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Promoting cycling through urban planning and development: a qualitative assessment of bikeability

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ABSTRACT

To increase cycling shares through urban planning and development, planners need sound tools to assess the built environment. This article presents a methodology to qualitatively determine bikeability, the extent to which it is possible and pleasurable to bike in or through a given area. It is a holistic assessment of four categories of built environment characteristics that affect bikeability. An assessment follows an iterative process combining secondary data and registrations from maps, aerial photos and fieldwork. The methodology does not require specialised tools and is applicable to different urban contexts and purposes. Two examples are included to demonstrate possible uses: assessment of existing built environments to establish a knowledge base when developing short- and long-term cycling plans and strategies, and assessment of planned urban transformations for use in planning processes to ensure new urban developments with a high level of bikeability. Possible methodological improvements are identified. Surveys and interviews with cyclists can provide further understandings of local context. Geographical information systems can inform an assessment but require specialist knowledge, better datasets, and more empirical data on cycling and the built environment from various contexts. As new insights emerge, the methodology must be continually updated to remain valid and reliable.

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bikeability; built environment characteristics; cycling; qualitative methodology; planning for cycling

1. Introduction

Increasing cycling shares is central in achieving a sustainable modal shift to reduce transport-related greenhouse gas emissions, and other negative externalities associated with everyday mobility (Gerike et al., 2019; Næss, 2012; Pucher & Buehler, 2017). In Norway, as in many countries, making people cycle more (e.g. longer and more frequently) is a longstanding goal (NMLGM, 2017; NPRA, 2012) and is included in the national Zero-Growth Objective, stating that increased transport demand caused by rapid population growth in major cities should be taken up by walking, cycling, and public transport (rather than growth in traffic volumes) (NMLGM, 2017; NMT, 2020; NMTC, 2013, 2017). National authorities, counties and municipalities are to follow up and realise these objectives through the planning and development of land use and transport systems that facilitate and enhance sustainable travel behaviour. To identify efficient interventions suited to the context, they must have sound knowledge of the current situation, including built environment barriers and opportunities

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for cycling. This, in turn, requires good assessment tools that are adaptable to different settings and scales. This article is a methodological contribution to qualitative assessments related to the built environment and cycling. The methodology is suited to evaluate the bikeability of a stretch, a neighbourhood in a city, and other smaller or larger built-up areas, exploring the immediate surroundings through which a person cycles and the preconditions for the trip as established by the larger urban context.

If more people are to opt for cycling, it must be seen as a realistic and attractive modal option by the broader population (Heinen et al., 2010; Krizek et al., 2009; Rynning, 2018; Stefansdottir, 2014). To achieve this, cycling must be facilitated in ways that accommodate all 'types' of cyclists, from the experienced and fearless to the inexperienced and risk averse (Dill & McNeil, 2013; McLeod et al., 2020). Furthermore, if cycling is to substitute driving (when and where possible), the relative competitiveness of cycling compared with driving must be strengthened (McLeod et al., 2020; Næss, 2012), as improved conditions for cycling alone are unlikely to result in a significant modal shift (and vice versa). It must be significantly better (easier, more pleasant, cheaper, etc.) to travel by bike compared to other modes, thereby making the former significantly more attractive and the preferred modal choice. This means ensuring that cycling is both a possible mode choice and a pleasurable experience (Rynning, 2018; Stefansdottir, 2014), while simultaneously reducing driving through restrictive measures. Being 'possible' relates to instrumental aspects of a trip, such as travel distance, the presence of infrastructure, and traffic safety; being 'pleasurable' relates to perceptual aspects, such as interesting and varied environments (Rynning, 2018; Stefansdottir, 2014). The two factors are strongly interdependent and affect the level of bikeability of a built environment and the spaces its attributes create *as a whole*. Bikeability describes the extent to which an area, with its natural and built environment, is both possible and pleasurable to cycle in or through for the experienced and the inexperienced cyclist.¹ It relates to macro-, meso-, and micro-scale qualities and characteristics that separately and together affect cycling shares and experience. To actively promote cycling, an area must have a high level of bikeability. Achieving this requires cycling to be prioritised in all levels of physical planning, from overall land use and transport planning, via more detailed planning of new urban developments or transformations of existing built environments, to planning and implementation of specific cycling interventions. Cultural, institutional, organisational and/or political barriers must also be addressed (McLeod et al., 2020), but are beyond the scope of this article. Experiences from cities with high bike shares show that good results require a comprehensive focus over a longer period, combining physical and non-physical measures from strategic to operational levels in a short- and long-term perspective, together with an active prioritisation of cycling over motorised transport modes (Koglin, 2015; Krizek et al., 2009; Pucher & Buehler, 2010; Yang et al., 2010).

In a project promoting cycling through urban planning and development in small towns, we sought an approach suited for planners to identify and address physical barriers and opportunities to cycling related to built environments. Based on the project-specific needs and findings from research (Dubois, 2014; Kirkeby, 2015, 2012; Skogheim, 2008), we established the following criteria as important to ensure relevance and usability for practice:

- No need for specialised, resource-demanding technical tools (some experience from urban and/or transport planning is assumed)

- Addresses various scale built environment characteristics related to cycling in a holistic manner
- Suited for analysis of a stretch, a neighbourhood in a city, and other smaller or larger built-up areas, with a particular focus on the Nordic context

Many approaches and methods for assessing cycling and the built environment exist (see, e.g. Arellana et al., 2020; Kellstedt et al., 2020; Muhs & Clifton, 2015). Recent reviews found that most are developed for non-European contexts, require the use of geographical information systems (GIS), and do not combine built environment characteristics at different scales (Arellana et al., 2020; Kellstedt et al., 2020). Assessment methods and other tools intended for planning are sometimes criticised for being too complex, expensive, inflexible, and incomprehensible ('black boxes') (Arellana et al., 2020; te Brömmelstroet et al., 2014; Dubois, 2014; Kellstedt et al., 2020). This reduces the transparency and soundness of an assessment. On a similar note, among the quantitative and qualitative cycling-approaches used by planning practice in Norway, we found that many lack descriptions of the relationships between the built environment and cycling they rely on, as well as which features to investigate and how to assess them. Moreover, many require the use of GIS or transport models. The latter is often criticised for using historic cycle trip patterns to anticipate future demand (McLeod et al., 2020), thereby not accounting for a sustainable modal shift in the planning for increased cycling. Not all municipalities have the skills or resources to use or procure highly specialised tools in their planning. In response, we developed a methodology for a holistic and qualitative assessment of micro-, meso- and macro-scale built environment characteristics influencing bikeability, intended for use by practice and research.

The remainder of the article is structured as follows. [Section 2](#) summarises what and how the characteristics of the built environment can make cycling possible and pleasurable. This constitutes the basis for the methodology outlined in [Section 3](#). In [Section 4](#), the methodology is demonstrated through two examples, and in [Section 5](#), we discuss experiences using the methodology and further development, as well as other possible uses within physical planning. Lastly, we reflect on how assessments can be used to strengthen bikeability and thus cycling competitiveness through land use and transport planning and development, especially at neighbourhood-scale planning.

2. Characteristics of the built environment that contribute to bikeability

There is widespread agreement in the literature on a positive relationship between cycling (and active travel in general) and the characteristics of the built environment (Arellana et al., 2020; Castañeda, 2021; Heinen et al., 2010; Muhs & Clifton, 2015; Nello-Deakin, 2020; Salvo et al., 2018; Wang & Wen, 2017).

Overall land use structure, together with the qualities of the transport system, establish significant premises for how and where we travel (Næss, 2012; Newman & Kenworthy, 2015; Tennøy et al., 2016). Strengthening cycling competitiveness to that of driving requires increased population density (e.g. through central urban densification), localisation of activities and destinations (including workplaces) within cycling distance, cycling connections to transit, improved conditions and network connectivity for cycling, safe and aesthetic surroundings, and restrictions on car use to reduce the overall driveability² (Muhs & Clifton, 2015; Næss, 2012; Nello-Deakin, 2020; Salvo et al., 2018; Tennøy et al., 2016; Wang & Wen,

2017). Built environment characteristics that influence cycling shares and experiences can be structured into four categories: *Natural and place-specific preconditions*, *Infrastructure and traffic*, *Urbanity*, and *Surroundings and activities*. This categorisation is inspired by Knapskog et al. (2019). Table 1 presents an overview of the four categories with associated attributes. The attributes affect the level of built environment bikeability separately and holistically through the spaces and urban environments they create. Most are addressable through physical planning, and some establish important preconditions for cycling being a possible modal choice. Natural and place-specific preconditions influence the possibility of cycling for different trips and purposes through premises established by land use and transport systems, topography, and local climate. Infrastructure and traffic influence the extent to which cycling is safe and perceived as possible for a broad range of cyclists as well as cycling competitiveness compared with driving. Urbanity influences the possibility of cycling and whether it is experienced as pleasurable, primarily through its impact on trip distances and route options. Surroundings and activities influence how pleasurable and safe an area is perceived as for cycling. It includes attributes such as the mix of functions, wayfinding, and design and aesthetics of the built environment, all of which, if done right, can provide pleasurable cycling experiences.

Table 1 also describes criteria for a built environment's 'performance' regarding bikeability, based on existing reviews of cycling literature and individual qualitative and quantitative studies from different urban contexts, scales, geographic units and measurements. The criteria are deliberately descriptive, as we consider generating quantitative performance scores unreliable and not adjustable to different contexts and the various types of cyclist. Previous studies have obtained mixed results on the correlation between built environment and cycling (Muhs & Clifton, 2015; Wang & Wen, 2017). Some claim we have enough empirical insights (Nello-Deakin, 2020), but we find that there is still a lack of empirical knowledge which hinders recommending fixed values. As an example, a recommended value of density that contributes to high levels of bikeability might be correct in one context but inadequate in another, and perform differently when simultaneously accounting for other attributes. Additionally, how a person perceives an attribute and how it influences their travel experience varies depending on cycling proficiency, preferences, needs, and more (Ewing & Handy, 2009; Krizek et al., 2009; Rynning, 2018). However, as many studies conclude, aiming for built environments with a high level of bikeability is likely to encourage even the most inexperienced and risk-averse to cycle more, thereby contributing to a significant increase in cycling shares and a large-scale sustainable modal shift (Krizek et al., 2009; McLeod et al., 2020).

3. A qualitative assessment of bikeability

Our methodology is a holistic, approach for an overall assessment of bikeability, suited to address a stretch, a neighbourhood in a city, and other smaller or larger built-up areas. Holistic refers to approaching the physical and built environment as a whole, focusing on the public spaces and urban environments that the sum of individual attributes creates, and to what extent they contribute to cycling being possible and pleasurable. Our experience in assessing walkability (Knapskog et al., 2019) served as a basis for the approach. We adjusted, for significant differences between walking and cycling, such as differences in range and speed, required skills and equipment (Muhs & Clifton, 2015; Nielsen & Skov-Petersen, 2018), as well as some built environment attributes affecting bikeability. The methodology is intended for

Table 1. Categories and attributes of built environments influencing bikeability and criteria for high and low bikeability performance. For simplicity, ‘city’ can here refer to the urban context of a city or a town.

CATEGORY: NATURAL AND PLACE-SPECIFIC PRECONDITIONS			
Attribute	Criteria for high bikeability performance for a Nordic context	Criteria for low bikeability performance for a Nordic context	References
Location and role of the area in its region	Primarily self-sufficient with dwellings, jobs, schools, services and amenities. Most trips take place within the city and are largely possible by bike	Part of a bigger region where jobs, schools, services and amenities are primarily located elsewhere. Most trips take place out of the city by other modes than bike	(Næss, 2012; Nielsen and Skov-Petersen, 2018; Tennøy et al., 2016)
Location and role of the area in the city	Well-connected to the rest of the city with easy bike-access and cyclable distances to most destinations. Note: Limits for cycling depends on the cyclist, trip purpose and more. 3-5 km is often used as acceptable for a majority, but some are willing to cycle 10km or more.	Disconnected or isolated from the rest of the city with low bike-access and long distances to other destinations	(Handy et al., 2014; Heinen et al., 2010; Krizek et al., 2009; Næss, 2012; Tennøy et al., 2016)
Topography	Relatively flat landscapes make cycling for the most part easy and effortless	Elevated surroundings make cycling an effort/hassle or requiring long detours to avoid steep slopes	(Fyhri et al., 2017; Hulleberg et al., 2018; Krizek et al., 2009)
Weather conditions	Stable weather conditions make cycling predictable. Light, warm, and dry (low precipitation) conditions with little wind encourage cycling	Unstable and changing weather conditions with seasonal variations and extreme temperatures make cycling unpredictable Dark, cold, wet (high precipitation), and windy conditions may increase car use	(Bergström and Magnusson, 2003; Böcker et al., 2019, 2013; Christensen and Jensen, 2008; Fyhri et al., 2017; Svorstøl et al., 2017)
CATEGORY: INFRASTRUCTURE AND TRAFFIC			
Attribute	Criteria for high bikeability performance for a Nordic context	Criteria for low bikeability performance for a Nordic context	References
Cycling infrastructure	Well-connected cycling network with good cycling facilitation through adequate infrastructure adjusted to geographic context and with alternative routes strengthens bikeability for different types of cyclists Separate infrastructure from car traffic (and preferably from pedestrians) is important for many, and is found to increase cycling shares and reroute cyclists from non-facilitated routes	Fragmented cycling network with little or no facilitation of cycling, weakens bikeability, especially for inexperienced or unsure cyclists Lack of separation, especially where traffic volumes (cars, pedestrians, cyclists) and speed levels are high, can discourage many from cycling	(Cervero et al., 2019; Fyhri et al., 2017; Heinen et al., 2010; Høye et al., 2015; Hull and O'Holleran, 2014; Hulleberg et al., 2018; Krenn et al., 2015; Krizek et al., 2009; McLeod et al., 2020 Pritchard et al., 2019; Pucher and Buehler, 2017; Vasilev et al., 2018)
Cycling facilities at destinations	High-standard bike parking at important destinations (workplaces, schools, city centres, shopping centres), bike service points for repair and maintenance, locker rooms and shower at workplaces and similar, support cycling as a mode option	Inadequate or lacking bike parking at important destinations weakens cycling as a mode option, more so if few or no other bike facilities	(Handy et al., 2014; Heinen et al., 2010; Muhs and Clifton, 2015)

(Continued)

Table 1. (Continued).

Traffic volumes	Low car traffic volumes strengthen feeling of safety, cause fewer conflicts with motorised traffic, and enable cycling in mixed traffic where separate cycling infrastructure is lacking (at least for some groups)	High car traffic volumes lower feeling of safety, can cause conflicts with motorised traffic, and create an unpleasant environment for cycling especially for cycling in mixed traffic	(Høye et al., 2015; Pucher and Buehler, 2017; Stefansdottir, 2014)
Speed levels	Low car traffic speeds strengthen feeling of safety, especially for cycling in mixed traffic and when separate cycling infrastructure is lacking. Speed limits below 30 km/h, traffic calming measures are associated with more cycling for transport and make the street environment safer (real and perceived) and more pleasant for cycling	High car traffic speeds lower feeling of safety, especially for cycling in mixed traffic and create an unpleasant environment for cycling. Speed limits over 30 km/h, no traffic calming measures, and no separation between modes are associated with less cycling for transport	(Adam et al., 2020; Høye et al., 2015; Krizek et al., 2009; Pucher and Buehler, 2017)
Traffic safety	Cyclists strongly consider safety in their route decisions, built environments that both are and feel safe from accidents promote cycling. Few accidents and many cyclists using a route might strengthen the real and perceived feeling of safety	Built environments that both are and feel unsafe from accidents are a substantial barrier to cycling. Many accidents and unprotected cycling facilities lower the feeling of safety, especially for those who feel vulnerable cycling on roads with motorised transport	(McLeod et al., 2020; Muhs and Clifton, 2015; Pucher and Buehler, 2017; Rynning, 2018)
Intersections	Cyclists have a defined position and priority in intersections, increasing the feeling of safety and reducing conflicts with other users. Few intersections, no/few signal regulation reduces delays and can make cycling more attractive	Little or no facilitation for cycling in intersections, might cause accidents/conflicts with others and create a feeling of unsafety. Many intersections and/or signal regulations cause delays and can make cycling less attractive	(Høye et al., 2015; Krizek et al., 2009; McLeod et al., 2020)
Accessibility by public transport (PT)	Cycling and PT are seen as part of the same sustainable urban transport system, linked through easy and high quality bike access to PT stops, bike parking at PT stop/nodal points, design of PT nodal points that facilitate easy transfers cycling/PT, the possibility to bring bike on board PT mode, thereby facilitating cycling as part of the daily commute and other multimodal travels	Separated urban transport systems with little or no connection between cycling and PT: lack of cycling routes to PT stops; lack of bike parking at PT nodal points; no possibility to bring bike on board PT mode; reduce the potential of multi-modal travels and cycling as part of the daily commute	(Adam et al., 2020; Kager et al., 2016; Pucher and Buehler, 2009)
Accessibility by car	Low level of driveability through complicated access to main roads, (high) car parking fees and/or few parking options, toll roads, congestion, and more make driving less attractive and increase cycling-competitiveness	High level of driveability through easy access by car to main roads and few restrictive car measures (free car parking, easily available parking options, large parking surfaces, free flowing traffic, no toll roads) make driving attractive and reduce cycling-competitiveness	(Handy et al., 2014; Næss, 2012; Tennøy et al., 2016)

(Continued)

Table 1. (Continued).

CATEGORY: URBANITY			
Attribute	Criteria for high bikeability performance for a Nordic context	Criteria for low bikeability performance for a Nordic context	References
Density	A concentrated development pattern with high densities contributes to high cycling shares through cycling possible for many trip purposes	Low densities contribute to lower cycling shares due to longer distances and less activities taking place in the same area	(Handy et al., 2014; Heinen et al., 2010; Næss, 2012; Nielsen and Skov-Petersen, 2018; Tennøy et al., 2016)
Proximity	Short distances between different activities and destinations make cycling a viable everyday modal option	Long distances between different activities and destinations make cycling a less viable everyday modal option	(Handy et al., 2014; Heinen et al., 2010; Næss, 2012; Nielsen and Skov-Petersen, 2018; Tennøy et al., 2016)
Urban structure	A continuous and compact urban structure with few 'empty slots' such as parking areas and dominating infrastructure (e.g., wide roads, railways) limits barriers and the need for detours	Disconnected urban structure with large empty surfaces and dominating infrastructure that create barriers and force detours	(Ewing and Cervero, 2001; Krizek et al., 2009; Pucher and Buehler, 2010; Stefansdottir, 2014)
Permeability	High permeability with short/small blocks and possible short cuts enables cyclists to choose among different routes and to avoid detours, thus improving cycling accessibility	Low permeability with long/large blocks, forced detours and no/few route choices reduce cycling accessibility	(Melia, 2015)
CATEGORY: SURROUNDINGS AND ACTIVITIES			
Attribute	Criteria for high bikeability performance for a Nordic context	Criteria for low bikeability performance for a Nordic context	References
Destinations, activities and functions	Multiple destinations, activities, and functions within or close by the site or the reduce distances and enable cycling for various trip purposes and high cycling shares	Few or no mix of activities and functions within or close by the site lead to increased trip distances and reduce cycling for various trip purposes	(Næss, 2012; Tennøy et al., 2016)
Maintenance	High focus on maintenance of cycling infrastructure and facilities is important for cycling-competitiveness	Low priority of maintenance of cycling infrastructure and facilities reduces cycling-competitiveness	(Svorstøl et al., 2017)
Perceived safety	The built environment is perceived as safe for cycling (crime, risk of accidents other than traffic)	The built environment is perceived as unsafe for cycling (crime, risk of accidents other than traffic)	(Fyhri et al., 2017; Krizek et al., 2009; McLeod et al., 2020; Pucher and Buehler, 2017)
Wayfinding and signs	Wayfinding is easy via logic connections, signs for cyclists, recognisable structures and/or features, etc.	Wayfinding is difficult with few logic connections, lack of signs, an environment with few recognizable structures and/or features	(Lynch, 1960; Rynning, 2018; Stefansdottir, 2014)
Design and aesthetics	Green connections and pleasant surroundings, historic buildings and places, can provide positive cycling experiences	Car-oriented environments where movement and prioritising of motorised traffic marginalise cyclists, unpleasant surroundings, urban decay; reduce attractiveness and competitiveness for cycling	(De Vos et al., 2015; Krenn et al., 2015; Stefansdottir, 2014)

(Continued)

Table 1. (Continued).

Street or road characters	Dense, gridded network with a 'street'-character focusing on place functions and movement for non-motorised transport is likely to ensure good cycling experiences., Typical 'street'-features include: aligned buildings, streetlights, benches, curb cuts, presence of sidewalks, buffers between streets and sidewalks.	Low-density and car-oriented environments with 'road'-characters without parallel bicycle infrastructure marginalise cyclists and weaken cycling experiences. Typical 'road'-features include: priority of motorised traffic, more and wider car lanes, less intersection density, lack of features inviting to stop and stay in a space (benches, etc.)	(Krenn et al., 2015; Marshall and Garrick, 2010; McLeod et al., 2020; Stefansdottir, 2014)
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practice and research, developed for assessments within the Nordic context, and addresses different scales of built environment characteristics related to the immediate surroundings through which a person cycles and the preconditions for the trip as established by the larger urban context. It resembles a typical site analysis within urban planning and design practices, where the aim is to establish an in-depth comprehension of a site and its catchment area, and identify strengths and weaknesses. Specialised tools are not required, but we assume that users have some experience with urban and/or transport planning.

The methodology is structured around the four categories and the associated micro-, meso- and macro-scale attributes presented in Table 1. In an assessment, the 'state' of these attributes is evaluated with regard to whether they contribute to a high or low level of bikeability based on the criteria in the table. Assessments are done as qualitative site analysis with data collection based on observations and registrations from maps, aerial photos, and fieldwork, together with document studies, as described by, for example, MacCallum et al. (2019; 61–90). If available, descriptive analyses of secondary datasets should supplement the assessment. The methodology follows the steps outlined in Figure 1 and Table 2.

The purpose of an assessment and the site and its catchment area must be clearly defined. A site can range from a particular stretch to a neighbourhood or even a larger

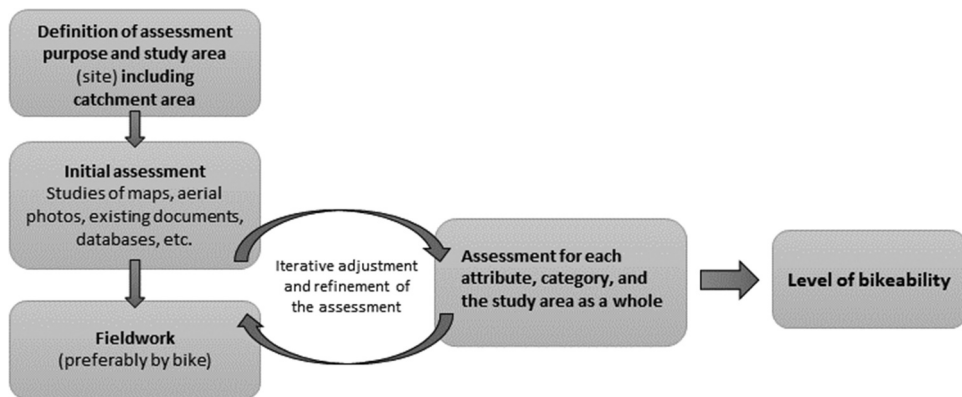


Figure 1. The various attributes are assessed in an iterative manner through a mixed-methods approach.

Table 2. Description of the mixed-methods approach to assessment.

Steps for assessing bikeability		
Obligatory	Studies of maps and aerial photos	Provide an initial understanding of the site and its catchment area; enable preliminary assessment of selected attributes. Contribute to identifying important aspects to explore during fieldwork.
Obligatory	Studies of the existing documents and databases (before [initial] and after [more in depth] fieldwork)	Deepen understandings of the site and its catchment area; may reveal important information, such as current state of the transport network, modal splits, planned interventions, etc. Essential documents include local and regional strategies and plans (land use and transport, public health, traffic safety, etc.), existing site analyses, impact assessments, etc. Databases may cover traffic levels, speed levels, accidents and more.
Obligatory	Fieldwork	Essential for assessment. Inspection of the whole site and its catchment area, selected parts and stretches in more depth, preferably by bike. Observations and findings are documented through notes, maps, photos/videos.

area where selected parts are studied more in detail. When the site is defined, the catchment area is given by the localisation of central destinations that a person might travel to (e.g. schools, a city centre, grocery stores). The geographical scale and available resources will influence the level of detail of the assessment. For example, while the site is assessed in detail, the assessment of the catchment area might be restricted to selected stretches connecting the site in question to specific destinations. Data and information about category attributes are collected through the above-mentioned mixed-methods approach, establishing a gradually detailed picture. Through a holistic, qualitative judgment of the attributes, bikeability is determined using a four-point scale: *very bikeable*, *bikeable*, *somewhat bikeable*, and *slightly bikeable* for each attribute and category, and then for the site and its catchment area as a whole. Attributes may be revisited in an iterative manner as the assessment advances, for example, by first collecting data from secondary datasets and then explore the attributes through fieldwork. When concluding on the bikeability of each category and the assessed area, context-dependent and holistic considerations are important. Attributes that are highly significant for bikeability in one urban context might be less so in another, depending on the area's built environment characteristics and the interactions among these. For this reason, neither the categories nor the attributes within each category are weighted; the evaluation is based on the assessors' professional judgements. The built environment as a whole and the cycling experiences it creates, determine the overall conclusion. Therefore, as seen in [Section 4](#), a site and its catchment area might be assessed as somewhat bikeable for two categories and as bikeable for the other two, then in total as somewhat bikeable. To be considered *very bikeable*, an area must perform well for most attributes; if it performs poorly for most attributes, the conclusion is likely *slightly bikeable*. Every assessment must include a thorough description of the determined level of bikeability, including how attributes and categories relate to each other. This explanation ensures transparency and reliability. We emphasise the need to explore all categories for a complete and holistic evaluation.

4. Demonstration of the bikeability assessments

Here, we demonstrate the use of the methodology through two examples from Norway. The first is an assessment of bikeability level of an existing built environment, while the second is a bikeability assessment of the planned built environment of a transformation site. Through the examples, we show how the approach can be adapted to the local context, how the attributes, categories, and the site and its catchment area as a whole are evaluated, as well as possible sources for an assessment.

4.1. Assessment of Sauda

The assessment was part of a project on how small municipalities can make people cycle more through urban planning and development. The methodology was first developed through this project. The aim was to identify possible measures to strengthen cycling conditions in the town of Sauda, and to provide a basis for developing a cycling strategy and plans. Situated in the western part of Norway, Sauda is a municipality with approximately 4,500 inhabitants.³ Most live in and around the town centre or in the neighbouring district of Saudasjøen. This continuous urban area was defined as the catchment area for the assessment, focusing on cycling to, within, and through Sauda centre. An initial assessment was done using online maps and aerial photos to gain information about the distribution of important destinations (living districts, workplaces, services, and amenities), distances within the community, existing cycling networks, and so on. Open-access national databases were used to evaluate attributes such as topography, traffic levels, speed limits, densities and more. We also explored plans, strategies, and other documents relating directly and indirectly to cycling, including travel surveys and surveys on use and perception of the local surroundings. This established a 'first take' on the bikeability of Sauda. Fieldwork took place over two days and included a guided bike-along with the local public health coordinator using e-bikes. This provided a valuable understanding of the local cycling experience, enabled us to evaluate attributes less 'detectable' through the other methods, and allowed exploration of particular aspects in detail. Cycling larger stretches, such as to and from the centre, was a particular benefit. More detailed registrations were done in the city centre by foot. Travel by car was used for the understanding of the regional context. Based on fieldwork observations and supplementary studies of maps, aerial photos, documents, and databases, we reviewed our initial assessment concluding upon the level of bikeability first for each attribute and category, then for Sauda centre and the catchment area as a whole (further referred to as Sauda). Table 3 summarises the assessment, including the sources employed. Figures 2, 3, 4, 5 and 6 illustrate some assessed attributes.

We found the level of bikeability of Sauda to be *bikeable*. Attributes related to natural and place-specific preconditions (assessed bikeable) and urbanity (assessed bikeable) enhanced the level of bikeability through short distances, flat topography in the centre (although some residential areas were located in more elevated parts), and a relatively permeable urban structure. See Figure 2 and 3. Attributes related to the category infrastructure and traffic (assessed somewhat bikeable), especially the lack of or inadequate cycling facilitation, lowered overall bikeability. See Figure 4. This was to some extent, compensated by cycling options (at least for more experienced cyclists) along streets and

Table 3. Bikeability assessment of Sauda.

CATEGORY: NATURAL AND PLACE-SPECIFIC PRECONDITIONS					
Attributes	Very bikeable	Bikeable	Somewhat bikeable	Slightly bikeable	Assessment
Location and role of the area in its region	X				Located at the end of a fiord, nearest larger cities (Stavanger and Haugesund) 2–3.5 hours away by car or express boat (only to Stavanger). Most activities take place within the municipality, which is largely self-sufficient with housing, jobs, trade, etc. About 80 per cent of employed inhabitants work within the municipality. Little outward commuting. Primary sources: Documents, maps, and information on commuting patterns from Statistics Norway.
Location and role of the area in the city	X				91 per cent of the inhabitants live within the assessed urban area. Cycling distance to most destinations within the concentrated urban area, with Sauda centre well connected to the rest. Primary sources: Population in urban settlements from Statistics Norway, maps, open access basic cycling accessibility tools ^{a)}
Topography		X			Flat topography in the centre makes cycling easy and effortless. Some residential areas located in more elevated parts make cycling an effort for some. Primary sources: Fieldwork, open-access elevation data from the Norwegian Mapping Authority
Weather conditions			X		Stable weather conditions make cycling predictable. Cold winters and a yearly precipitation above national average can discourage cycling, warm and dry springs and summers can encourage it. Primary sources: Document studies, online weather statistics from the Norwegian Meteorological Institute
Level of bikeability natural and place-specific preconditions: Bikeable					
In total, natural and place-specific preconditions in Sauda are assessed as contributing to a bikeable area. The majority of everyday trips take place within the municipality. These are possible by bike, as internal distances are short, and the centre is well connected to the rest of the town. The topography of Sauda centre is flat, while some residential areas are located in more elevated parts. This is likely somewhat challenging for cycling, though it is relatively easy to overcome with e-bikes. The weather is, for the most part, stable despite cold winters.					
a) There are several open-access cycling accessibility tools that provide illustrative information about cycling distances, such for example, https://maps.openrouteservice.org					
CATEGORY: INFRASTRUCTURE AND TRAFFIC					
Cycling infrastructure			X		Cycling partly facilitated along central roads, but no separation between pedestrians and cyclists. Often lacking/inexistent cycling infrastructure and varied quality. In streets and along residential roads, cyclists share road space with cars. Some cycling and pedestrian routes along the fiord, rivers, fields, and through green spaces offer good alternative routes. Primary sources: Maps, open-access road traffic data from the Norwegian Public Roads Administration, fieldwork
Cycling facilities at destinations			X		Lacking/inadequate bicycle parking at important destinations in the city centre. Primary sources: Fieldwork

(Continued)

Table 3. (Continued).

Traffic volumes	X		Highest car traffic volumes along main roads are 2500–3000 Annual Average Daily traffic. Low numbers of traffic in general enable cycling in mixed traffic, though main roads likely most for confident cyclists. Primary sources: Open-access road traffic data from the Norwegian Public Roads Administration, fieldwork	
Speed levels		X	Low speed levels (30 km/h) on most streets in the centre and residential areas support cycling in mixed traffic. Higher speed levels on main roads through the centre (50 km/h) and the urban area between Sauda and Saudasjøen (70 km/h), as well as outside the urban area (80 km/h) reduce the feeling of safety when cycling in mixed traffic. Primary sources: Open access road traffic data from the Norwegian Public Roads Administration, fieldwork	
Traffic safety			X	Few reported accidents involving cyclists (13 reported after year 2000, 0 killed) might strengthen the feeling of safety when cycling. Primary sources: Open-access road traffic data from the Norwegian Public Roads Administration, fieldwork
Intersections			X	No facilitation for cyclists at intersections might cause accidents, and create feelings of unsafety. Primary sources: Maps and fieldwork
Accessibility by public transport (PT)			X	Low PT-offer in Sauda (but on-demand bus pilot started July 2018). Weak links between cycling/PT, e.g. no cycling facilities on the pier where speed boat to Stavanger and partly inadequate cycling infrastructure to the pier. Primary sources: Fieldwork
Accessibility by car			X	High driveability with free flowing traffic, no toll roads, easy access to main road system, easy access to free and plentiful parking in the centre (Curb side parking in the centre, larger parking lots, and 'left over' areas used for parking) facilitate car use. Primary sources: Maps and fieldwork
Level of bikeability infrastructure and traffic: Somewhat bikeable				
In total, infrastructure and traffic in Sauda are assessed as contributing to a somewhat bikeable area. The lack of or inadequate infrastructure along important stretches, in intersections, and at important destinations is a significant drawback. Where disjointed from motorised traffic, pedestrians and cyclists are not separated, which is negative for cycling. Street character (in the town centre) and residential roads with low speeds and low traffic volumes enable cycling in mixed traffic along several routes, which is positive. Cycling along such roads depends on experience and confidence. The area has a high level of driveability, and the connection to public transport is weak, both reducing bikeability.				
CATEGORY: URBANITY				
Density			X	Dense (relative to the context) and concentrated urban area which has the potential to contribute to high cycling shares. Primary sources: Maps and statistics from Statistics Norway, fieldwork
Proximity	X			Short internal distances enable cycling as an everyday modal option. Sauda and Saudasjøen as a whole are covered within 20 minutes by bike. Largest residential areas are within 1 km radius from the centre, Saudasjøen within a 3 km radius. Primary sources: Maps, open-access basic cycling accessibility tools

(Continued)

Table 3. (Continued).

Urban structure	X	Continuous urban area. Low rise, but high coverage of buildings, cohesive building structure and few empty slots in the centre area. Outside the centre mainly single-family housing and typical residential streets. Some main roads central for cycling create barriers for less experienced cyclist. Primary sources: Maps and fieldwork
Permeability	X	High permeability in the town centre with short blocks and short cuts, mostly similar in residential areas, makes cycling easy and accessible and several route options. Primary sources: Maps and fieldwork

Level of bikeability urbanity: Bikeable

In total, urbanity of Sauda is assessed as contributing to a bikeable area. Cycling is a viable option for most trips due to short internal distances, proximity between various destinations, and a well-defined centre with a compact and cohesive building structure. The whole urban area is covered within 20 minutes by bike. Outside the centre are primarily single-family housing and typical residential streets with relatively high permeability, which further shortens distances and offers several route options. Some central roads create barriers and reduce bikeability.

CATEGORY: SURROUNDINGS AND ACTIVITIES

Destinations, activities and X functions		Multiple destinations, activities and functions (including workplaces) located in or close to the centre, few empty premises support everyday cycling. Primary sources: Maps, document studies, and fieldwork
Maintenance	X	Seemingly good operation and maintenance of existing cycling infrastructure, important for attractiveness and competitiveness for cycling Primary sources: Fieldwork
Perceived safety	X	Several of the main routes are according to both adult and young residents perceived as unsafe for cycling (and walking), primarily related to traffic. Reasons include lacking/inadequate lighting and infrastructure on stretches and intersections. Primary sources: Document studies (findings from two recent surveys)
Wayfinding and signs	X	Easy wayfinding due to nature, topography, and routes along rivers and roads. Lack of cycling signage (and other) is a drawback for those new to the area, although the compact urban area is easily navigable. Primary sources: Fieldwork
Design and aesthetics	X	Several routes along green and blue connections allow choosing cycling route according to preferences and needs, often in pleasant surroundings where it is easy to orient oneself. Primary sources: Fieldwork
Street or road character	X	Sauda centre has a dense, gridded street network with street character, which supports cycling. Main roads with road character and no cycling facilitation reduce the cycling experience. Primary sources: Maps and fieldwork

Level of bikeability surroundings and activities: Bikeable

In total, the surroundings and activities in Sauda are assessed as contributing to a bikeable area. The mix of functions and activities in or in proximity to the centre makes it possible and pleasurable to cycle. The continuity of the urban tissue towards residential areas provides pleasant surroundings for cycling, and alternative routes along green and blue connections to/from the centre allow cyclists to adapt a trip according to preferences and needs. There are, however, some issues related to perceived unsafety from traffic and road characters, which lower bikeability. Nature, topography and the compactness of the community facilitate wayfinding, but signage is somewhat lacking. Maintenance and operation of existing cycling infrastructure is seemingly good.

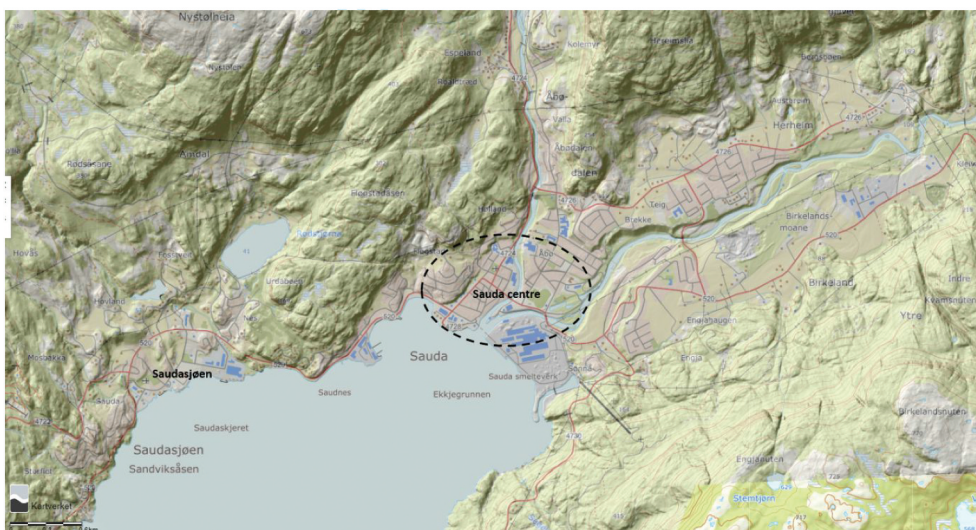


Figure 2. Natural and place-specific preconditions include topography, here assessed through open-access elevation data from the Norwegian mapping authority and fieldwork. Sauda centre is relatively flat, making cycling relatively easy and effortless. Some residential areas are located in elevated parts, making cycling an effort for some.



Figure 3. In Sauda, the low rise but high coverage of buildings and cohesive building structure in the centre area contribute positively to the level of bikeability within the category Urbanity.

roads with low traffic speeds and volumes, as well as alternative cycling routes. Attributes related to surroundings and activities (assessed bikeable), such as pleasant surroundings, mix of destinations and activities and functions close to each other, contributed positively. See [Figure 5](#). However, many stretches were perceived as unsafe for cycling,



Figure 4. Traffic conditions are assessed in the category infrastructure and traffic. Cycling in mixed traffic along main roads with low traffic volumes and speed levels from 50 km/h and above makes cycling an option for more experienced cyclists, less so for the inexperienced.



Figure 5. Alternative cycling routes in green and pleasant surroundings away from motorised transport make cycling a more viable option for less-experienced cyclists.

a significant barrier to cycling. This illustrates how deficient facilitation for cycling and perceived safety can reduce the influence of positive aspects.

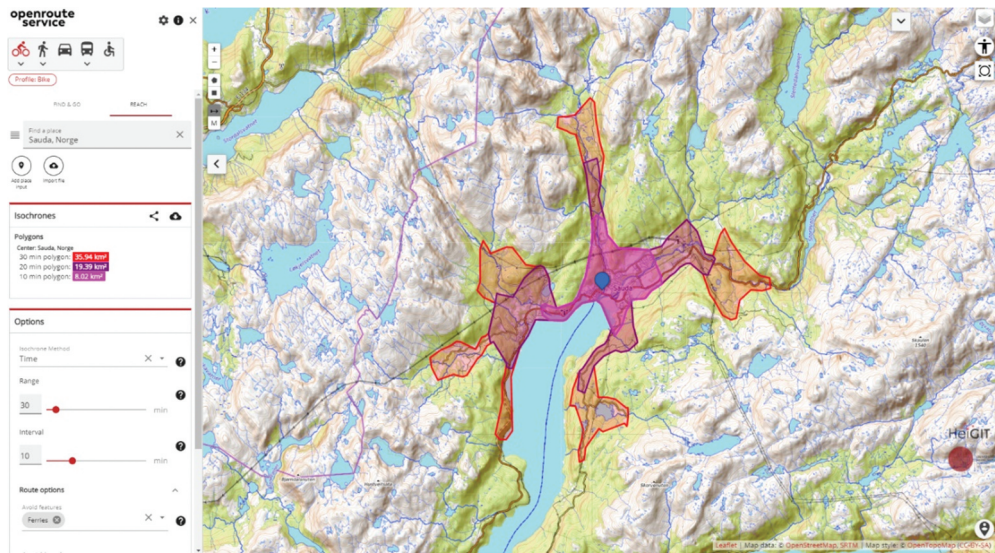


Figure 6. Open access tools used to illustrate cycling accessibility from Sauda centre. The reach based on cycling time is illustrated in 10 minutes' intervals based on Openrouteservice, developed and provided by Heidelberg Institute for Geoinformation Technology (HeiGIT), which offers routing services by using user-generated, collaboratively collected free geographic data from OpenStreetMap. Source: <https://maps.openrouteservice.org/>.

4.2. Assessment of Klosterøya

The bikeability assessment of the planned built environment of the neighbourhood Klosterøya is part of a research project on sustainable adaption and resilience in urban regeneration. The project explores, in part, how sustainable travel behaviours can be facilitated through urban transformation, with bikeability being one of several studied aspects.

Previously an industrial site, Klosterøya is a centrally located island in Skien city (55,000 inhabitants), the commercial and administrative centre of the Grenland city region (107,000 inhabitants).⁴ Skien and the neighbouring city Porsgrunn form a more or less continuous urban area, with 30 minutes of cycling time between the two city centres. The urban transformation will be an extension of the Skien city centre, with a combination of commercial enterprises, cultural and educational institutions and dwellings. Three new walking and cycling bridges from Klosterøya to neighbouring districts will connect different parts of the city with the city centre. The transformation is ongoing, with parts of the site already in use.

The bikeability assessment followed the explained setup in Section 3, with some adjustments as the transformation was not yet completed. We focused on the *planned* built environment of the site with the neighbouring districts and city centre as catchment area. Primary sources were document studies of the legally binding zoning plans, with provisions and feasibility studies and assessments produced for the planning processes. Existing maps and aerial photos were used to assess the site in relation to the surrounding city. Open-access national map solutions and databases were used for only a few attributes due to the non-completed development. Fieldwork of the site and parts of the catchment area (by foot) included a guided tour by a municipal planner who explained the ongoing and planned developments. Parts of the site were closed due to construction works. The level of bikeability was assessed first for each attribute and category,

Table 4. Bikeability assessment of Klosterøya.

CATEGORY: NATURAL AND PLACE-SPECIFIC PRECONDITIONS					
Attributes	Very bikeable	Bikeable	Somewhat bikeable	Slightly bikeable	Assessment
Location and role of the area in its region	X				<p>Skien is the commercial and administrative centre of its region. Most activities take place within the urban area of Skien and Porsgrunn (30 min cycling away), which is largely self-sufficient with housing, jobs, trade, etc. About 84 per cent of the employed inhabitants in Skien work here. The region holds a low labour market integration. The development of Klosterøya will contribute to strengthen Skien city as a destination.</p> <p>Primary sources: Documents, maps, information on commuting patterns from Statistics Norway, open-access basic cycling accessibility tools ^{a)}</p>
Location and role of the area in the city	X				<p>Klosterøya will be an extended part of the city centre, well-connected to the rest of the town with cycling distance to most destinations. Cycling and walking connections to the mainland strengthens the bikeability of both Klosterøya and the rest of the city by offering alternative routes and short cuts. The planned development with a mix of housing, jobs and activities, strengthens Klosterøya as a destination.</p> <p>Primary sources: Zoning plans, maps, open-access basic cycling accessibility tools</p>
Topography		X			<p>The general topography of the island is flat, but the height difference between the main road of Klostergata and the rest of the island creates a barrier for onsite cycling. Skien centre is flat, but other parts are elevated compared to Klosterøya, making cycling an effort for some.</p> <p>Primary sources: Fieldwork, open-access elevation data from the Norwegian mapping authority</p>
Weather conditions		X			<p>The local climate is relatively stable with some rain falls. Cold winds from the surrounding waters can create unpleasant cycling conditions.</p> <p>Primary sources: Document studies and online weather statistics from the Norwegian Meteorological Institute</p>
<p>Level of bikeability natural and place-specific preconditions: Bikeable</p> <p>In total, the natural and place-specific preconditions in Klosterøya are assessed as contributing to a bikeable area. The central location, role in the region and in the city, as well as an increasing number of residences, jobs, and activities strengthen Klosterøya as a destination and contribute positively to bikeability. The region holds a low labour market integration. Bridges for non-motorised transport across the island strongly support cycling, including for Skien city. Within the site, the topography is relatively flat, but the elevated main road of Klostergata is a significant barrier. Other parts of the city being elevated to that of Klosterøya can be a challenge for some cyclists, though relatively easy overcome with e-bikes. Relatively stable climate but cold winds from the surrounding waters.</p> <p>(a) There are several open-access cycling accessibility tools that provide illustrative information about cycling distances, such for example, https://maps.openrouteservice.org</p>					
CATEGORY: INFRASTRUCTURE AND TRAFFIC					
Cycling infrastructure			X		<p>The planned cycling network provide several bike paths and alternative routes, allowing cyclists to choose the option best suited for them. Positive for cycling. New bridges for non-motorised transport increases accessibility by bike. All cycling infrastructure is planned as shared solutions with either pedestrians or cars, a source for conflicts. Width of walking and biking paths seems under-dimensioned for planned increases in cycling shares. Planned tunnels for non-motorised tunnels across the island strengthens bikeability, but only 2 out of 5 realisable.</p> <p>Primary sources: Approved zoning plan, maps, fieldwork</p>

(Continued)

Table 4. (Continued).

CATEGORY: NATURAL AND PLACE-SPECIFIC PRECONDITIONS		
Cycling facilities at destinations	X	Bike parking is a requirement in the zoning plan, but minimum numbers are not provided. Primary sources: Approved zoning plan, fieldwork
Traffic volumes	X	The cycling path along Klostergata (divided from car traffic, shared with pedestrians) seems very cycling unfriendly due to high traffic volumes (14,700 annual average daily traffic) and traffic noise. Planned, alternative routes enable cycling in less car-oriented environments. The planned development is calculated to generate 7,000 vehicles/day, distribution along internal streets is not discussed in the planning documents. Some of the intended solutions for internal traffic via underground parking areas is abandoned, making more cycling to take place in mixed traffic (shared space). This might be a barrier to cycling, especially for less experienced cyclists. Primary sources: Open-access road traffic data from the Norwegian Public Roads Administration, approved zoning plans, feasibility studies and assessments, fieldwork
Speed levels	X	Klostergata has speed levels of 50 km/h. Shared space streets are likely to have low speed levels. Primary sources: Open-access road traffic data from the Norwegian Public Roads Administration, approved zoning plans, fieldwork
Traffic safety		One reported traffic accident along Klostergata since 2000. It is difficult to be overly conclusive regarding traffic safety as the traffic situation will change when the transformation is complete, and all activities and new inhabitants are in place. We therefore refrain from setting a score. Primary sources: Open-access road traffic data from the Norwegian Public Roads Administration, zoning plans, fieldwork
Intersections	X	The main cycling connection from Klostergata to the rest of the island is a car-oriented and cycling-unfriendly junction. A new connection from the north are probably to improve access, but details are not yet given. Internal intersections, where non-motorised infrastructure meets with streets, seem have the potential of creating conflicts between motorised transport, cyclists and pedestrians. Lack of facilitation for cyclists at intersections might cause accidents and feeling of unsafety. Primary sources: Approved zoning plan, maps, and fieldwork
Accessibility by public transport	x	One bus stop, along Klostergata with frequent routes to central destinations (the city centre, train station and more). Access by bike along sidewalks and main intersection, no bike parking. Short cycling distance (2,5 km) to Skien train station. Primary sources: Approved zoning plan, fieldwork, public transport timetables

(Continued)

Table 4. (Continued).

CATEGORY: NATURAL AND PLACE-SPECIFIC PRECONDITIONS		
Accessibility by car	X	Situated along the main road, the planned development is highly accessible by car. Minimum parking restrictions for various amenities but no maximum numbers limit the potential effect on reducing car usage. The mix of underground parking and parking garage facilitates driving and contributes negative to the competitiveness of cycling versus driving. A toll system is implemented in the region, reducing competitiveness of driving. Internal street network of shared space might reduce attractiveness of driving as compared with street and roads. Primary sources: Approved zoning plan, fieldwork
Level of bikeability infrastructure and traffic: Somewhat bikeable		
In total, the infrastructure and traffic in Klosterøya are assessed as contributing to a somewhat bikeable area. There are various cycling (and walking) routes (existing and planned) through and within the island, which heighten internal connectivity and support cycling. No planned separation between pedestrians and cyclists can create conflicts, however. Klostergata is to be given a stronger 'street' character, but high traffic volumes and noise levels seem unpleasant for cycling through the island. Internal streets are planned as shared spaces that are not purely positive for cycling. The main junction providing access to the site from Klostergata is cycling unfriendly. Bike parking and easy access by car will lead to a high level of driveability, weakening cycling competitiveness. In the local context, the island is highly accessible by public bus transport with good connections to the city centre, the city terminal, and other districts; the combination of PT and bike seems less facilitated.		
CATEGORY: URBANITY		
Density	X	Dense (relative to the local context) and concentrated urban area having the potential of contributing to high cycling shares. Primary sources: Planning documents, fieldwork
Proximity	X	Short internal distances enable cycling as an everyday modal option, and existing and planned connections increasing proximity and accessibility. The urban area of Skien and the city centre of Porsgrunn is covered within 30 minutes by bike. Primary sources: Maps, open-access basic cycling accessibility tools, planning documents
Urban structure	X	Compact, urban built environment with dense and quite high-rise buildings, a street network with a grid-like structure on the east side and several public spaces of varying character – all with a human scale. The total volume of public spaces seems small in relation to the multiple purposes planned for. The west side has a less defined urban structure, but the waterfront provides a structure. Larger park areas are included in the plans. Primary sources: Planning documents, maps, and fieldwork
Permeability	X	The elevated main road is a barrier for permeability, reopening non-motorised tunnels under the street should improve internal permeability but only 2 out of 5 realisable. High permeability within the already developed part, the final building structure in the eastern part and its influence on block size is yet not given. Primary sources: Planning documents, maps, and fieldwork

(Continued)

Table 4. (Continued).

CATEGORY: NATURAL AND PLACE-SPECIFIC PRECONDITIONS		
Level of bikeability urbanity: Very bikeable		
<p>In total, the urbanity of Klosterøya is assessed as contributing to a very bikeable area. Cycling is a viable option due to short internal distances and proximity between destinations on site, to the city centre, and to surrounding neighbourhoods. The plans should result in a compact, urban development with attention given to human scale, with streets, plazas, and parks, providing good cycling experiences. Existing and planned bridges will increase accessibility and connectivity to and from the island, strengthening cycling-competitiveness. Planned and built buildings are dense and quite high rise compared to the local context, although still on a human scale. Reopening tunnels under the main road Klostergata should ensure internal permeability. The grid-like structure on the east side is positive. The west side is less defined, but the waterfront provides a structure. Several public spaces of varying character are positive for bikeability, but the total volume seems small.</p>		
CATEGORY: SURROUNDINGS AND ACTIVITIES		
Destinations, activities and functions	X	<p>Planned as an active part of Skien and the city centre, mixing commercial enterprises, cultural and educational institutions, and dwelling.</p> <p>Many buildings will apparently have active facades and ground floors – positive for the liveability of the public realm and inviting for active travel.</p> <p>Primary sources: Planning documents, maps, fieldwork</p>
Maintenance		<p>Seemingly good operation and maintenance of existing cycling infrastructure, important for attractiveness and competitiveness for cycling. As the transformation is ongoing we refrain from assessing this category.</p> <p>Primary sources: Planning documents, fieldwork</p>
Perceived safety	X	<p>Main cycling route along Klostergata might be perceived as uncomfortable for cycling (and walking), primarily related to traffic volumes and lack of separation from pedestrians. The shared space streets might also contribute to conflicts between cyclists and other users which may influence perceived safety.</p> <p>Mixed uses are likely to contribute to a feeling of safety in public spaces due to people present at various times of the day.</p> <p>Primary sources: Planning documents, fieldwork</p>
Wayfinding and signs	X	<p>Easy wayfinding due to a relatively comprehensible and transparent public space, an easily navigable and compact urban area, with different parts of the area having distinctive characters (closeness to water, existing greenery, planned larger parks, historical buildings, etc.) Details regarding cycling signage are not assessed.</p> <p>Primary sources: Planning documents, fieldwork</p>
Design and aesthetics	X	<p>Main route along the main road not very inviting. Several alternative routes along green and blue connections allow cyclists to choose according to their preferences and needs, including pleasant surroundings where it is easy to orient themselves. Qualities related to closeness to water, existing greenery, and historical buildings are mostly preserved, giving the island a distinctive character. Not all details concerning design and aesthetics are in place, but the developer appear highly interested in creating attractive surroundings.</p> <p>Primary sources: Planning documents, maps, fieldwork</p>
Street or road character	X	<p>The main road, Klostergata, links Klosterøya with the mainland. Parts have a road-like character, others a street character with buildings 'right up to' the street. The 'street'-character is suggested strengthened in the approved plans which is good for cycling experiences, but still seems car-oriented due to traffic levels. The internal street network being planned as streets with sidewalks or shared space – street features that might make cycling possible and pleasurable. The elevated Klostergata is a barrier for establishing an internally dense, gridded street network.</p> <p>Primary sources: Approved zoning plans, maps, fieldwork</p>

(Continued)

Table 4. (Continued).**CATEGORY: NATURAL AND PLACE-SPECIFIC PRECONDITIONS**

Level of bikeability surroundings and activities: very bikeable

In total, the surroundings and activities in Klosterøya are assessed as contributing to a very bikeable area. However, not all relevant details are given in the plans. The transformation is planned as an active part of Skien and the city centre, mixing commercial enterprises, cultural and educational institutions and dwellings. The likelihood of people being present at various times of the day contributes to the attractiveness and feeling of safety in public spaces. Many buildings will apparently have active facades and ground floors – positive for the liveability of the public realm. A relatively comprehensible and transparent public space strengthens wayfinding. Qualities related to closeness to water, existing greenery, and historical buildings contribute to pleasant surroundings.

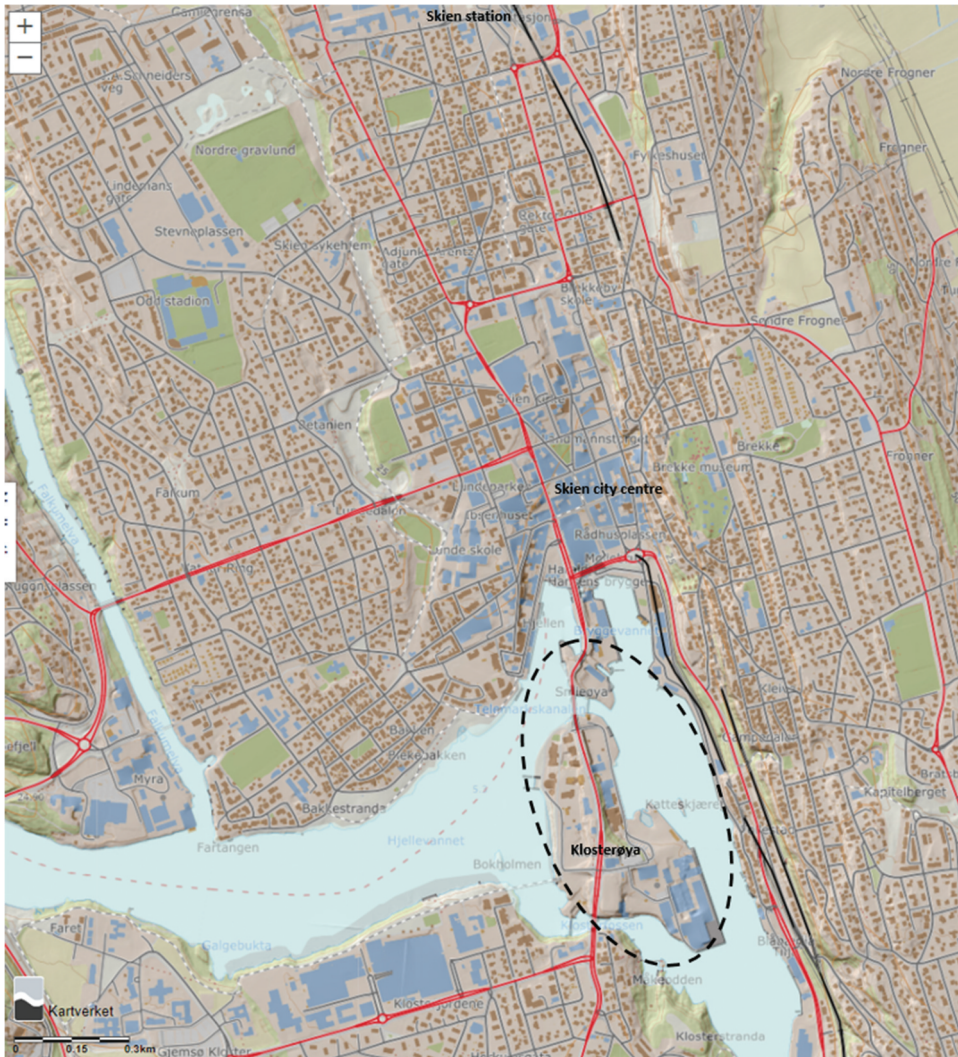


Figure 7. Natural and place-specific preconditions include topography, here assessed through open-access elevation data from the Norwegian mapping authority and fieldwork. Klosterøya is relative flat, but the hilly surroundings and cool winds from the water can, however, be a barrier for cycling.



Figure 8. The elevated Klostergata is a barrier partly reduced through reopened tunnels connecting the eastern and western parts of the island of Klosterøya.



Figure 9. Alternative biking routes in pleasant surroundings at Klosterøya. The city centre of Skien is easily visible and which strengthens wayfinding.



Figure 10. Biking along the main road Klostergata separated from motorised traffic, but in a car-oriented environment.

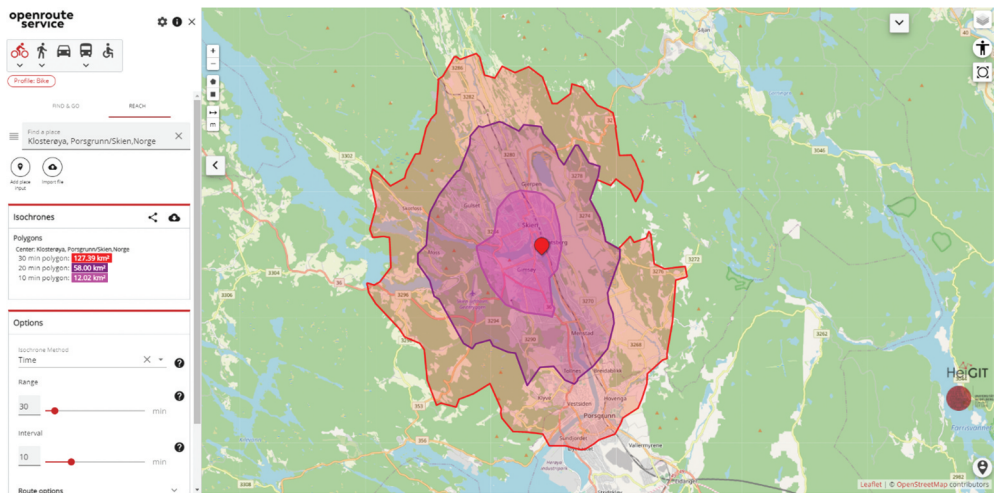


Figure 11. Open-access tools used to illustrate cycling accessibility from Klosterøya. The reach based on cycling time is illustrated in 10 minutes' intervals based on Openrouteservice, developed and provided by Heidelberg Institute for Geoinformation Technology (HeiGIT), which offers routing services by using user-generated, collaboratively collected free geographic data from OpenStreetMap. Source: <https://maps.openrouteservice.org/>.

then for the planned transformation and its catchment area as a whole. The findings are provided in Table 4. Figures 7, 8, 9, 10 and 11 illustrate some assessed attributes.

We found that the planned transformation of Klosterøya has the potential to produce a bikeable area. The category natural and place-specific preconditions was assessed as bikeable. Central localisation in the city and region (see Figure 7), new connections to surrounding neighbourhoods, and relatively low outward commuting provide good preconditions for bikeability. Within the site, the topography is relatively flat, but the elevated main road dividing the island into two parts is a significant barrier. The hilly surroundings of other parts of the city (though relatively easy overcome with e-bikes) and cool winds from the water can be a barrier. Attributes regarding infrastructure and traffic were what primarily reduced overall bikeability (assessed somewhat bikeable). There is no planned separation between pedestrians and cyclists, which can lead to conflicts (already an issue). Overall, the planned cycling network appear under-dimensioned, considering the intended increases in cycling shares. Due to the main road (Figure 10) the site will be highly accessible by car. Combined with a lack of parking restrictions and inadequate cycling infrastructure, this reduced the competitiveness of cycling (and other sustainable modes) to that of driving. The planned urbanity is likely to produce a very bikeable built environment with relatively high density and good walking and cycling connections to neighbouring districts, which increases proximity and accessibility. However, the elevated main road reduces the overall urbanity and connectivity. See Figure 8. The planned surroundings and activities, with a mix of functions, several plazas and parks, and a waterfront, are likely to contribute to a very bikeable environment. As the site is under development and adjustments and detailing of the plans are still being made, there were uncertainties regarding the level of bikeability for some attributes, for example, which and where 'everyday' amenities will be located as well as the final urban structure. The final level of bikeability might yet be tipped in a more positive or negative way after completion.

5. Discussion

Our aim was to develop a methodology for a holistic, qualitative bikeability assessment of built environments, suited to address a stretch, a neighbourhood in a city, and other smaller or larger built-up areas, and employable by practice and research. Overall, we believe that we succeeded in this. In the following section, we reflect on our experiences employing the methodology, including strengths and weaknesses and further development, as well as other possible uses for bikeability assessments.

5.1. Experiences

The methodology is systematic and structured, with a clear definition of which attributes to assess and criteria for high or low bikeability performance. Combined with a required detailing of how conclusions are reached, this strengthens transparency and reliability. Attributes are evaluated through an iterative use of maps, aerial photos, and secondary data sets together with document studies and fieldwork for a thorough assessment. The approach does not need specialised tools, enabling local planners to undertake assessments themselves. The holistic nature of the methodology aligns with how practitioners tend to approach site analyses in urban planning, although it is more structured and with a particular focus on cycling. This increases its applicability in their work. The methodology is likely best suited for use by those with some experience in urban and/or transport planning and a certain understanding of how people interact with and are affected by the built environment. Some familiarity with site analysis might be an advantage.

We have demonstrated two possible uses of the methodology. It was, to some extent, easier to assess an existing urban area than a planned transformation due to uncertainties about the final outcome of the latter, as not all details are given in the zoning plans. Adjusting an assessment to the local context is very important, which the descriptive levels of bikeability-performance allows for. As with most methodologies, the assessment can be time consuming. We do not find this excessive compared with other approaches, but it might be a barrier for use. To avoid a prolonged and complicated assessment, it is important to properly define the site and its catchment area and scope to determine the right level of detail and geographical scale. The methodology is adaptable to different urban contexts and purposes, as shown through the examples. When assessing larger areas, selecting central cycling stretches and destinations is advised to reduce fieldwork time. We recommend fieldwork done by bike, to allow for cycling longer stretches and to actually experience cycling in the local context. Walking through the site allows for in-depth registrations of selected attributes. Driving can be an alternative for understanding the regional context. However, we underline that this methodology is developed for assessments of stretches, neighbourhoods and other built up areas, other approaches may be better suited for larger-scale assessments (e.g. city level). Basing assessments on fieldwork as well as existing secondary data, information from standardised and open accessible sources, etc. further reduces the required time, as less details need to be collected in the field. It should be noted that the availability of such data has increased rapidly in Norway; this may not be the case in other contexts.

An aspect potentially subject to critique is how the methodology largely depends on the assessor's professional, qualitative judgment. Some might consider this less transparent and reliable than the use of quantitative approaches with numbered scores. Knapskog et al. (2019) made a similar note regarding their walkability assessment. One way to ensure that the assessor's

professional judgment strengthens reliability is for the assessment to be made by multiple assessors, first separately, then jointly for comparison and adjustments. A potential lack of consistency should then result in a new assessment, which fits well with the iterative assessment process. Another way of supplementing the judgment of the assessor(s) is to include the user's perspective through interviews and/or surveys. This can provide complementary perspectives, for example, how inhabitants experience and perceive cycling or how relevant actors (region, municipal, developers, etc.) consider the built environment for cycling. In the Sauda example, existing surveys provided insights on perceived safety. If done as a basis for an assessment, questions could be adapted such that the answers would inform the assessments. The need to undertake interviews and surveys depends on existing data and analyses and available time and resources.

5.2. Possible areas of use

In this study, we demonstrated the use of the bikeability assessment with two examples. Bikeability assessments of existing environments should inform different levels of planning and policy making to ensure that cycling is both possible and pleasurable through further development of the land use and transport system. Having sound knowledge about the local context and the 'state of things' is important to identify interventions that efficiently address barriers and challenges for cycling through long- and short-term strategies and investments. The four categories offer a systematic approach to do so across disciplines and scales, providing a basis to establish an 'action plan' to promote cycling. The assessment of Sauda permitted the identification of opportunities and barriers to cycling. This is, amongst others, used by the municipality as a knowledge base when developing their local cycling strategy with measures and strategies to facilitate and promote cycling. The methodology could also be used to compare the bikeability of areas within a city or in different cities, but comparisons across cities must account for different local settings.

In planning and design processes, early decisions can significantly influence the end result's characteristics (e.g. a highly bikeable built environment) (Rynning, 2018). Assessing a site's current bikeability at the beginning of a process can help identify important measures and strategies needed to facilitate cycling. A bikeability assessment of a planning proposal for an urban development can be used to strengthen the project's capacity to promote cycling. Our assessment of the Klosterøya development identified shortcomings in the plan regarding achievable level of bikeability. Including a bikeability assessment in the environmental impact assessment could contribute to explore the extent to which the plan ensures a built environment that is both possible and pleasurable for cycling. Another prospect for use is early- or mid-stage assessments to identify key features for a project to achieve a high level of bikeability, which must then be included and made legally binding through the zoning plan and planning provisions. If done before planning approval, mitigating measures could be added. If addressed after planning approval, as the case for Klosterøya, the assessment could serve to identify interventions to address in forthcoming, detailed zoning plans or in building applications. Developers' and municipalities' willingness to prioritise cyclists and strengthen bikeability, and thus to undertake assessments, is a key point in this. One could envision bikeability assessments (as well as walkability assessments) becoming a requirement in planning processes to strengthen urban developments as a strategy to promote sustainable mobility. Another possible use is in combination with similar assessments of walkability and driveability to explore the extent to which urban transformations can be a catalyst for sustainable travel behaviour, particularly by increasing the competitiveness of walking and

cycling to that of driving. This feeds into a larger discussion on how to ensure that the set goals and objectives for a sustainable mobility shift are enabled through urban planning and development. We do not pursue this here but invite further deliberations.

5.3. Further developments

The methodology can be further developed through the use of GIS. Although this requires specialised tools, it may be relevant for those with such competence. In our assessments, we used open-access data and basic analytical online tools from local and national websites to evaluate some of the attributes in question. A more systematic GIS approach could be useful, though perhaps for larger assessment areas than those demonstrated here. Layering of datasets through GIS-analyses could be used to, for example, identify and illustrate densities, travel distances, and the presence or lack of cycling infrastructure, and how various features overlap. Utilising GIS in combination with a qualitative assessment is also a feasible approach, where city-level GIS-analyses can be used to select areas for more in-depth fieldwork. There are, however, some aspects that hamper the use of GIS-tools. First, the need for specialised knowledge that smaller municipalities might lack, both in terms of making or requesting such analyses. Second, for relevant GIS-analyses, appropriate datasets are needed. In Norway, standardised datasets exist, but their quality must be assured prior to analyses. A cycling network should, for example, not only contain all bikeable paths, but preferably also their design and quality. Ensuring this is time consuming, as the standardised datasets do not contain all the information needed. Third, the lack of empirical knowledge on bikeability in Norway (and other contexts) is a significant hinder for GIS use. Few studies link built environment characteristics with actual cycle shares and people's opinions of cycling, given these qualities and characteristics. Consequently, we do not know, for example, which levels of density contribute positively to cycling in various urban contexts, especially for small cities. Better empirical knowledge can render GIS-analyses a valuable part of an assessment. Until this is available, we believe that combining the described qualitative approach with GIS for selected parts of an assessment could be interesting, although not of major importance for further methodological development and use. More empirical insights could, furthermore, make it possible to define reliable thresholds for levels of bikeability (as commented in [sections 2 and 3](#)).

An interesting possibility with GIS is combining geocoded 'hard' information from register data and geospatial data with geocoded 'soft' knowledge from users (i.e. experience of cycling in an area) gathered through public participation GIS-tools to analyse connections between the two (see e.g. Kytta, 2012). The suggested surveys and interviews to supplement the judgment of the assessor could provide valuable inputs and new empirical insights if used in this way. Combining qualitative approaches and quantitative measurements of built environment attributes in GIS with local cycling shares, surveys and interviews with local cyclists and non-cyclist can provide valuable knowledge about causal influences between cycling and built environment (Næss, 2016).

6. Concluding remarks

If people are to cycle more, the larger majority must view cycling as possible and pleasurable (Rynning, 2018; Stefansdottir, 2014). To this end, cycling must be facilitated by improving or ensuring the bikeability of the built environments. Urban planning and development represent opportunities to make people cycle more through changing the spaces and surroundings in which people cycle in or through. Addressing attributes and knowledge across the fields of

urban design, public health, engineering, safety, politics, and transport economics is key in cycle-planning (McLeod et al., 2020; Wang & Wen, 2017). In this study, we demonstrated a structured and holistic methodology to qualitatively assess bikeability, intended as a contribution to this. By translating empirical knowledge on the relationship between cycling and various scale built environment characteristics to a specific context, sound knowledge about the 'state of things' can be derived. This is important to efficiently address barriers and challenges for cycling through long- and short-term strategies, planning, and investments, as well as to inform different levels of urban form policies. We believe that our methodology can contribute to this. The four categories with associated attributes and their performance in terms of level of bikeability offer a systematic approach to identifying the challenges and shortcomings to cycling. Addressing these attributes and categories provides insights at various scales and across disciplines, conditions needed to address to improve built environment bikeability (McLeod et al., 2020; Nielsen & Skov-Petersen, 2018; Wang & Wen, 2017). Through applicable examples, we found that the methodology can be adapted to different urban contexts, geographical scales, and to different purposes. Assessments can be used alone or in combination with other explorations and insights to establish a knowledge base for cycling planning and facilitation. Feedback from practice supports this. Relevance and usability for practice was a key criterion. We believe we have achieved this, for example, through the lack of need for specialised instruments, and the use of open-access information for the assessments. This addresses some of the criticisms of many accessibility and transport planning tools, as stated earlier.

Continued use by research and practice could provide more empirical knowledge on cycling and bikeability from different urban contexts, which will be important for cycling promotion through urban planning and development. As new insights become available, the methodology must be updated to ensure that it remains valid and reliable. We will continue to do so and welcome others to contribute to it.

Notes

1. We use the term bikeability in relation to physical and built environment characteristics and features, not in terms of physical ability or skills to bike (McNeil, 2011; Nielsen & Skov-Petersen, 2018).
2. We use the term drivability to describe built environment characteristics associated specifically with car use (Den Braver et al., 2020).
3. Data on inhabitants and commuting based on Statistics Norway 2020. <https://www.ssb.no/kommunefakta>.
4. Data on inhabitants and commuting based on Statistics Norway 2020, <https://www.ssb.no/kommunefakta>.

Authors' contributions

The authors both contributed to the study conception and design, the methodological development and the assessments. The paper was written by both authors, and both read and approved the final manuscript; they are listed alphabetically for simplicity.

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