. Sometimes embracing the robust character of materials (e.g., The Silo in Nordhavn in Copenhagen by COBE) or their changeable aesthetics caused by weathering (The Waterfront in Stavanger by AART) adds a referable, authentic value that constructs identifiable and long-lasting space, see Fig. 16. Therefore, it results in a more sustainable housing development that builds on connections and memories more than architectural trends.

Figure 16
Copenhagen, Nordhavn: Copenhagen International School, The Silo and the Waterfront in Stavanger.
SOURCE: U. KOZMINSKA

Better connections can also be emphasised through free fluxes of nature and people, increasing green areas and public spaces, together with diverse and more extensive spacing between buildings, as in the Arabia development in Helsinki or Sørenga district in Oslo (see Fig. 17). The connection to nature would also improve biodiversity, attracting wildlife and people as in Bo01 harbour development in Malmo (Fig. 17). Bo01 serves as a good example for improved accessibility to the waterfront and walkability with its range of opportunities for cycling, walking, sitting, sunbathing, etc. It is also inspiring in its topography design (climate adaptation) and the various elements that naturally drain, purify and buffer the water in interconnected outdoor spaces.



Figure 17
Internal passage through Sørenga in Oslo. Greenfields around Arabia in Helsinki. Bo01, Malmo, relationship to water at the canal and the seafront with seating as well as open water gutters and permeable surfaces.

Many of the merits of the projects mentioned above successfully integrate solutions that address many issues at once. However, this does not seem to be the case in Aarhus Ø based on the current construction phases. For example, Bo01's asymmetrical layout protects from the wind, creating a pleasant microclimate, allows natural light and creates close and physical connections to the water (which is visible in all areas). It also allows nature to flourish (acting as natural water filtration), creating diverse settings.

To summarise some key considerations, waterfront developments need to:

- Consider the site context as a complex whole; including climatic, environmental, non-human and human needs. Thus, holistically integrating sustainable design within all aspects of the development. (Parameters 1, 3, 4, 6, 16, 17, 18)
- Celebrate the finite waterfront resource in the city as a public good: Prioritise a diversity of public and other activities and limit residential uses only – facilitating the social flux. (Parameters 3, 4, 5, 8)
- Create green areas and other external public open spaces that connect to the waterfront and the rest of the city, beyond a public pathway that circles the waterfront perimeter. (Parameters 3, 4)
- Step down building heights and give equal access to waterfront views, daylight and solar access, both for internal and external communal and public spaces – creating better microclimates and embracing the flux of natural processes. (Parameters 16, 17)
- While not discussed here, consider more holistically the opportunities for renewable energy (Aarhus Ø has small isolated examples of façade solar panels and seawater heat pumps). (Parameter 20)
- Planning considerations to evidence that each development is a good neighbour to the surrounding buildings, as well as the public spaces, instead of each building exploiting solar access and waterfront views at the expense of others. (Parameter 16, 17)
- Ensure sufficiently large communal courtyards and open space and sufficient spacing between units.

The research presented and demonstrated a "Residential Waterfront Development Framework" as a useful method to analyse, evaluate and discuss waterfront developments' characteristics. However, this analysis must be combined by detailed site analysis approaches for each of the 20 parameters, qualitative methods (experiential and observational analysis), with quantitative methods such as solar studies, site sections, material and environmental research and mapping.

Through a case study demonstration of the framework, this article identified and unfolded how the three themes of climate and social adaptation, climate and materiality and climate and comfort issues can be overcome to create more sustainable living environments now and in the future.

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