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Urban Monitoring of Innovation Districts—A Qualitative Urban Sustainability Indicator Identification Methodology for the Case of Oslo

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Abstract

Innovation districts have emerged as a prominent urban strategy to catalyse knowledge-based development and economic growth. Yet their contribution to sustainability and an understanding of what they entail beyond economic growth remains underexplored. This paper proposes a conceptual framework rooted in urban monitoring to identify and synthesise the contributions of innovation districts (or similar development strategies) into the city's sustainable development. Specifically, it targets the initial processes of intention and objective setting, where different and conflicting policies overlap to define definite city-level objectives. Using Oslo as a single embedded case study, the paper further proposes a methodology for identifying and localising urban sustainability indicators (USIs) based on the city's three innovation districts: Oslo Science City, Hovinbyen Circular Oslo, and Punkt Oslo. This methodology integrates global frameworks, such as the UN Sustainable Development Goals and the Global Urban Monitoring Framework, with local priorities and stakeholder perspectives through a combined top-down and bottom-up approach. The process resulted in a set of 40 indicators across five sustainability domains—social, environmental, economic, cultural, and governance—revealing governance as a critical enabler for sustainable implementation. While most indicators stem from theoretical conceptions of innovation districts, governance indicators rather reflect local experiences and institutional dynamics.

Keywords: innovation district; sustainability indicators; sustainable development; urban monitoring; urban development; innovation ecosystems; urban innovation



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1. Introduction

The use of knowledge work to catalyse the transformation of urban spaces via “knowledge-based urban development” (KBUD) [1,2] has resulted in spatial manifestations in urban areas, such as “innovation districts”. Innovation districts are defined as physically dense mixed-use urban regions, where anchor knowledge institutions are located alongside start-ups, businesses, incubators, and other private actors, to enable easier creation and transfer of knowledge, thus enabling the reshaping of the economy through place-making, networking, and directionality that enables innovation [3–5]. While these districts are primarily introduced into the urban fabric to improve cities’ economic competence on a global scale [6], the priority and characteristics of these sites are highly contextual and are rooted in local priorities, with many also striving to contribute to an overall sustainable development of the region and its associated communities.

Inspired by the establishment of innovation districts in European capitals, Oslo endorsed its ambition to transform the city's existing business landscape into a "knowledge capital" that attracts international and local businesses by proposing the establishment of three innovation districts: Oslo Science City (OSC), Punkt Oslo (or Innovation District Centre), and Hovinbyen Circular Oslo (HSO) [7]. The three innovation districts, while ultimately intending to fulfil a common vision entailing an increase in innovation, value creation and number of jobs in Oslo (ibid), are distinct in their functions and characteristics, and goals rooted in the dominant local industries, businesses or planning objectives of each district. Furthermore, they are established as public-private entities with individual strategies and approaches, while simultaneously being governed by the Municipality of Oslo.

In the case of Norway, local and regional authorities have been entrusted with the responsibility to address local challenges by using the UN SDGs as the foundational component of planning strategies by the national government [8,9]. Bardal et al. [8] further notes that the local authorities in Norway have difficulties relating to the UN SDG tools and its indicators on a local level. While the UN SDGs themselves have actively encouraged the inclusion of sustainability in public policies and development strategies, their success depends on contextualisation to suit local planning frameworks and situations [10]. In the case of Oslo's innovation districts, such contextualisation could entail juxtaposing the theoretical conception of "innovation districts" [4], the UN SDGs, and developmental policies and plans, further complemented by individual visions of each district, with inputs rooted in the discourse of ground actors.

Seasons [11] suggests managing such stratified complexity in planning through monitoring processes that continuously evaluate policies, programmes, and strategies to determine if they achieve their desired outcomes. While attempts to develop frameworks for monitoring and evaluating innovation districts exist [12–16], the question of what inherent factors in these districts inform their strive for sustainability is lacking. This also holds for the case of Oslo's innovation district, where it is still unclear how this development can balance innovation and sustainability. While the UN SDGs [17] and their 79 suggested indicators form a pivotal core, and are a largely accepted standard for defining and monitoring sustainability in urban developments, to the best of our knowledge, an attempt to incorporate them is missing, despite UN-Habitat's [17] advice that users localise the suggested indicators before use. This identified gap is also supported by our interviews with practitioners involved in work related to innovation districts in Oslo and beyond.

Research Aim

This research roots itself in the urban monitoring field and proposes a conceptual framework for indicator identification and to synthesise the contributions of Oslo's innovation districts into the city's sustainable development. Specifically, it targets the initial processes of intention and objective setting, where diverse policies collude to define city-level objectives that such innovation districts conform to. The elements related to city-level sustainability of innovation districts are consolidated into an "urban sustainability indicator", created through the triangulation of multiple qualitative data sources, which helps decision-makers conceptualise the different facets of sustainability in these districts, based on ongoing discourses. While the scope of this research is limited to identifying current sustainability priorities of the innovation districts via the proposed frameworks, these indicators may be weighed and fine-tuned to enable their employment in future monitoring work.

This article is based on a master's thesis, "Monitoring Innovation Districts Through The Lens Of Urban Sustainability" [18] and is adapted with an updated structure, addi-

tional analysis, clearer methodology, replicability, and applicability to other contexts. It was conducted in close collaboration with a start-up, Svale AS, that has a niche in strategy development of innovation districts and has worked closely with this planning typology since its very inception. The topic draws inspiration from an existing activity of the organisation to develop a dashboard that aids local authorities in prioritising the key conformance objectives of such developments in Norwegian cities, following the recommendations from The Bass Initiative [19], while also ensuring that they contribute to the fulfilment of the Sustainable Development Goals of the City. This research aims to test a conceptual framework to deduce a consolidated understanding of “sustainability” for the districts, from the scale of improving the urban conditions on a city level.

2. Theoretical and Conceptual Background

2.1. *The Need for Sustainability in Innovation Districts*

The concept of place-based development to boost the economic and technological competency of cities can be traced to the 1980s, when policymakers used science parks as an avenue to uplift regional and national economies [20]. These parks are typically located in car-centric peri-urban areas, providing the physical infrastructure necessary for networking and accelerating entrepreneurialism, thus also supporting the development of surrounding areas [21,22]. Innovation districts are a contemporary rendition of traditional science parks, rooted in the concept of agglomeration [23], but unlike science parks, are located closer to the city centre. They attempt to integrate business-oriented functions with urban planning concepts like mixed-use development and transit-oriented development, well within the urban fabric of the city centre [24]. Such innovation districts were originally conceptualised by Katz & Wagner [4], who define the concept as relatively small multi-functional areas, where business functions such as clusters, start-ups, business incubators, and institutional anchors coexist with residential, commercial, and social infrastructure. In doing so, innovation districts intend to give way to the implementation of related concepts such as walkable neighbourhoods, where housing, jobs and amenities intermix [4].

Innovation districts are now seen as a way to enhance the city centre beyond its economic values, by restructuring the traditional notion of a “Central Business District” to a more favourable “City Lifestyle District” [25,26], by aligning this restructuring with contemporary urban discourses where urban density, inclusive public spaces, employment opportunities, multi-functionality of space, and climate adaptation [27] inform the way cities are planned. The concept is based on a multi-actor partnership model that brings together government, industry, and academia, widely theorised through innovation ecosystem frameworks such as Sabato’s knowledge triangle and the triple helix model [28]. More recent extensions of this model show the increasingly holistic lenses for understanding innovation ecosystems, such as the quadruple helix [29], which incorporates civil society, and the quintuple helix [30], which adds the natural environment as a fifth actor.

Some innovation districts claim to offer an alternative to neoliberal urbanism by using it as a socio-economic regeneration tool focused on inclusivity [4,31]. Yet, they still rely on large-scale urban interventions that aim to attract global capital, enhance competitiveness and stimulate economic growth through, for example, public–private partnerships and in some cases market deregulation [32]. It should be noted that innovation does not inherently require deregulation. Initiatives such as EU-Inc., by contrast, aim to reduce structural complexity by allowing firms to operate under a single, harmonised legal framework, thereby reducing incentives for startups to relocate outside the European Union [33].

The claim that embedding ‘innovation’ within urban development frameworks results in sustainable, inclusive and resilient cities [34] is contested on the pretext that the responsibility of urban development should not be on the shoulders of entrepreneurs, like

in the case of innovation districts [35]. Thus, Chayka [36] critiques “innovation districts” as self-perpetuating buzz-words, that benefit “corporates in-training” who already have the means to innovation capital—education, real estate and connections. This causes privatisation and gentrification [35] of urban land, ultimately resulting in the widening of socio-economic gaps between knowledge “haves” and “have-nots” [37]. Furthermore, the deregulated, independent nature of such developments and their impacts on a regional scale make coordinating policy across multiple levels of governance and physical scales an added challenge [38].

To truly be the engine of growth, innovation district actors must actively work towards the benefit of all socio-economic groups as described by Katz & Wagner [4]. A further reduction in the development’s negative externalities can result from action-based policies that ensure that the benefits of innovation districts are distributed more widely in order to limit displacement and socio-economic polarisation [39]. Lastly, collaborative efforts that enhance co-learning between scientists and stakeholders, such as local communities, cities, and businesses, must be put in place to tailor the innovation districts to the unique conditions of their context [40]. In doing so, these districts go beyond treating cities as growth-centric economic engines and extrapolate themselves into other urban sectors, thus contributing to sustainability.

2.2. Urban Monitoring as a Procedural Lens to Define Sustainability in Innovation Districts

Although innovation districts are primarily implemented to enhance the economic capabilities of cities, they are increasingly being framed as instruments to make cities more sustainable. Yet, in this context, “sustainability” is often invoked as a broad and flexible notion, with an emphasis on innovation-led competitiveness and socio-economic transformation, while environmental and distributive dimensions are only selectively addressed [41,42]. Corporate sustainability discourses have similarly grappled with these tensions through frameworks such as the triple bottom line [43] and environmental, social and governance (ESG) criteria [44]. While these frameworks share the ambition of integrating economic, social and environmental performance, they are primarily designed for organisational-level reporting rather than spatial urban planning contexts.

In spatial planning contexts, the concept of “urban monitoring” [11] takes centre stage. The idea of urban monitoring was originally articulated at the Earth Summit of 1992 to promote the role of cities in steering development towards sustainability. It builds on urban sustainability indicators (USIs) understood here as the specific sustainability dimensions that require systematic measurement or investigation in a given project [45–47]. As a process of regularly tracking ongoing development against agreed sustainability objectives, Urban Sustainability Monitoring aims to inform decision-making and policy, and to provide managers and key stakeholders with timely insights into the degree of progress and goal achievement. In doing so, it supports stakeholders in pursuing sustainable development not only in environmental, economic and social domains, but also in cultural and value-based dimensions [48–50].

Identifying indicators to inform future monitoring could be one way of defining the sustainability of innovation districts. In this vein, Trillo [51] suggests that the UN Sustainable Development Goals (SDGs) can serve as a cornerstone for structuring and nudging sustainable strategies, particularly by embedding innovation-driven economic activities within Goal 11 on Sustainable Cities and Communities, so that “innovation” is situated in a broader sustainability frame rather than reduced to economic performance alone. However, experience with applying SDGs in urban planning shows that their usefulness depends on how far global targets and indicators are made relevant, practical and adaptable to local development agendas. Contextualising SDGs and indicators at

the project and neighbourhood scale is thus a critical step for defining directionality, for standardising and reporting progress and for firmly embedding sustainability within planning and monitoring processes [10,52,53]. In innovation districts, this localisation can be operationalised through an urban monitoring framework that translates global sustainability ambitions into concrete, measurable and context-sensitive indicators from the outset of planning.

2.3. Indicator Identification to Conceptualise Sustainability Goals

Indicators are the foundation for monitoring the progress of a strategy and ensuring its alignment with predefined objectives [11]. The exact definition of indicators is ambiguous and can include a wide range of components such as ideas, variables, objects, variable values, etc. [54]. In the context of this research, indicators are defined as qualitative or quantitative components which describe complex system characteristics and facilitate learning and judgement about the situation of a system [54,55] as an impact assessment. They bridge the gap between theoretical concepts and decision-making, and should be based on a conceptual framework with available, reliable data [49,55].

One way to determine indicators for a certain context is by collating indicator sets developed by different indicator developers, to first form a heterogeneous set of suggestions with potential indicators [54]. Then, these sets can be contextualised via structured discussions, which probe what indicators should be monitored and why [11,48,56]. Furthermore, the contextualised indicators that arise from such an investigation should be able to identify trends, patterns and positions within the case [48,49]. Kaur & Garg [57] identify five urban sustainability domains that are recognisable across several global indicator sets. These domains are:

1. The social dimension, which includes indicators associated with social and health wellbeing, urban layout/pattern and design, transportation and connectivity, amenity, safety/security, comfort in outdoor areas, innovation, and governance.
2. The environmental dimension, which includes indicators related to atmosphere/climate, environmental and ecology, land use and green infrastructure, resources and energy, water, natural hazards, waste management, buildings and resources, and material management.
3. The economic dimension, with indicators of financial concepts, economic impact and economic structure.
4. The cultural dimension, with indicators of local community, cultural and heritage, and visual aesthetics.
5. The institutional dimension, with indicators related to the institutional framework and institutional capacity.

Indicators can also vary based on the nature of the information, be it quantitative or qualitative. Quantitative indicators can be measured or counted, and qualitative indicators are more descriptive in nature [58]. Quantitative indicators allow easier comparisons between different entities, while qualitative indicators can be subjective or less precise [59] but capture a broader range and may capture reasoning or process. To allow measurement and comparison, urban monitoring tools used in planning have traditionally been mainly quantitative [11]. As a result, qualitative particularities that incorporate human relationships for wellbeing, inclusion and cohesion have often been downplayed. Components that describe the perceptions, feelings, and values of planning goals, policies, and projects have also seen less uptake [11,60]. Therefore, Seasons [11] recommends the use of indicator sets where quantitative and qualitative information complement each other.

A categorisation of indicators based on source of origin has been made by Asare-Kyei et al. [56]. In the process of localising indicators for urban monitoring, indicators

are extracted, either through a pre-existing super-set of indicators, or through fieldwork involving experts, locals and decision makers. Asare-Kyei et al. [56] refers to the former as “reference sheet indicators”, and the latter as “elicited indicators”. A combination of both is recommended for selecting urban sustainability indicators, which this work follows.

3. Context of Study: Oslo’s Innovation Districts

In 2018, the Department of Industry and Ownership, City of Oslo, formally proposed a place-based development strategy to accelerate knowledge growth and innovation in three business centres within Oslo city. It was inspired by other Scandinavian cities, such as Copenhagen and Stockholm, that have employed urban planning as an avenue to revitalise and strengthen economic offerings within the city centre. “Innovation districts” were introduced in the urban fabric of Oslo to develop place-based infrastructure to accelerate knowledge-based growth through a document titled “Campus Oslo—Strategy for the development of the capital of knowledge” [7]. This planning strategy proposed three innovation districts as a result of a series of workshops and participatory collaborative activities conducted with actors from the public sector, private sector, and academia (ibid). The three districts are: Oslo Science City, Punkt Oslo (originally called Innovasjonsdistrikt sentrum), and Hovinbyen Circular Oslo (HSO), as shown in Figure 1, each with distinct objectives and agendas [61]. The differences between the three districts are briefly explained in Section 5, USI Set for Innovation Districts in Oslo.

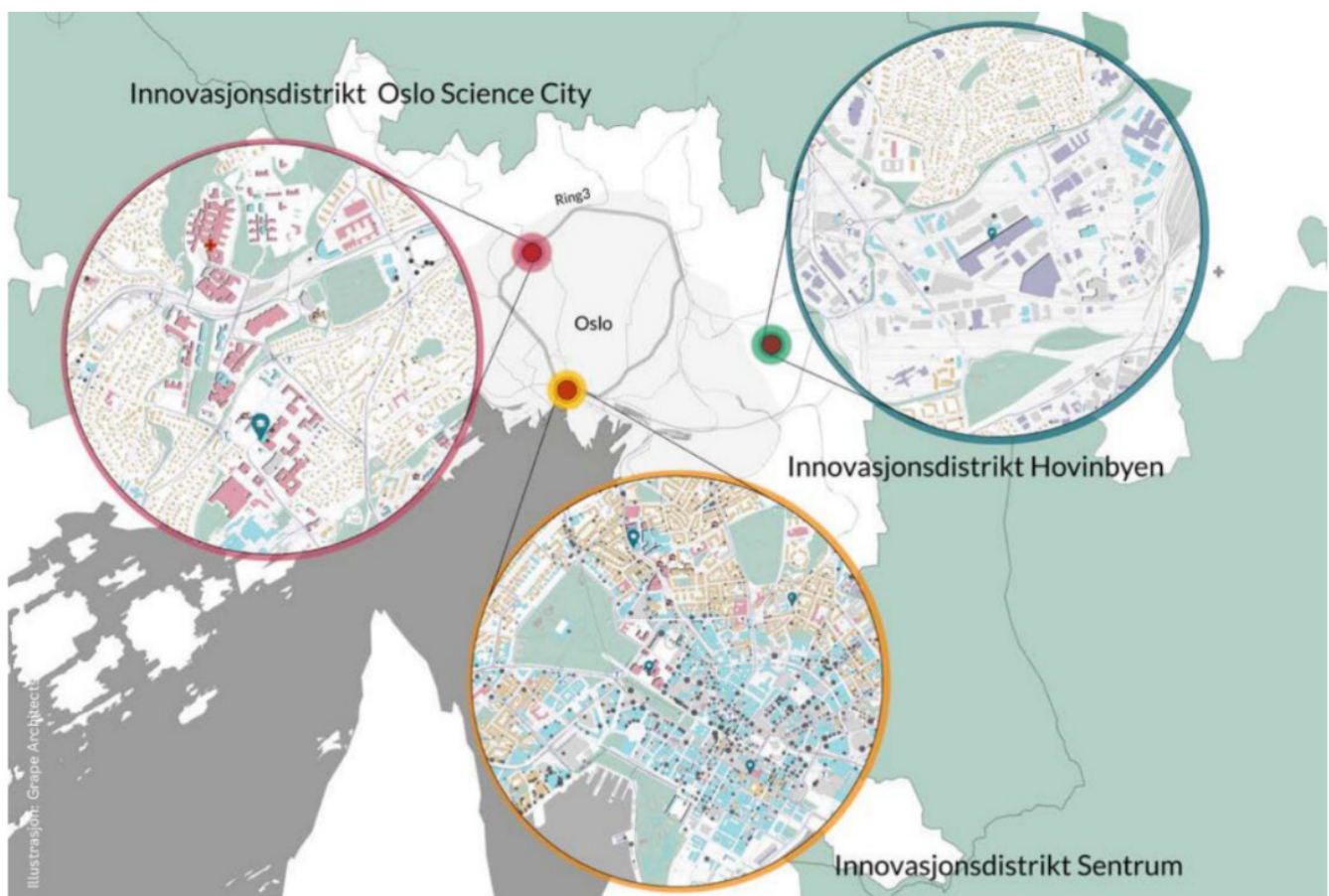


Figure 1. Spatial demarcation of Oslo’s three innovation districts (Source: [7]).

In the Norwegian Planning context, the local municipalities have the primary authority for decision-making related to land use. However, this can be influenced by regional and local governments, where the regional level coordinates plans across the local bodies in

the county [8]. In the context of the three innovation districts, they are headed by their respective organisations, which are responsible for strategy development at the district level. Oslo Municipality coordinates developmental activities both locally and on a regional level (throughout Oslo). It was Oslo Municipality (“Oslo Kommune” in Norwegian) who oversaw the Campus Oslo Strategy [7].

The decisions on the district and regional scale are, in turn, influenced by national priorities and agendas. On a national level, the document “National Expectations for Regional and Municipal Planning 2019–2023” by the Ministry of Local Government and Modernisation prescribes that the SDGs will provide direction to Norway’s development policies and must therefore be the foundation for social and land-use planning strategies [9]. The Campus Oslo Strategy also recommends that the follow-up of innovation districts be carried out based on the SDGs. The purpose of innovation districts in the Campus Oslo Strategy is also strongly aligned with the functions and definitions of innovation districts by Katz & Wagner [4].

Three distinct levels of governance thereby influence Oslo’s innovation districts, and their influence on the city’s sustainability:

1. The neighbourhood/district level, which includes the three innovation districts as organisations enforcing developmental trends within their respective spatial extents and users.
2. The regional level, which comprises the Oslo municipality and coordinates the activities of the innovation districts and other business-related activities in Oslo.
3. The national level, whose agendas are influenced by supranational strategies, including the SDGs.

The national/supranational levels define the overarching themes of this paper: innovation districts and sustainable development through its strategies and policies. The regional level represents the case used in this research—Oslo’s three innovation districts as combined components of the city, while the district level denotes the innovation districts as embedded independent entities. This paper incorporates perspectives from each of these levels to give a holistic understanding of indicators necessary to steer sustainable development in Oslo’s innovation districts.

4. Urban Sustainability Indicator Identification Methodology

The urban sustainability indicator methodology is rooted in “the single embedded case study method” [62] to embody different layers and systems for introspection as interlinked elements feeding into a single urban sustainability indicator set. It is also analogous to a city system, which comprises multiple integrated elements that exist as individual entities, as well as interlinked processes. The research methodology was formulated on the basis that the three innovation districts in Oslo function as isolated organisations, while they intend to collectively contribute to Oslo’s economic development on a regional scale.

The process of indicator identification employs a primarily qualitative, narrative analysis approach to collect data required for identifying indicators. It was informed by literature studies [11,63–65] and fine-tuned for applicability via interviews with experts in the field of monitoring and policy, both locally and internationally. This helped achieve the initial goal of determining an integrated methodology that combines complementary and conflicting priorities which influence the single planning strategy. The research design was iterative and implemented in close collaboration with an Oslo-based start-up, Svale AS, that had extensively worked with conceptualising innovation districts like Punkt Oslo and Hovinbyen Circular Oslo. The methodology underwent multiple revisions during the research, informed by new understanding of concepts obtained during data collection. Svale AS’s extensive collection of internal project documents further supported

comprehension of Oslo's innovation district context. The process, data and results were extensively discussed with organisational stakeholders on multiple occasions, and the resulting feedback was incorporated.

A merged top-down and bottom-up method was employed for data collection. The samples were collected based on the three levels of governance previously identified: national level (as informed by the supranational level), regional level, and the innovation district level. Interviewees at the regional and innovation district levels were selected based on their involvement and knowledge in the context and were approached through Svale AS's existing networks. Field experts involved in monitoring works and concepts analogous to innovation districts were contacted for supranational and national-level data. To avoid skewing data towards bureaucratic "experts", users based in the innovation district, identified via snowballing, were also interviewed. Interviewees were granted anonymity and are identified only by professional role and affiliation. This formed the basis of deliberative indicator identification [66]. The spatial comprehension of the study context was achieved through on-site observation [67]. Secondary data, such as strategy documents, existing best practices, internal project reports from Svale AS, and best practice monitoring frameworks, formed the basis of prescriptive indicator identification [68].

Sources from different levels of relevance to the context of Oslo, and aligned with the broader global agendas, were included. The documents were then separated into reference sheet indicators or RSIs (from the literature) and elicited indicators or EIs (from fieldwork) [56] based on the source and type of information. The overview of sources is tabulated in Table 1. The result of the process is the identification of an "urban sustainability indicator" set. The workflow employed is shown in Figure 2.

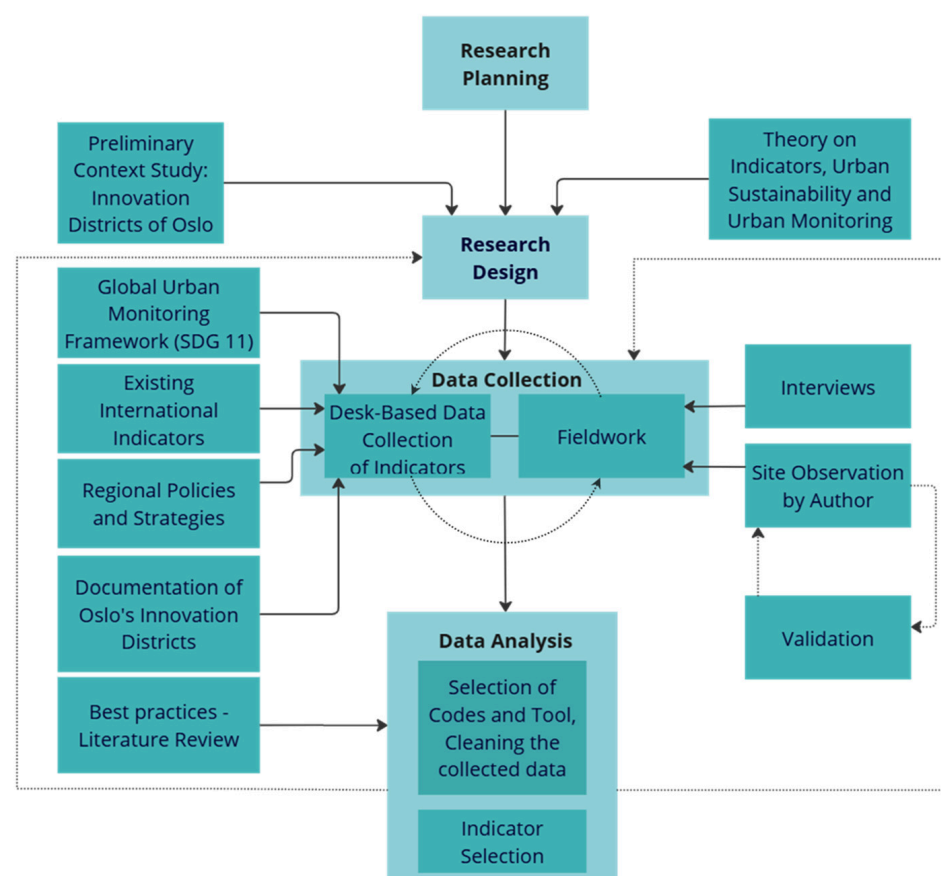


Figure 2. Workflow for indicator identification for the innovation districts of Oslo, adapted from the methodological flow suggested in [62].

Table 1. Indicator collection source and the type of indicator set it contributes to in the urban sustainability indicator identification process.

Sl. No	Indicator Collection Source and Method	Input into Indicator Set Type
Supranational And National Level		
1	Global Urban Monitoring Framework [17]	RSI
2	Assessing Your Innovation District: a How-To Guide [19]	RSI
3	Interview of International Field Expert from the UN—SDG 11 and UMF [69]	EI
4	Interview of International Field Expert from the UN—Innovation-Based Urban Development [70]	EI
Regional Level		
5	Oslo Business Region: Oslo State of The City 2022 [71]	RSI
6	Interview for Political Perspective of Oslo’s Innovation Districts [72]	EI
7	Campus Oslo Strategy [7]	EI
8	Planning Strategy for Oslo 2020–2023 [73]	EI
9	Interview for Municipality’s Perspective of Oslo’s Innovation District (Department of Industry Ownership) [74]	EI
10	Interview for Innovation District Policy and Strategy Perspective [75]	EI
District Level		
Hovinbyen Sirkulaere Oslo		
11	Program for Feasibility Study [76]	EI
12	Stakeholder Interview for Hovinbyen Sirkulaere Oslo [77]	EI
13	Site Observations—Hovinbyen Sirkulaere Oslo	EI
14	Feasibility Study [61]	EI
15	Stakeholder Interview for Oslo Science City [78]	EI
16	Stakeholder Interview for Oslo Science City [79]	EI
17	Site Observations—Oslo Science City	EI
18	Needs Study Innovation District Centre [80]	EI
19	Informant—Punkt Oslo [81]	EI
20	Site Observations—Punkt Oslo	EI
User Perspective (District and Regional Levels)		
21	Interview of Resident [82]	EI
22	Interview of Employee and Planner [83]	EI
23	Interview of Private Member in Hovinbyen Sirkulaere Oslo [84]	EI

4.1. Process for Indicator Identification

After categorisation into material for elicitation and reference sheet indicator set creation, the data were analysed and triangulated. Overall, this process was conducted in four steps:

4.1.1. Step 1: Adapting Existing Frameworks as a Foundation for Indicator Identification

The objective of this research is to identify what urban-level sustainability priorities innovation districts cater to. Thus, based on information gathered via interviews and focus group discussions at Svale AS, the ‘Global Urban Monitoring Framework’ (UMF), an assessment tool rooted in Sustainable Development Goal 11—Sustainable Cities and Communities, was chosen to inform indicators related to urban sustainability. The UMF lists 75 indicators to monitor urban contexts, encompassing five sustainability domains: society, economy, environment, culture and governance. Similarly, the document suggests four city objectives: Safe & Peaceful, Inclusive, Resilient and Sustainable, but simultaneously encourages cities to explore topics of their own interests. To incorporate the perspective of innovation districts in the USI for the research context, the indicators suggested in

“Assessing your Innovation Districts: A How-To Guide” [19] have been used as a reference. This assessment framework helps policymakers identify and audit the strengths and challenges in the area and to further conceptualise associated innovation districts. It aims to steer resources towards economic development that is both inclusive and innovative, by centring the assessment around five key questions related to critical mass, innovation capacity, diversity and inclusion, quality of place, and leadership. As recommended by UN-Habitat [17], our developed indicator matrix combines the five domains pertinent to SGD 11, derived from the Global Urban Monitoring Framework (UMF)—society, economy, environment, culture and governance—and employs five city objectives important to innovation districts, suggested by The Bass Initiative [19]. The matrix thus created is shown in Table 2.

Table 2. Final indicator set for monitoring the sustainability impact of innovation districts on the city of Oslo.

	Critical Mass	Innovation Capacity	Diversity and Inclusion	Leadership	Quality of Place
Society	Distribution of Employees and Residents	Educational Attainment of Local Residents	Access to Resources for Low-Income Groups	Mediation for Social Cohesion	Equity in Access to Public Transport
			Diversity of Workers and Residents		Neighbourhood Safety
Economy	Employment Opportunity Growth	Digitisation of the Innovation Districts	Unemployment Rate		Affordability of Real Estate
	Distribution of Small and Mid-Size Businesses and Startups in the City	Connections Between Industry and Anchors	Wealth Distribution and Mean Household Income		Innovation District as a Test Arena
	Proportion of Knowledge Intensive Businesses	Research and Development Activities	Suitability for Start-Ups and Small-Scale Businesses		
		Annual Growth Rate of GDP per Capita			
Environmental	Greenhouse Gas Emissions	Research and Innovation that Contribute to the Green Shift	Education for Sustainable Development	Budget for Actions Related to Climate Change Mitigation	Quality of Infrastructure of Sustainable Mobility
	Renewable Energy Share	Waste Reduction, Reuse and Recycling			Efficient and Multi-functional Land-Use Access to Open Public Spaces
Cultural	Retention of Local Values and Culture	Integration of Innovation District Culture	Culture for Social Cohesion		

Table 2. Cont.

	Critical Mass	Innovation Capacity	Diversity and Inclusion	Leadership	Quality of Place
	Contribution and Ownership of Members	Short-Term Wins	Direct Participation Structure of Civil Society and the Public in Planning	Efficiency in Urban Governance	Coordination with Urban Development Strategies
Governance		Flexibility of Policy	Legal Framework for Equality	Clear Goal Setting	
		Utilisation of E-Governance and Digital Governance Tools			

4.1.2. Step 2: Creating Reference Sheet Indicators

The selection of reference sheet indicators from different levels and backgrounds helped ensure that different established perspectives are used for the process. Figure 3 shows the flowchart for decision-making to identify reference sheet indicators and elicited indicators, which further create the urban sustainability indicator set for Oslo's innovation districts, adapted from [56]. The documents that contributed to the reference sheet indicators have been listed in Table 2.

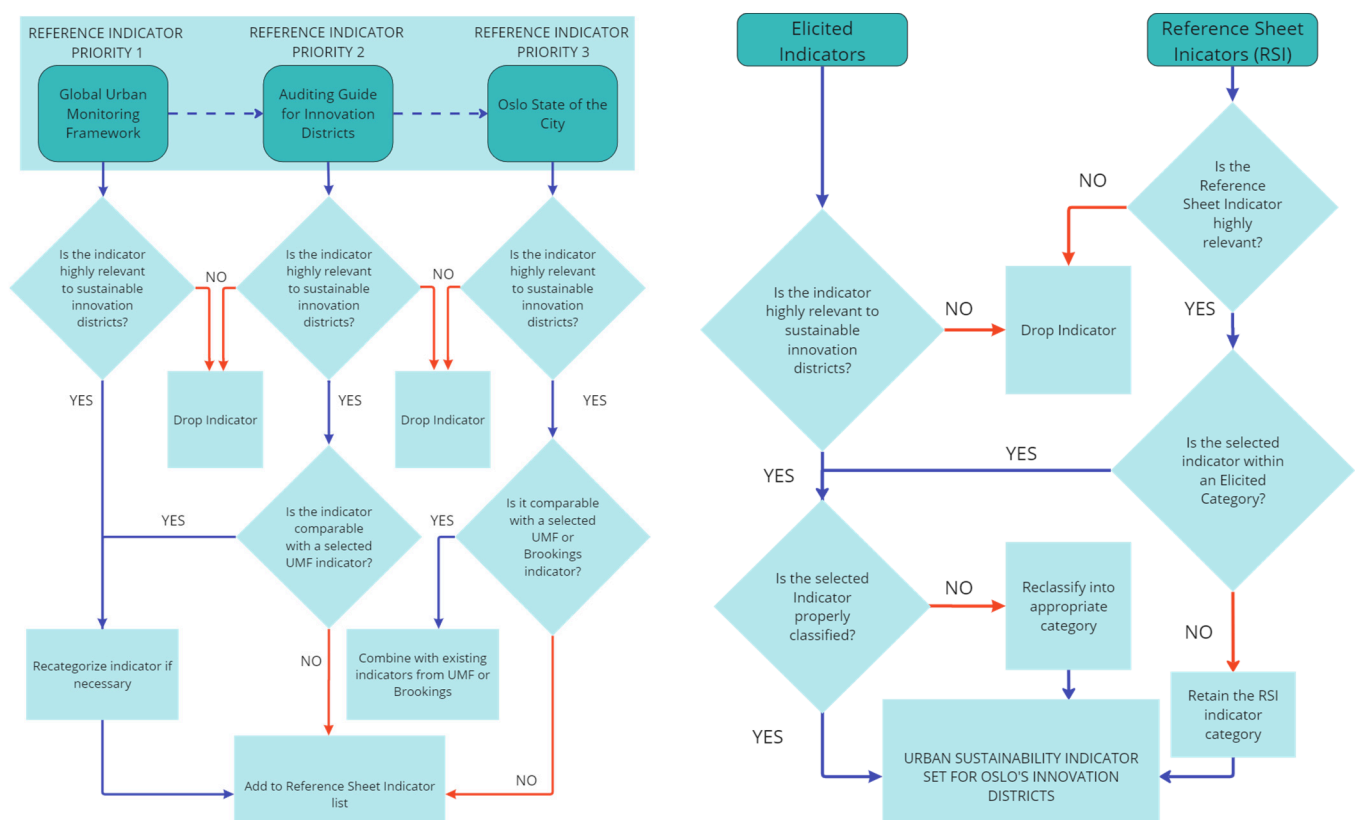


Figure 3. Flowchart for decision-making to identify reference sheet indicators (left) and elicited indicators (right), that further create the urban sustainability indicator set for Oslo's innovation districts, adapted from [56].

The following classification rule was applied when assigning indicators to the matrix: each indicator was placed in a single cell, determined by the primary domain and pillar

which the underlying evidence most consistently pointed to. For indicators drawn directly from the reference indicator documents (for example, the UMF), the document's own domain classification was adopted as the reference (as shown in Figure 3).

4.1.3. Step 3: Creating Elicited Indicators

Interview transcripts, field notes from site observations, and relevant policy documents were coded using NVivo 12 software [85,86] to identify patterns and priorities, which were further translated into indicators. These elicited indicators were analysed against the sustainability pillars as recommended in the UMF [17] and the five innovation district pillars, suggested by The Bass Initiative [19]. If classification under one of the categories is possible, the indicator is deemed to be relevant for sustainable innovation districts and added to the indicator list for aggregation, under their respective sustainability domains. Next, reference sheet indicators are investigated again. If the indicator was already captured in the elicited indicator list, the indicators are aggregated. If they have not been captured yet, they are either added to the indicator list or dropped if they lack relevance to the Oslo Context. This developed process is illustrated in Figure 3 and was adapted from the analytical framework proposed by Asare-Kyei et al. [56].

For elicited indicators, the DPSIR framework [87] guided domain assignment. For instance, passages identified as Pressure or State indicators related to institutional processes were assigned to governance; those related to environmental conditions or transitions were assigned to environment, and so on. The innovation district pillar was then determined by which aspect of the district's functioning the indicator most prominently addressed, based on the cumulative weight of coded evidence across sources.

To illustrate this process concretely, the development of indicator "GO-5: Direct Participation Structure of Civil Society and the Public in Planning" can be traced as follows. During an interview with an informant from Punkt Oslo [81], the respondent noted that citizen engagement in the district is primarily structured around testing innovation outputs, rather than substantive involvement in planning or decision-making. This passage was examined through the DPSIR lens and identified as a Pressure indicator: a direct measure of the gap between stated inclusion objectives and actual participatory structures. It was then assigned to the governance domain, given its institutional nature, and to the diversity and inclusion pillar, reflecting its concern with whose voices are represented in planning processes. This interpretation was corroborated across 10 data sources and 26 coded references, spanning interviews at the district, regional, and user levels. It was further cross-referenced with the corresponding reference indicator from the UMF [17], which defines civil society participation in urban planning as a governance concern. Because both the elicited evidence and the reference indicator described the same phenomenon from different angles, they were aggregated into the single final indicator GO-5. This sequence from raw interview passage to DPSIR classification to domain and pillar assignment to aggregation with reference indicators was applied consistently across all 23 data sources. A more detailed account of all indicator sources and their rationale is available in the underlying master's thesis [18].

4.1.4. Step 4: Aggregation of Indicators to Create Urban Sustainability Indicator Framework for Oslo's Innovation Districts

A long list of indicators can be overwhelming for local authorities to investigate [8]. Furthermore, several indicators can be correlated or measure the same phenomena [65]. Therefore, indicators with high similarities were grouped based on their definitions and the type of information required for assessment. Where an indicator could plausibly span multiple domains, the UMF-derived indicators, reference indicators retaining the UMF's

or their original classification, and elicited indicators followed the most recurrent DPSIR categorisation across sources [87].

To illustrate: “EN-05: Education for Sustainable Development” is placed under the environment domain and the diversity and inclusion pillar. Its environmental classification follows the UMF directly, where it is defined as a measure of how far sustainability is mainstreamed in education policies, curricula, teacher education, and student assessment [17]. Its placement under diversity and inclusion reflects the weight of the supporting evidence, i.e., a local politician [72] and an innovation district expert [75], both of whom framed education for sustainability primarily as a matter of equitable access to the knowledge and skills needed for the green transition, rather than as a social cohesion concern, which distinguished it from society domain indicators and anchored it firmly under environment. Although dual classification is possible here, it was deliberately avoided to preserve the parsimony of the framework and to keep the classifications simple, clear, and practical for further use.

In total, approximately 951 coding references were generated across 23 data sources, using the eclectic coding method [88], resulting in 130 codes, which were progressively consolidated into the 40 final indicators through the described aggregation process.

5. USI Set for Innovation Districts in Oslo

Oslo’s innovation districts are each uniquely defined and have therefore resulted in individual strategies, primarily guided by the local context, the priorities stated by their respective members, and project-level goals. While Oslo Science City focuses on building its existing research and development strengths through colocation and marketing strategies [79], Hovinbyen Circular Oslo aims to be the pioneer for the circular economy [77]. During the period of this research up to 2023, Punkt Oslo was still finding its grounding [74], albeit employing themes such as social innovation and data-driven innovation [80,81] to inform its efforts in contributing to the larger city.

Nevertheless, the nexus of these individual strategies and their underlying goals intend to positively benefit the entirety of Oslo. Despite differences in the goals stemming from organisational differences, several commonalities were identified between them. These commonalities form the “urban sustainability indicator” set. For Oslo’s three innovation districts, it is a collection of quantitative and qualitative system characteristics that facilitate investigating innovation districts from the perspective of urban sustainability, as defined by UN SDG 11 [54,55]. The application of the developed process resulted in 40 indicators, using the matrix in Table 2. A more detailed justification and elaboration of these indicators can be found in [18]. Below, these indicators have been categorised based on the five sustainability domains suggested by the UMF—society, economy, environment, culture and governance, and five innovation district pillars as suggested by The Bass Initiative—critical mass, Innovation and Capacity, diversity and inclusion, leadership, and Quality of Space.

5.1. Sustainability-Based Classifications

5.1.1. Domain 1: Society

Innovation districts worldwide have a certain reputation for propagating neoliberalist values, which may ultimately favour the elite [70]. A local authority representative [74] however argues that this will not be the case in Oslo. The city’s innovation districts have been envisioned as spaces for the “common person” [80] with areas to live, work, and play. The society domain for the innovation district includes indicators that ensure the interests of citizens are upheld by incorporating a diverse range of social phenomena, such as equality, migrant welfare, education, and resource and transport accessibility, across the

city's diverse demographic groups to equitably elucidate the socio-economic conditions of its residents. Eight indicators were identified for this domain as shown in Table 3.

Table 3. USIs to monitor the “society” domain.

Innovation District Pillar	Indicator	Indicator Definition
Critical Mass	SO-01. Distribution of Employees and Residents	The ratio of people employed in the area to people living in the area.
Innovation and Capacity	SO-02. Educational Attainment of Local Residents	The level of education attained by people over the age of 16 years [7,89].
Diversity and Inclusion	SO-03. Access to Resources for Low-Income Groups SO-04. Diversity of Workers and Residents	Qualitative indicator that identifies the accessibility to the benefits of innovations, as perceived by low-income groups. Distribution of economic, ethnic, and gender diversity of workers in the area.
Leadership	SO-05. Mediation for Social Cohesion	Action-based measures that improve the other indicators in the social domain, either directly via the innovation districts or through mediation with civic bodies and member organisations.
Quality of Space	SO-07. Equity in Access to Public Transport	The amount of time taken by groups to reach the innovation districts by public transport as opposed to by car, from different parts of the city, is mapped against the socio-economic condition of the group [90].
	SO-08. Neighbourhood Safety	As defined by the UMF. “Proportion of population that feels safe walking alone around the area they live in after dark” [17].

5.1.2. Domain 2: Economy

The main intent for the proposal of innovation districts in Oslo is to accelerate economic growth by being a bridge that fosters public–private–academic partnerships [7]. Thus, this domain contains the highest number of indicators. The 12 indicators monitor the city's economic resilience because of the innovation districts' success by analysing contributing factors such as human capital, skills, opportunities, support for entrepreneurship, digitalisation, networks and support for residents as shown in Table 4.

Table 4. USIs to monitor the “economy” domain.

Innovation District Pillar	Indicator	Indicator Definition
Critical Mass	EC-01. Employment Opportunity Growth	Increase in the number of jobs per industry in a given period, based on the emphasis of the three innovation districts to attract and retain a higher number of jobs via the strategy [75,77,78,81].
	EC-02. Distribution of Small and Mid-Size Businesses and Startups in the City	Clustering, dispersion, spread and co-location of small and mid-size businesses and startups [19].
	EC-03. Proportion of Knowledge-Intensive Businesses	The percentage of businesses that are knowledge-intensive in nature [19,71,75]. A business is classified as “knowledge-intensive” if at least 33 percent of its workforce holds higher education qualifications [91].

Table 4. Cont.

Innovation District Pillar	Indicator	Indicator Definition
Innovation and Capacity	EC-04 Digitalisation of the Innovation Districts	Incorporating digital technologies and infrastructure into existing and new operations to foster collaboration and improve the overall efficiency of processes [17,69].
	EC-05 Connections between Industry and Anchors	Number and quality of networks and connections created by the innovation district among its industry actors and between industry and knowledge actors.
	EC-06 Research and Development Activities	Reflects efforts and progress in commercialising knowledge assets. Includes the number of research and development activities that have received funding, the number of research publications, and the number of research commercialisations.
	EC-07. Annual Growth Rate of GDP per Capita	Derived from UMF, “the sum of the gross value added, or the total final demand, relative to the city’s total population” [17].
Diversity and Inclusion	EC-08. Unemployment Rate	Percentage of population that is unemployed against demographic categories, such as age, background, education level, etc. [17,19].
	EC-09. Wealth Distribution and Mean Household Income	Maps the income distribution in different parts of the city and compares the mean household income with [62] in the innovation district against the city-level mean.
	EC-10. Suitability for Start-Ups and Small-Scale Businesses	Growth in the number of new businesses, start-ups, scaleups, etc. Can be studied qualitatively by the policies and support available for small-scale businesses to establish their base in the innovation districts [19,70].
Leadership		In the context of Oslo, the research showed that the innovation districts do not intend to lead economic sustainability but rather to be mediators of growth. This has been explained by an innovation district stakeholder [79], who compares innovation districts to a dance floor: “We could construct the dance floor, but people need to dance themselves”. No indicators on the leadership pillar of economic sustainability were identified.
Quality of Space	EC-11. Affordability of Real Estate	Value of real estate within the innovation district against the city median.
	EC-12. Innovation District as a Test Arena	The extent to which the innovation districts have been used as a test arena in the city. May be measured by the number of innovations or ideas that were tested in the districts in each period.

5.1.3. Domain 3: Environment

Creating an economy that propels the city’s transition to a greener way of life is one of the intended objectives [7]. This was asserted by a local politician [72] who believes in the crucial role of this strategy in the city’s efforts to achieve the goals of the Paris Agreement. The three innovation districts have their individual ways of contributing to this green shift: HSO can be attributed as the most aligned with environmental sustainability, with its main vision being to establish a culture of circular economy within the district. OSC, in its feasibility study, lists emission-free transport and environmental research as its proposed contributions to environmental sustainability. Punkt Oslo aims to contribute to the climate goals by acting as a testbed for innovation [81]. Eight urban-environmental indicators have been identified in this domain as shown in Table 5. Many of these indicators have been

adapted or adopted from UMF due to a lack of potential reference indicators pertaining to “environment” in the other sources.

Table 5. USIs to monitor the “environment” domain.

Innovation District Pillar	Indicator	Indicator Definition
Critical Mass	EN-01. Greenhouse gas emissions	The “Total greenhouse gas emissions per year per capita” [17], from the built environment, focuses on zero-emission transportation and, as a result of research and testing, carbon emission innovations through its member institutions [72,78,83].
	EN-02 Renewable Energy Share	Defined by UMF, “Renewable energy share in the total final energy consumption” [17] due to the adoption of new renewable energy technologies.
Innovation and Capacity	EN-03. Research and Innovation that Contribute to the Green Shift	Number of studies conducted, research papers published, patents filed, and innovative products tested each year in the field of environmental sustainability.
	EN-04 Waste Reduction, Reuse and Recycling	Efforts and effectiveness of innovation districts in minimising waste generation, promoting reuse of materials, and increasing recycling rates as part of their sustainability and circular economy goals.
Diversity and Inclusion	EN-05 Education for Sustainable Development	Defined in UMF: “Extent to which education for sustainable development is mainstreamed in (a) education policies; (b) curricula; (c) teacher education; and (d) student assessment” [17].
Leadership	EN-06. Budget for Actions Related to Climate Change Mitigation	Adapted from UMF [17], allocation of budgets specifically for climate change mitigation and adaptation actions within the innovation district (including greenhouse gas emissions reductions).
Quality of Space	EN-07. Quality of Infrastructure of Sustainable Mobility	Provision, adoption, and performance of sustainable mobility infrastructure in innovation districts for better walkability, bicycle connections, and public transport use.
	EN-08. Efficient and Multi-Functional Land Use	Land consumption within innovation districts incorporates several purposes including increasing building and development density, implementing mixed-use development, repurposing underutilised spaces, expanding residential opportunities, ensuring sufficient green areas per capita, enhancing connectivity to neighbouring areas, and considering the aesthetic appeal of the district.
	EN-09. Access to Open Public Spaces	UMF: “Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities” as stated by SDG 11.7.1 [17]. Additionally, it also investigates the porosity of the first floor of building plinths in the district and their adjacent street environment, as increased porous building plinths improve the district’s urban life.

5.1.4. Domain 4: Culture

Culture in Oslo’s innovation districts is approached in terms of identity creation. While HSO, Oslo Science City and Punkt Oslo mention the provision of “cultural offerings” in their respective areas, a local innovation district [75] clarifies that these cultural offerings are more leisure-oriented, such as theatre, music, and concerts. Only three relevant indicators have been identified for the culture domain, as shown in Table 6.

Table 6. USIs to monitor the “culture” domain.

Innovation District Pillar	Indicator	Indicator Definition
Critical Mass	CU-1. Retention of Local Values and Culture	Safeguarding and recognising the importance of the unique characteristics and local identity in and around the innovation districts.
Innovation and Capacity	CU-2. Integration of Innovation District Culture	Effectiveness of innovation districts in being embedded in local identity.
Diversity and Inclusion	CU-3. Culture for Social Cohesion	Adapted from UMF, it aggregates “Intercultural tolerance (Percentage of people who do not object to having a neighbour from another culture); Interpersonal trust (Percentage of people reporting that other people can be trusted).” Additionally, intercultural inclusion is also aggregated into this indicator. The UMF also recommends investigating “the perception of gender equality” [17].
Leadership		Qualitatively analysing marketing and identity creation of innovation districts, which can also be assessed by the indicator “CU-2. Integration of Innovation District Culture”. Therefore, a dedicated indicator has not been provided.
Quality of Space		No specific indicators were identified. While it can include attributes such as the number of leisure and cultural spaces, these elements can also be investigated as part of indicator EN-08, “Efficient and Multi-Functional Land Use”.

5.1.5. Domain 5: Governance

Oslo Municipality [7] describes the three innovation districts as areas that can, over time, become multi-functional urban spaces, through “positive interactions between its actors”—private sector, public sector, and academia. As a result, many of the functions of the district currently deal with mediation and coordination [81], for a continued momentum, interest and support from stakeholders. Furthermore, the hierarchical placement of innovation districts as public–private entities governed by the city implies that local decisions are coordinated with regional frameworks to be implemented as intended. Nine indicators have been identified, as shown in Table 7.

Table 7. USIs to monitor the “governance” domain.

Innovation District Pillar	Indicator	Indicator Definition
Critical Mass	GO-1. Contribution and Ownership of Members	The indicator qualitatively assesses the engagement of member organisations of the innovation district in terms of their contribution.
Innovation and Capacity	GO-2. Short-Term Wins	The indicator assesses the number and type of “success stories” achieved within a specific short time frame.
	GO-3. Flexibility of Policy	This indicator refers to the ability of regional frameworks to adapt to and accommodate the requirements of the innovation districts in a way that also upholds city-level sustainability goals.
	GO-4. Utilisation of E-Governance and Digital Governance Tools	Adapted from the UMF, the indicator refers to the integration of Information and Communication Technologies (ICTs) in governance networks and sharing of public information to facilitate efficiency, accountability and inclusivity [17].

Table 7. *Cont.*

Innovation District Pillar	Indicator	Indicator Definition
Diversity and Inclusion	GO-5. Direct Participation Structure of Civil Society and the Public in Planning	The indicator has been adapted from UMF and investigates the involvement of civil society and citizens in planning, management, decision-making and the involvement of citizens in the innovation district. The indicator involves both the participation of civil society and public engagement by innovation districts.
	GO-6. Legal Framework for Equality	This indicator investigates the implementation and monitoring of legal frameworks and programmes that enforce equality in terms of gender, race, and socio-economic class.
Leadership	GO-7. Efficiency in Urban Governance	The indicator investigates the availability of a framework to efficiently coordinate the governance of an innovation district.
	GO-8. Clear Goal Setting	The indicator inspects the clear articulation of the goals and intended outcomes of the innovation district.
Quality of Space	GO-9. Coordination with Urban Development Strategies	This indicator investigates the incorporation of innovation districts in regional-level plans proposed by local authorities.

6. Discussion and Conclusions

The methodology of this research drew inspiration from the work of Bardal et al., [8], who highlight the challenges of implementing sustainability and SDG frameworks at the local level in Norway, such as a lack of tools, expertise, and contextual relevance. In response, this proposed USI identification framework offers a flexible and simple yet robust approach, rooted in qualitative narrative analysis, to identify key sustainability indicators within existing empirical discourses. By combining policy narratives with the experiences of associated stakeholders and users, it addresses both the national pressure for SDG incorporation and the local concerns of relevance and expertise.

6.1. Reflecting on Indicator Distribution

The distribution of indicators across sustainability domains shows that economy resulted in the most (12), followed by governance and environment (nine each), society (seven), and culture (three). The dominance of economic indicators reflects the theoretical grounding of innovation districts in economic development. Several identified indicators may have cross-domain implications (e.g., EC-08 Unemployment Rate also has social implications), but they have been simplified for practicality, as described in Section 4.1.4.

The prominence of governance indicators in this study, however, notably contrasts with Rapetti et al. [16], where governance was identified as the least developed sustainability domain in innovation districts. While indicators in the social, economic, environmental and cultural domains were largely grounded in general theories of innovation districts, governance indicators in this study were shaped by the individual and local, day-to-day experiences of stakeholders at the district and regional levels. This suggests that governance gaps and needs in Oslo's innovation districts are structural and operational, not merely theoretical. As membership-based organisations whose strategies reflect the priorities of their most represented sectors, the districts require robust governance frameworks before other sustainability objectives can be meaningfully pursued. Monitoring governance indicators may therefore be a practical precondition for the effective implementation of indicators across all other domains. This finding aligns with perspectives that frame institutional governance as an enabling condition for sustainability outcomes across domains, rather than simply one dimension among several [92].

6.2. *The Role of Innovation Districts in Governing “Sustainability”*

The process of indicator identification showed that the city’s innovation districts had an understandably strong inclination towards enhancing the city’s economic capacity, while occasionally touching on governance, social and environmental pillars of sustainability. Although the stakeholders unanimously agreed on the influence of the UN SDGs in their conceptualisation, the pitfalls of innovation districts, such as land privatisation and gentrification, were nevertheless suggested as unavoidable consequences of transforming the city for the common good. Furthermore, the research also highlighted that the innovation districts’ indicators, strategies, and objectives relied heavily on the decisions made by their respective boards, which often favoured the sector with the highest representation. For instance, a greater representation of certain private sectors on the board of members resulted in decisions being more aligned with their individual interests. The membership-based nature of the districts raises the question of whether the definitions, ideas of sustainability, and goals are merely reflections of member goals. Related governance dynamics, such as lobbying, elite capture, and the influence of private sector actors on political decision-making, were, however, not explicitly captured as standalone indicators in this study, as they did not emerge distinctly enough across the data sources to warrant a dedicated indicator within the methodology employed. These dynamics nonetheless represent an important avenue for future indicator development, particularly as Oslo’s innovation districts mature and their political influence grows.

Analysing indicators across different data sources also highlights the dynamic and contextual nature of sustainability assessment. While city-level stakeholders suggested in their conversations that economic growth indicators were the most crucial for the districts and could be achieved through innovation capacity indicators, stakeholders working on larger political and supranational levels differed in their standpoint, placing greater emphasis on socio-economic impacts such as gentrification and high real estate values. Furthermore, it was found that most urban sustainability indicators in the social, environmental, economic, and cultural domains were founded on a theoretical understanding of innovation districts, even when discussed by interviews and group discussions. The governance indicators were shaped by the day-to-day experiences of stakeholders associated with the planning strategy. One notable observation is that while the innovation district objective “leadership” presented the least number of indicators, the “governance” domain identified nine sustainability indicators. Several sources used for USI identification in this study, including policy documents and interviews, stressed the need to establish a fair and transparent decision-making system [17] as opposed to a strong organisational leadership [19] to drive sustainability efforts. In other words, a governance-based approach of managing innovation districts was more important than organised leadership.

However, it is crucial to recognise that sustainability strategies built around innovation districts, like other urban planning approaches, are inherently multifaceted and require coordinated engagement among a wide range of stakeholders to achieve a holistic and positive impact on the city. Thus, the interviewed stakeholders involved in the implementation of these districts nevertheless highlighted the influence and role of intermediary organisations who served as a bridge between the public sector, private sector and users to mediate expectations and minimise possible pitfalls from implementing developmental plans. Furthermore, these developments were undertaken in close collaboration with other sectors of governance in the city (for example, mobility) to ensure an area-based extrapolation of benefits. Lastly, although innovation districts are positioned at the policy level as urban planning strategies focused on the alignment of business and land-use functions, the work of innovation district project coordinators was more intermediary, centred on convening actors across sectors.

6.3. Utilisation of the USI Identification Framework for Stakeholder Engagement

The concept of innovation districts has been interpreted differently in the three districts, creating ambiguity about what an innovation district really is in Oslo. This is further emphasised by a comment made by a UN expert on innovation-based development [70] that the idea of innovation districts is vague also in international contexts. It was observed that such fragmentation often results in process ambiguity, which the methodology tested in this research can help mediate. While the indicators identified in this study are specific to Oslo's planning and governance context and are not intended to be directly transferable to other cities, the methodology used to construct them is. The process of combining reference sheet indicators with stakeholder-elicited indicators, which were structured through the UMF's sustainability domains and The Bass Initiative's innovation district pillars, can be applied in other contexts to identify locally relevant sustainability indicators for innovation districts at any stage of conceptualisation, planning, or implementation. Particularly, it was noted that this process of indicator identification, which was qualitative and rooted in stakeholder engagement, fostered dialogue and reflexive insights.

For example, in an interview with an informant of Punkt Oslo [81], the importance of citizen engagement for social inclusion in innovation districts and urban planning was emphasised, aligning with the considerations for civil participation suggested by UN-Habitat [17] and The Bass Initiative [19]. The informant highlighted the current indirect methods of citizen engagement and reflected on the need to explore more direct ways of engaging with citizens. Similar moments of reflection occurred during other stakeholder interviews. Furthermore, the process also unveiled the sharing of some conflictual information and challenges that informants may not have expressed in a public setting.

These findings suggest that while monitoring processes provide a formal assessment of progress, the methodological process of indicator identification is equally crucial, as it fosters mediation through dialogue and reflection. Moreover, it is worth noting that while stakeholder interviews conducted one-on-one facilitated dialogues between the interviewer and respondent, focus group discussions held at Svale AS for the validation of site observations revealed the benefits of group discussions, as they promoted broader dialogue, reflection, and peer-based learning. Therefore, a combination of both interviews and focus group discussions is recommended to capture a comprehensive range of perspectives.

6.4. Future Work: Application of the Identified USI in Monitoring Processes

The next steps for the USIs for monitoring Oslo's innovation districts include defining a measurement/data collection technique, weighing the indicators, and assigning targets [93]. The indicators can either be weighed equally, statistically, or based on public/expert opinions [65,93]. By setting targets and objectives, efforts and associated costs (economic, social and political) involved in achieving them can be measured. These can be in the form of threshold values, critical values derived from existing standards, and target values based on predefined outcomes of the process being monitored.

In terms of implications and applications of these indicators, the UMF's Results Chain logic, "Input, Output, Outcome, Impact" [17], offers a structure for applying the identified indicators in practice. Input indicators, such as EN-06 (Budget for Climate Change Mitigation) and GO-1 (Contribution and Ownership of Members), capture the resources and commitments invested in the district. Output indicators, such as GO-2 (Short-Term Wins) and EC-12 (Innovation District as a Test Arena), measure direct deliverables of district activity. Outcome indicators, such as EC-01 (Employment Opportunity Growth) and EN-01 (Greenhouse Gas Emissions), reflect medium-term changes resulting from those outputs. Practitioners are encouraged to map each indicator to its position in this chain before designing measurement approaches, as this clarifies both the sequencing of monitoring

efforts and the causal logic connecting district activities to city-level sustainability goals. The mapping should also incorporate different stages of project inception, implementation, and management. For instance, some indicators could be more important during planning while others become relevant during implementation. The mediative nature of this process could also help resolve more critical questions, like, for instance, are there tensions between economic growth goals and social or environmental objectives? Lastly, the indicator set should not be treated as stationary. As innovation districts evolve, as definitions of sustainability shift, and as local priorities change, periodic re-evaluation of the indicator set through the same stakeholder engagement methodology is recommended.

The identification of measurement and data collection techniques should involve local data experts to identify the right source of data for a certain indicator, the access to such data, available competence, and relevant district-level and regional-level stakeholders who can come to a consensus on the sub-priorities for each indicator. The selection of sub-priorities can be carried out by reflecting on the following questions:

“What is happening with respect to the specific indicator? Are they effective? What can make them more effective? What kind of technology might make some of those processes more effective? Is there any innovation needed, and what kind?” [70].

Since many of the indicators have been adapted from UN-Habitat [17] or The Bass Initiative [19], these documents can also be referred to for application guidelines. An expert on SDG11 and urban monitoring [69] further explains that if the measurement is qualitative in nature, the result can be displayed as key messaging. When quantitatively measured, it allows for a comparison of results. Qualitative measurements may be performed through surveys, focus group discussions, etc., if needed. A diverse range of stakeholders associated with the innovation districts and local experts, adept at urban monitoring, may be brought together to decide on the best way to weigh the indicators based on their importance for the development of the district. Alternatively, the indicators may also be weighed equally if they are all deemed important to the same extent [65]. The following target-setting process involves defining a baseline and expected performance. Indicators can be compared to this target to determine their actual performance. The application of formal participatory decision-making methods, such as the Analytic Hierarchy Process (AHP) or similar multi-criteria techniques, could enhance transparency and methodological rigour in future iterations. Incorporating such approaches would allow for a structured, participatory assessment of indicator importance and trade-offs across sustainability dimensions.

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Abbreviations

The following abbreviations are used in this manuscript:

KBUD	Knowledge-based urban development
OSC	Oslo Science City
HSO	Hovinbyen Circular Oslo
UN SDGs	United Nations Sustainable Development Goals
USIs	Urban sustainability indicators
UMF	Global Urban Monitoring Framework (UMF)

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