

AI-driven sustainable cities: A Nordic-inspired requirement framework

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Abstract. This paper examines the integration of AI and data technologies into sustainable urban development, emphasizing Norway's unique cultural and environmental context. It first explores how concepts like trust and sustainability inform urban planning and operations. Then, the study assesses AI's potential to enhance urban development, and, through case studies, it identifies challenges and opportunities in adopting these technologies. Finally, it proposes a Nordic requirement framework for AI and data integration, promoting sustainability aligned with Norway's values and adaptable for broader European contexts.

Keywords. Sustainability; Urban development; Artificial Intelligence (AI); Ethical governance; Nordic framework

Résumé. La durabilité est devenue un enjeu crucial dans la planification urbaine moderne, alors que les villes du monde entier doivent faire face aux défis du changement climatique et de l'urbanisation rapide. Assurer la résilience, l'efficacité des ressources et la qualité de vie dans les villes tout en minimisant l'impact environnemental est désormais une préoccupation centrale pour les urbanistes et les décideurs. La Norvège, reconnue pour son approche avant-gardiste de la durabilité, a été un leader mondial dans les stratégies de développement urbain intégrant la gestion environnementale, l'innovation technologique et la participation communautaire. L'intégration de technologies émergentes telles que l'IA et les données massives offre de nouvelles opportunités pour atteindre ces objectifs, mais nécessite une prise en compte attentive des impacts éthiques, environnementaux et sociaux. Cet article examine comment l'IA et l'intégration des données peuvent soutenir le développement urbain durable, avec un accent particulier sur le modèle nordique et les valeurs norvégiennes de confiance et de durabilité. Il propose un cadre de référence nordique pour l'intégration de l'IA et des données, visant à promouvoir un développement urbain durable en Norvège et au-delà.

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1 Introduction

1.1 Backgrounds

Sustainability has become a critical issue in modern urban planning, as cities worldwide grapple with the twin challenges of climate change and rapid urbanization. Ensuring that cities remain resilient, resource-efficient, and livable while minimizing environmental impact is now a central concern for urban developers and policymakers.

Norway, renowned for its forward-thinking approach to sustainability, has been a global leader in urban development strategies that integrate environmental stewardship, technological innovation, and community participation. As cities continue to evolve, emerging technologies like AI and big data offer new opportunities. However, the integration of such technologies requires careful consideration of ethical, environmental, and social impacts, making it essential to establish frameworks that ensure these advancements align with sustainable development principles.

This paper addresses these pressing concerns by exploring how AI and data integration can support sustainable urban development, with a particular focus on the Nordic model, with cities in the Nordic countries of Denmark, Finland, Iceland, Norway and Sweden often ranking high in diverse “sustainable cities” indexes [1].

1.2 Objectives and scope

This paper aims to examine first how unique Norwegian concepts—such as *tillit* (trust) and *bærekraft* (sustainability)—shape urban planning and operations. By focusing on Norway's distinct geographical, cultural, and environmental contexts, the study highlights how these cities integrate sustainability principles within their urban fabric.

Additionally, the paper explores the growing role of artificial intelligence (AI) and data technologies in advancing urban sustainability. With AI's capacity to process large datasets, the study assesses its potential to enhance urban management, increase citizen engagement, and improve decision-making in Norwegian cities. Drawing on case studies and ongoing projects, the research delves into the challenges and opportunities AI presents, including the need for high data quality, the final goal of value creation, and the integration of human insights.

The study ultimately proposes a Nordic requirement framework for AI and data integration for fostering sustainable urban development in Norway and potentially across the broader Nordic region. The framework emphasizes transparency, ethics, and environmental stewardship, grounded in Norway's sustainability values, but adaptable for future European collaboration.

2 A selection of some central Norwegian concepts and their impact on Norwegian cities

This section introduces key Norwegian concepts that are deeply rooted in the country's unique geography, culture, and values. Their influence on the design, management, and everyday use of urban spaces is discussed and illustrated through examples related to urban development and city planning in Norway.

2.1 Nature: «marka» and «friluftsliv»

Marka: *Marka* refers to protected forested areas on the outskirts of Norwegian cities. These areas are legally safeguarded to prevent urban expansion into these natural environments. They are reserved for recreation and ecological preservation, and their existence ensures that residents have direct access to nature close to urban centers.

Friluftsliv: The term *friluftsliv* represents a lifestyle that emphasizes outdoor recreation and deep interaction with nature. It is a cultural cornerstone in Norway [2], where spending time outdoors is seen as essential for physical health, mental well-being, and community bonding.

Impact on Urban Development: *Marka* and *friluftsliv* together have had a profound influence on the development of Norwegian cities. The strict boundaries established to protect *marka* prevent urban sprawl and promote compact city development. This has led to the adoption of urban densification strategies, where city planners maximize the use of limited space while preserving the surrounding natural areas. As a result, urban cores become denser and more efficient but remain connected to nature through the integration of green corridors and parks, which ensure that residents can still enjoy easy access to nature even within highly developed urban zones.

The cultural importance of *friluftsliv* further shapes city infrastructure, emphasizing outdoor activities and recreation. Cities are designed with extensive networks of trails, parks, and green spaces that encourage activities such as hiking, skiing, and cycling. Public access to nature is prioritized, even in densely populated urban areas, where green spaces serve as essential outlets for relaxation and recreation. This approach not only preserves the natural environment but also promotes public health, making cities spaces where active lifestyles are encouraged and facilitated by design.

Selected examples: Markaloven [3] is a Norwegian law governing the forest and rural areas in Oslo and 18 surrounding municipalities. Enacted in 2009, it aims to protect these regions, preserve nature and cultural environments, and promote outdoor activities. The law arose from the rapid urbanization of Oslo in the 20th century, addressing the need for recreational spaces amidst urban growth. With Oslo and Akershus being densely populated, Markaloven plays a critical role in safeguarding green spaces while accommodating future housing developments.

Friluftsliv, or outdoor life, significantly influenced the design of Oslo's urban environment by integrating urban and peri-urban forests, such as Oslomarka. These forests provide essential ecosystem services, including recreational opportunities, which enhance the well-being of city dwellers. Over the past 50 years, while some provisioning and habitat services have declined, the cultural and recreational benefits have increased, highlighting the importance of urban forests for promoting outdoor activities and sustainable living in urban environments [4].

2.2 Demographics and geography: “fortetting” and “areal under press”

Fortetting Strategi: This term refers to Norway's strategy of urban densification, which involves concentrating development within existing urban areas [5] to prevent suburban sprawl and minimize land use. The goal is to make cities more sustainable by utilizing space efficiently, reducing the environmental footprint of urban growth, and supporting the use of public transportation.

Areal Under Press: This term refers to "land under pressure", particularly in urban areas where population growth and economic expansion put stress on available space. The concept highlights the tension between development needs and the limited availability of land for construction, especially in environmentally sensitive areas.

Impact on Urban Development: The *fortetting strategi* and the concept of *areal under press* together drive urban development toward efficiency and sustainability in Norwegian cities. The densification strategy (*fortetting strategi*) often involves the construction of mixed-use buildings that integrate residential, commercial, and recreational functions, fostering a more vibrant urban environment. These compact city models result in walkable, bike-friendly neighborhoods with robust public transportation networks that reduce reliance on private vehicles. Vertical growth, through taller buildings, becomes a prominent feature, allowing for more efficient use of space, energy, and water within city limits.

At the same time, *areal under press* highlights the challenges of limited available land, particularly in cities facing environmental and geographic constraints. This scarcity pushes city planners to prioritize brownfield development, revitalizing former industrial or unused urban areas, while also safeguarding natural and agricultural spaces from further urban encroachment. Urban zoning becomes essential in managing this balance, with cities like Bergen and Stavanger implementing strict policies to limit development in ecologically sensitive coastal and mountain areas. This pressure on available land drives innovation in architecture and urban planning, encouraging solutions that optimize land use while preserving natural resources and protecting the environment.

Selected examples: The Norwegian government is actively promoting urban densification and transformation, focusing on developing transport hubs and existing urban areas to reduce land use, improve public transport, and enhance sustainable development [6]. As a result, most of the main Norwegian cities have been working with issuing guidelines, e.g. Oslo municipality [7]; evaluations of past strategies, e.g. Bergen municipality [8]; and dimensioning reports, e.g. Ås municipality [9].

NRK, Norway's national public broadcasting company, published in 2024 a comprehensive article highlighting that artificial intelligence has revealed 44,000 nature interventions in Norway over the past five years [10]. These interventions have resulted in the loss of 79 square meters of natural land every minute due to various projects, including roads, sports facilities, and housing developments. The Norwegian government's response to the concerns over nature degradation includes the launch of the new action plan for biodiversity [11], aiming to reduce the development of critical natural areas. The plan promotes sustainable land management principles and aims to enhance municipal competencies to balance various interests, prioritizing public goods like renewable energy and critical infrastructure during conflicts over land use.

2.3 Governance, Policy, and Culture: "tillit" and "dugnad"

Tillit: *Tillit* translates to "trust" and is a core value in the Nordic region, reflecting the strong social cohesion and high levels of trust in public institutions, government, and among

citizens. In governance, this trust ensures smooth implementation of policies and widespread public cooperation. The Nordic region has the highest levels of social trust in the world, which benefits the economy, individuals and society as a whole [12].

Dugnad: *Dugnad* refers to the Norwegian tradition of collective voluntary work. It is a cultural practice where communities come together to accomplish tasks, whether maintaining shared spaces or organizing community events [13].

Impact on Urban Development: *Tillit* and *dugnad* are deeply embedded in the governance and community dynamics of Norwegian cities, shaping urban development in meaningful ways. High levels of trust (*tillit*) between the public and government institutions play a critical role in the planning and management of urban environments. This trust fosters more effective collaboration during public consultations and participatory decision-making processes, enabling cities to implement sustainable urban policies with widespread public support. Transparency is a key outcome of this trust, as city management practices become more open and inclusive, encouraging citizens to actively participate in shaping their neighbourhoods and ensuring long-term sustainability.

Meanwhile, *dugnad*, the tradition of voluntary community work, enhances a sense of collective ownership and responsibility for urban spaces. Neighbourhoods are often designed with shared spaces such as gardens, playgrounds, or communal areas where residents can come together for *dugnad* activities. This communal spirit extends beyond social interaction, directly supporting sustainability initiatives like urban farming, green space maintenance, and environmental cleanup efforts. Urban planners, in turn, design spaces that promote collective engagement and social cohesion, creating vibrant neighbourhoods that reflect the values of participation and community involvement.

Selected examples:

The high levels of trust ("*tillit*") between Norwegian citizens and government institutions have been highlighted as a crucial factor in shaping urban development [14]. Trust facilitates collaborative governance and public participation, allowing urban planning to prioritize transparency and citizen engagement. An example of this is seen in participatory planning models, where local communities are actively involved in decision-making processes, ensuring that urban initiatives align with public interests and sustainability goals [14]. Trust ensures smoother implementation and greater long-term success of urban projects. As an example, Oslo Municipality won the European Green Capital Award in 2019 by leveraging the "*dugnad*" spirit [15], encouraging collective community engagement and collaboration in environmental initiatives. The city implemented various sustainable solutions, such as reducing emissions, improving public transportation, and enhancing green spaces, with the active participation of residents, businesses, and local government.

2.4 Climate: «allvær» and «klimatilpasning»

Allvær: *Allvær* refers to the wide range of weather conditions that Norwegians experience throughout the year, from extreme cold and snow in winter to mild summers and heavy rainfalls. Adapting to this variability is an inherent part of Norwegian culture.

Klimatilpasning: This concept translates to climate adaptation and refers to efforts to respond - and adapt - to climate change's long-term effects, such as rising sea levels, increased rainfall, and more extreme weather events.

Impact on Urban Development: The concepts of *allvær* and *klimatilpasning* significantly shape how Norwegian cities are designed to handle diverse and sometimes extreme weather conditions. The idea of *allvær*, which acknowledges the need for urban environments to withstand a range of weather types, drives the development of energy-efficient and moisture-resistant buildings that are well-insulated and equipped with heating systems suited for cold winters. Public spaces are designed to endure rain, snow, and ice, with robust drainage systems and infrastructure that includes e.g. heated sidewalks to prevent ice buildup, ensuring safe pedestrian access throughout the year. The freeze-thaw cycles common in Norwegian climates also influence material choices, as cities prioritize durable construction materials capable of withstanding these fluctuations.

Climate adaptation (klimatilpasning) further intensifies these efforts, focusing on creating urban environments resilient to climate change. City planners are investing in green infrastructure such as permeable surfaces, urban wetlands, and advanced stormwater management systems to prevent urban flooding, a growing concern in many Norwegian cities. Buildings are designed not only to be energy-efficient but also to incorporate renewable energy sources, e.g. solar cell panels, and features like green roofs, which help mitigate the impact of strong rain events by absorbing and retaining water, and thus significantly reducing runoff and delaying peak flows during heavy downpours. Coastal cities such as Bergen and Stavanger face additional challenges from rising sea levels, prompting the implementation of coastal defense strategies to protect urban areas. Together, *allvær* and *klimatilpasning* ensure that Norwegian cities are not only weather-resistant but also forward-thinking in their approach to climate resilience.

Selected examples: The Klima 2050 project operated from 2015 to 2023, focusing on enhancing climate adaptation and resilience in Norwegian cities. It aimed to foster collaboration among municipalities, businesses, and research institutions to address climate-related challenges through innovative strategies and sustainable urban development. By sharing knowledge and best practices, the project sought to empower local communities to effectively respond to climate impacts. The research centre published more than 300 publications, dealing with e.g. the stakeholders' attitude towards implementation of sustainable urban drainage systems [16], the design and implementation of nature-based solutions [17], and the municipal planning for climate resilience in the built environment [18].

Energy: «vannkraft», «strømpris» and «elbil»

Vannkraft: Norway is one of the world's largest producers of hydroelectric power (*vannkraft*), which accounts for nearly all the country's electricity generation [19]. This renewable energy source is not only a cornerstone of the national energy supply but also a key element in reducing carbon emissions and supporting a sustainable energy infrastructure.

Strømpris: Electricity prices (*strømpris*) in Norway are influenced by market fluctuations, energy exports, and seasonal factors like water levels in hydropower reservoirs. While generally lower than in many European countries [19], variations in electricity costs can have significant impacts on household energy consumption.

Elbil: Norway leads the world in the adoption of electric vehicles (*elbil*), driven by government incentives, subsidies, and a comprehensive charging infrastructure. Electric cars are now a common sight in Norwegian cities, contributing to the country's ambitious climate goals and reducing urban pollution.

Impact on Urban Development: The integration of *vannkraft*, fluctuations in *strømpris*, and the adoption of *elbil* have collectively transformed urban energy systems and infrastructure in Norwegian cities. The reliance on hydropower (*vannkraft*) ensures that cities have access to clean, renewable electricity, which has been pivotal in designing energy-efficient urban infrastructures aimed at minimizing carbon footprints. The abundance of hydropower facilitates the electrification of city services, from public transportation to heating systems, thereby promoting greener urban living. Urban districts are increasingly planned with smart grids and energy-efficient buildings that optimize the use of this renewable resource, supporting cities in their transition toward carbon-neutral goals and sustainable growth.

However, the variability in *strømpris* influences how energy is consumed within urban environments. City planners respond by implementing strategies that promote energy efficiency and reduce costs for residents. Smart energy systems are integrated into buildings to monitor and decrease electricity usage, particularly during peak pricing periods. This responsiveness has spurred investments in energy-efficient technologies and green building standards, such as passive house designs, ensuring cities remain resilient to fluctuations in energy prices. Additionally, urban areas are increasingly designed to incorporate decentralized energy systems like solar panels and district heating, which further mitigate dependence on the grid and alleviate pressure from high energy costs.

The widespread adoption of electric vehicles (*elbil*) has also significantly impacted urban infrastructure. Cities are focusing on enhancing support for electric mobility, with charging stations becoming common in public spaces, parking lots, and residential areas. City planners ensure that new developments are equipped with the necessary EV infrastructure, while public transportation systems are being electrified, featuring more electric buses and trams. This transition helps reduce urban air pollution and noise, enhancing livability. Moreover, the shift toward electric mobility influences urban road planning, prioritizing EV-friendly lanes and creating infrastructure for shared mobility options, such as electric scooters and bikes.

Selected examples: In Norway, several studies have been exploring the potential of diverse control strategies to enhance building energy flexibility [20], many of them within the context of the Research Centre on Zero Emission Neighbourhoods (ZEN), which operated from 2017 to 2024. It encompassed nine pilot projects across Norway focused on achieving zero greenhouse gas emissions throughout their life cycle. These projects served as innovation hubs for testing new solutions in zero-emission neighbourhoods and involved collaboration among building professionals, public authorities, and energy companies. Covering over one million square meters and impacting more than 30,000 residents, these initiatives included both new developments and upgrades of established areas. For example, one of the pilots: Campus Evenstad, a Norwegian university campus, took energy actions that contributed to the clean energy transition campus, developed over several years, and demonstrated a number of innovative and sustainable technologies and energy solutions.

Such solutions include vehicle-to-grid (V2G) [21], solar energy [22], energy storage [23], energy efficiency measures [24], and a zero-emission building [25].

2.5 Sustainability: «bærekraft» and «olje»

Bærekraft: *Bærekraft* (sustainability) is a guiding principle in Norwegian policy. The term gained prominence when it was first introduced by former Norwegian Prime Minister Gro Harlem Brundtland in 1987, through the Brundtland Commission's report, *Our Common Future* [26]. This report defined sustainable development as 'meeting the needs of the present without compromising the ability of future generations to meet their own needs,' which has since shaped global and national sustainability efforts.

Olje: Despite Norway's global leadership in sustainability, the country's economy has long relied on oil and gas (*olje*) production. While the oil industry has generated substantial wealth, it presents a tension with national and global sustainability goals, as fossil fuel extraction and export contribute to greenhouse gas emissions.

Impact on Urban Development: The emphasis on *bærekraft* and the wealth generated from *olje* have fundamentally shaped urban development in Norwegian cities, driving them toward sustainable practices while navigating the complexities of transitioning away from fossil fuels. The focus on *bærekraft* propels cities to adopt comprehensive sustainable urban development strategies. Urban planners are designing energy-efficient buildings, creating extensive green spaces, and implementing sustainable transportation options. They prioritize reducing the environmental footprint of cities through renewable energy systems, smart waste management practices, and circular economy initiatives. The overarching goal is to build resilient urban environments that can adapt to future challenges, such as climate change and population growth. Additionally, *bærekraft* influences social policies, promoting inclusivity, affordable housing, and equitable access to essential services for all residents. This commitment ensures that Norwegian cities strive to balance economic development with environmental preservation, securing a sustainable future for generations to come.

On the other hand, the wealth generated from the *olje* sector has provided Norwegian cities with the resources needed to invest in high-quality infrastructure, public services, and social programs. However, recognizing the necessity to reduce dependence on fossil fuels, urban planners are steering cities toward carbon-neutral development. This includes a concerted focus on renewable energy, adherence to green building standards, and the promotion of sustainable transportation. Furthermore, investments from the Government Pension Fund Global (often referred to as the oil fund) are increasingly being channeled into green technologies, further accelerating the push for urban sustainability projects. As urban planners navigate the legacy of the oil industry, they are tasked with aligning cities with long-term sustainability goals, including carbon neutrality and reduced environmental impact.

3 Navigating the AI landscape: challenges and opportunities in urban development

The rapid advancements in artificial intelligence (AI) present significant challenges and opportunities across various sectors, including urban development. The value of AI extends beyond mere data collection; it lies in how data is structured, analyzed, and applied to create meaningful services. This section examines the foundational role of data, the creation of

value through digital services, and the critical importance of maintaining human involvement in the digital transformation process.

3.1 Data as a foundation

Data Collection: Costs and Quality The costs associated with data collection have decreased due to advancements in sensor technology, IoT devices, and data processing capabilities. However, the quality of this data remains a pivotal concern. High-quality data is essential for accurate analysis and reliable AI applications. For instance, various projects across Norway, including Smart Molde [27], collect extensive environmental data using IoT sensors. The reliability of these initiatives depends on the accuracy and precision of the collected information.

Data Structuring: Essential for Value Creation Structuring data is indispensable for generating value. Unstructured data lacks the organization needed for efficient analysis and application. Recent developments in AI, particularly large language models (LLMs) and knowledge graph theory, provide promising solutions for automatic data structuring. Knowledge graphs enable the linking of data across diverse domains, enhancing contextual understanding. Research efforts in Norway illustrate how AI-driven data structuring facilitates better decision-making processes in urban planning by integrating various data sources, e.g. noise, into coherent frameworks [28].

Data Availability: Storage and Infrastructure The storage and availability of data present significant challenges. Efficient storage solutions must balance capacity, accessibility, and sustainability. The open data concept, highlighted in the recent Norway's digitalization strategy [29], promotes transparency and innovation by making data publicly accessible, as seen in the Geonorge map catalogue[30], which provides comprehensive geospatial data for urban development projects. Moreover, the energy consumption of data centers is a growing concern, prompting innovative approaches to mitigate environmental impacts, such as utilizing excess heat for district heating [31].

3.2 Creating value

Creating value from data necessitates the development of effective urban digital services. Successful examples, such as the "Oslo Smart City" initiative, leverage data to enhance urban mobility, reduce emissions, and improve public services. As a consequence, Oslo ranked second in the IMD Smart City Index 2024 [32]. Conversely, unsuccessful projects often suffer from poor data quality, lack of user engagement, or insufficient integration with existing systems.

The concept of a "digital twin" is central to value creation. Digital twins are virtual representations of physical entities that enable real-time monitoring and simulation. Pilot cities in Norway, including Oslo [33] and Trondheim [34], are pioneering the use of digital twins to acquire environmental knowledge, which can increase public awareness and contribute to advancing sustainability efforts by informing decision-making processes and government initiatives. Furthermore, the Norwegian World of Wild Waters project demonstrated that the integration of extended reality (XR) technologies with gamification of natural hazards can be used as a future tool for analysing and communicating cause and effect of potential natural hazards as floods and landslides [35]. Other examples include the

Vesterålen region, contributing to the RESIST project, using digital twin technology to demonstrate the effects of climate change, with focus on rising sea levels [36].

Linking digital services to the circular economy offers another avenue for value creation. Digital platforms facilitating the reuse and recycling of construction materials align with sustainable urban development goals. Among other initiatives, Trøndelag County's material reuse initiative emphasizes the use of digital marketplaces and smart sorting systems to efficiently recycle building materials [37]. These technologies streamline the process of reusing materials from deconstructed buildings, reducing waste and supporting a circular economy.

3.3 Integrating human perspectives

Maintaining human involvement is crucial for the successful digital transformation of cities. The concept of "citizen engagement" is particularly important, emphasizing community participation in planning and implementing digital services. Trondheim municipality was for example enabling citizen participation and co-creation in the transition to a positive energy city within the European Horizon2020 smart city project, +CityxChange [38]. Another Norwegian city: Stavanger, adopted a smart city policy after becoming an EU Lighthouse Smart City in 2015. Initially focused on testing technologies, the approach later expanded to include co-creation and broader stakeholder involvement, e.g. involving children, highlighting democratic participation and environmental responsibility in urban planning [39]. Designing AI and data-driven services with a human-centered approach is essential.

4 AI and data integration for sustainable urban development: a (Nordic) requirement framework

The integration of Artificial Intelligence (AI) and data technologies plays a pivotal role in enhancing urban sustainability, optimizing resources, improving public services, and fostering resilient infrastructures. Some methods for identifying key indicators to assess urban environmental sustainability exist [40], however, the effective integration of AI and data technologies into urban development necessitates a comprehensive framework. Below is a selection of suggested key requirements for an AI-driven sustainable urban development system, aligned with core Norwegian values and concepts.

Transparent

Why: Transparency builds trust between citizens and authorities, ensuring that residents understand how their data is used in AI applications, which reflects the Norwegian value of *tillit* (trust).

Definition: Establish clear guidelines on data collection, processing, and sharing, ensuring that citizens are informed about how their data contributes to urban development and decision-making processes.

Community-driven

Why: Active citizen participation fosters a sense of ownership and responsibility, which is vital for successful urban initiatives. This reflects the *dugnad* spirit of collective effort.

Definition: Implement platforms and initiatives that allow for ongoing community input and collaboration in the development and deployment of AI-driven services, ensuring that solutions are tailored to the community's needs.

Efficient

Why: Reducing energy consumption and shifting demand to off-peak hours (thus taking into account the *strømpris*) is crucial for sustainable urban development, especially in cold climates like Norway. Integrating resource-efficient practices ensures that cities minimize their environmental impact while meeting energy needs efficiently, while at the same time ensuring that AI-driven energy savings outweigh the energy costs of running the AI systems. This also aligns with the overarching goal of *bærekraft* (sustainability).

Definition: Promote energy flexibility in urban infrastructure by using smart controls, renewable energy sources, and demand-response technologies. Establish guidelines to evaluate the energy use of AI technologies in urban systems, prioritizing solutions that deliver substantial energy savings, e.g. reducing carbon footprints, enhancing resource efficiency, and supporting the circular economy, while minimizing their own operational energy consumption.

Integrated and (open-)shared

Why: Seamless data integration enables comprehensive analysis and helps manage land use pressures (“*areal under press*”) while preserving cultural values like *marka* and *friluftsliv*. It also enables better decision-making for urban planning and promotes knowledge sharing to foster collaboration and collective learning.

Definition: Develop systems that integrate data from various sources and make it accessible to all relevant stakeholders. This ensures a holistic approach to urban development, supporting more informed and sustainable decisions. Encourage collaboration between public and private sectors, academic institutions, and communities to share insights and best practices for utilizing AI and data technologies in urban contexts.

Adaptable and Resilient

Why: Urban areas must adapt to changing climate conditions and societal needs. This aligns with the concept of *allvær* (all-weather) and the need for climate-robust infrastructure (“*klimatilpasning*”).

Definition: Design AI systems to be flexible and resilient, capable of adjusting to future climate scenarios and evolving urban challenges, ensuring a future-proof urban infrastructure.

Equitable and Ethical

Why: Ensuring both equitable access and ethical practices in AI technologies is vital for promoting inclusivity and fairness in urban development, aligning with Norwegian values of equality, social justice, and trust.

Definition: Develop policies that guarantee universal access to AI, enabling all community members to benefit regardless of socioeconomic status. Simultaneously, enforce ethical guidelines that address data privacy, bias mitigation, and accountability, ensuring transparent and fair AI applications in urban planning and governance.

5 Conclusion

The integration of AI and data technologies into urban development presents transformative opportunities for enhancing sustainability, optimizing resources, and improving public services. This paper has proposed a Nordic requirement framework that emphasizes key principles such as transparency, community engagement, sustainability, and ethical practices. These principles are essential for ensuring that technological advancements align with the core societal values inherent in Norwegian concepts.

As cities evolve in response to climate change and urbanization, the ongoing validation and adaptation of these requirements will be crucial. Continuous evaluation will help ensure that they remain relevant and effective in addressing emerging challenges and leveraging new technologies. Additionally, comparing Nordic approaches with broader European practices may yield valuable insights into successful strategies and highlight potential areas for collaboration. Such comparisons can inform collective efforts toward creating data-driven sustainable urban environments.

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