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A Spatial Analysis of City-Regions: Urban Form & Service Accessibility

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Executive summary

This project was completed on behalf of the Nordic working group for Green Growth – sustainable urban regions under the Nordic Committee of Senior Officials for Regional Policy, Nordic Council of Ministers. This working group focuses on how spatial planning can support the development of attractive and sustainable city-regions, along with contributing to the development of beneficial tools for city-regional planning.

To understand the urban form of a city, planners must engage with questions of density, land use distribution, and accessibility to services and amenities. These issues, in turn, relate to critical strategic planning goals, such as regional equity, attractiveness, and environmental sustainability. In this text, we seek to test a new methodological approach that can be used to measure several of these dimensions. In doing so, we provide a spatial analysis of population density, service accessibility, and commuting pattern metrics of four case study areas in the Nordic Region: Funen (DK), Stockholm (SE), Tampere (FI) and Trondheim (NO). This analysis is applied with the following general principle in mind: where many types of services, public transportation and other amenities that people take benefit from in their everyday life are available within a convenient time distance, we can talk of well-functioning nodes in the urban form of a city. By considering this principle in relation to the urban patterns that are mapped, we aim to determine how our analytical approach can be relevant for strategic planners working at the municipal or regional level.

Included within our analysis are maps and visuals for each city-region that allow for comparisons of population density, commuting patterns, service accessibility, and public transport accessibility. Our research also involves the use of open-source data on residence locations, routing information, amenity and service point location, and public transport offerings, which in turn allows for providing findings on the issue of Nordic urban data availability. In order to clearly display ‘accessibility’ based on non-car forms of mobility, a 20-minute time/distance threshold, based on an average walking speed of 4 km/h, was selected for mapping the results. For determining public transport reachability, we determined how many public transportation

trips were accessible within 500m by each person per municipality. These thresholds were agreed upon with local stakeholders in each of the case city-regions.

Being that our spatial focus is on cities in a functional perspective, a first step in our research is to define the city-regional extent for each of the four study areas. This is itself a complex process, however. In general, the term “city-region” refers to a ‘functional’ urban and economic agglomeration, often defined in reference to the relative accessibility of central urban areas and employers. Given the need to apply this definition in practice, we analyzed each area according to three common spatial delineations of city-regions: Functional Urban Areas (FUAs) and Local Labour Markets (LLMs). Urban Morphological Zones (UMZs) are also included within our maps and wider analysis. However, the UMZ offers a strictly spatial delineation of the specific urban areas within a city-regional perspective. This is in comparison to the FUA and LLM delineations, which identify the city-regions according to assemblages of administrative areas (municipalities). Local stakeholders for each study area were then introduced to the above city-regional perspectives and were asked to thereby define the most appropriate study area / definition for each city-region.

Within our maps of population density, the wide variation of population size and geographical scale between the city-regions is clearly displayed. Stockholm, as the only study area with local rail-based public transportation, contains a well-connected series of high density nodes radiating outwards from the city-centre. A similar type of settlement pattern is visible in Trondheim and Tampere, where a clear city centre is connected to smaller settlements along main transportation corridors. Settlements in Funen appear more dispersed, separated by agricultural and natural landscapes. In all cases, topography (water, elevation, etc) is an underlying driver of settlement structure.

Our visualizations of commuting patterns in each city-region show that, in all cases, the core is a dominant recipient of commuters from surrounding areas. This trend is the strongest in Trondheim and Tampere, where all municipalities have their dominant commuting flows to a main urban core. By contrast, in

Stockholm and Funen, it is clear that city-regional sub-centres (such as Solna and Svendborg) are operating as individual labour markets/commuter catchments.

Utilizing data for service accessibility in our maps reveals more nuances regarding the urban form of each study area. Compared with the patterns of population density and commuting, urban service nodes are more visible and clearly defined. Service areas are highly concentrated in central consumer catchments; suburbs, by contrast, contain more monofunctional tracts of housing, which will often require car transport for effective service access.

The service accessibility mapping also reveals many smaller functional urban areas within the larger city-regions of Stockholm, Tampere, Funen, and Trondheim. Norrtälje in Stockholm, for example, appears to function as its own service catchment and settlement area, along with Svendborg in Funen and a large number of more disparate communities in Tampere and Trondheim.

When considering a population-weighted measure for service accessibility (i.e., focusing on where a majority of people live in each municipality), it seems that Stockholm and Funen have the most balanced pattern of service development. Trondheim sticks out within our results for its very low levels of average service accessibility. This implies that, compared to the other cases, a high share of the people in the Trondheim city-region have few services close to them. This also implies that a large portion of people in Trondheim live in suburban or rural areas. By comparison, Stockholm clearly outperforms all other study areas in terms of the average number of services that the population has good accessibility to.

To further augment our analysis of service accessibility, we have mapped our calculations of public transport accessibility for each city-region. This is displayed both on its own and in combination with population data to show cases where population density and public transport are not aligned. When comparing the mapsets for each city-region, only Stockholm appears to have a public transportation network that closely resembles the distribution of services. Due to its extensive rail-based transport services, Stockholm also con-

tains, by far, the most frequently used public transport network. In Funen and Tampere, by contrast, smaller communities lack sufficient public transport links with the city centre. In both cases, only the city centre itself appears to be well-served by public transport. Trondheim displays a wider distribution of daily trips/public transport access, especially along its main regional transportation corridors. This appears to include their more widespread use of bus commuting from second-order urban nodes outside of the city center.

Our methodology, presented here within a pilot study, has the potential to provide new, valuable knowledge for planners, investors, and public actors. Critically, ‘mismatches’ in urban development structures can be identified. This can be seen in areas with good service/public transport accessibility but low population density, therefore offering infill urban development potentials. Conversely, ‘service gaps’ can also be seen in areas with high population density but poor service/public transport access, therefore indicating areas where policy can support better service distribution.

The application of high-resolution spatial data is another factor that makes our methodological approach unique. However, differences in the availability, openness, and quality of data between countries can make adaptations of our method for comparative analyses challenging. There is potential for greater Nordic cooperation on common spatial data infrastructures, which could provide researchers and policymakers with more tools and indicators for city-regional development.

We also caution against expanding our analysis for ‘benchmarking’ between Nordic city-regions. Competitive comparisons of different city-regions are difficult to properly contextualize and often provide little in the way of action-oriented results. Rather, we recommend that future applications of our methodology focus on a deeper analysis of local socio-economic phenomena within a single regional entity, be it a city, region, or even a national context. In particular, we contend that visual maps of service distribution and transport intensity could provide an engaging way to frame broader discussions on urban socio-spatial inequalities.

1. Introduction

Countless components and perspectives of cities can be spatially analysed. For example, the streetscape of a single urban block – what you see as you walk down the street – is a type of urban form interpretation. So too are the patterns of buildings and landscape designs that characterise urban spaces. There are also a number of ways to analyse the urban form across an entire city-region, and with them comes a more generalised conceptualisation of urban form. For instance, accessibility or connectivity analyses often investigate urban mobility and transportation in relation to residential, workplace and/or building density. Here, GIS (Geographic Information Systems) has become an increasingly relied upon tool to practically implement this wealth of analytical approaches and perspectives on urban form. In particular, this information can complement existing knowledge of land use planners and regional development workers to make more informed strategic development decisions.

An important role for strategic planners working with urban sustainability is to understand how a city's urban form – including questions of density, distribution of land uses, accessibility to services and amenities, etc. – relates to key strategic planning issues such as regional equity, attractiveness and environmental performance. In response, this paper will provide a concrete and thought-provoking understanding of city-regions in the functional perspective of service accessibility. We will pilot-test a spatial accessibility analysis of public and private services that local residents consume within their everyday lives - using the assumption that: where many types of services and other amenities that people take benefit from in their everyday life are available within a convenient time distance, we can talk of well-functioning nodes in the urban form of a city. In carrying out the analysis in four case areas we will also be able to describe different types of spatial definitions of city-regions, as well as assess the availability of detailed urban spatial data in the Nordic Region.

The aim of our work is to present a new way of analysing accessibility to services in cities using different types of open-source data at the city-regional scale. We utilize four city-regions in different Nordic countries to map and analyse the distribution patterns and reachability of urban amenities (e.g., restaurants, schools, shops, etc.) throughout the city.

The following main objectives follow-up on this aim and are presented sequentially with respect to the research process:

1. to compare existing approaches to spatially defining city-regions from the OECD, EEA and Nordregio, and to use them to define the city-regional delimitations for our analysis;
2. to test and develop a new methodology for the spatial analysis of service accessibility in cities. This will pair open data with GIS technologies to measure the accessibility (that is, reachability) of selected urban amenities and public services; and
3. to support the further use of urban spatial analysis in Nordic urban planning by providing new, visual and engaging research results, as well as a critical assessment on the issue of data availability.

The following section will present our methods and research approach, articulating how and why our approach to urban morphology is useful and significant. After this, we engage with an understanding of functional city-regions from the spatial perspective, which will include a process of analysis that defines the study area of the four case studies presented in this report: Funen (DK), Stockholm (SE), Tampere (FI) and Trondheim (NO). This will lead into the presentation of population density, service accessibility, and commuting pattern metrics for each case study area. We will then conclude with a discussion of main findings and future research opportunities.

2. Method

In terms of our research approach, this will be a type of urban morphological analysis, where urban morphology is understood as “the study of form and structure in cities that focuses on the dynamics of change and rules underlying these dynamics” (Batty, 2013, p. 179). The basis of urban morphological analysis is that urban form matters for many urban development issues, including: resource consumption and greenhouse gas emissions, resilience, attractiveness, infrastructure efficiency, public transportation effectiveness and land value.

While using new types of data and innovative GIS analytical methods, our approach to analysing urban form is based on the general assumption that: where many types of services and other amenities that people take benefit from in their everyday life are available within a convenient time distance, we can talk of well-functioning nodes in the urban form of a city. It is an analysis that scopes the spatial makeup of cities in a way that accentuates the everyday life of people, whether we are considering people tending to the balance between work and domestic affairs, families with children in school, or those outside the workforce.

Our analysis depends on the availability of four fundamental spatial data components:

1. The location of residences. We use the best and latest available population data at grid level. This shows the distribution of people at grid resolutions between 100 m and 250 m. This was obtained for all areas in the defined study areas, with the exception of Uppsala and Trosa municipalities, in the Stockholm case area, where data quality was insufficient for our study.
2. Routing information. This accounts for the streets, walkways, pathways and other established routes for people to move throughout the city. OpenStreetMap (OSM) network data was used, and the pgRouting open source routing library was used for executing the routing algorithms.
3. Location of amenity and service points. Amenities and services are seen as the collection of public and private (commercial) offerings that are needed to sustain a good quality of life. Which specific amenities to include in the analysis was one of the first considerations when we began our study. In dialogue with stakeholders in the local areas of our study, our objective was to identify which specific amenities and services, when put together, describe a well-rounded set of essential features in the city. Likewise, we wanted to balance an objective for covering a wide range of amenities and services while at the same time narrowing the search to a manageable list. We therefore identified five key sectors, each with two components. Through these ten components, there were 20 individual amenities or services included in the analysis (Table 1).
4. In order to conduct an assessment on data availability for this type of analysis, a prerequisite was to only include amenity and service data that could be obtained non-commercially. We also aimed to have 100% coverage of all amenities. Multiple cross-checks were applied in each study area, conducted by comparing location points of multiple data sources, most typically OpenStreetMap, Yellow Pages (e.g. Gula Sidorna) and Google Maps.
5. The location of public transportation offerings in each of the four study areas. This basic analysis requires spatial data with all stop/station locations and timetable data showing the intensity of traffic at each stop. In the cases of Tampere, Funen and Stockholm, the public transport frequencies for business days were calculated from openly available GTFS (General Transit Feed Specification) timetable data and attached to corresponding stop/station locations. The data was obtained from the following sources: www.trafiklab.se (Stockholm), Region of Southern Denmark (Funen) and the Finnish Transport Agency (Tampere). As for Trondheim, the public transport frequencies were estimated from route-specific trip intervals at different times of the day, originally created and provided by Trondheim Region.

Table 1: List of Amenities and services considered in the study. Detailed data sources are available in Appendix 2.

Sector	Component	Amenity/Service
Culinary	1.Restaurants	Restaurants
		Bars
		Cafes
	2.Grocery	Grocery stores Convenience stores
Culture and leisure	3. Fitness	Fitness centers / gyms
	4. Arts	Swimming halls
		Cinema
		Theatre Library
Health	5. Hospitals	Hospitals
	6. Clinics and pharmacies	Clinics
		Pharmacies
Education	7. Pre-school facilities	Day-cares Kindergartens
	8. Schools	Primary
		Secondary
		Tertiary
Commerce	9. Banks and ATMS	Bank ATM
	10. Postal offices	Post offices or kiosks

Choosing study regions and utilizing stakeholder interaction

To choose which city-regions to carry out our analysis in, we first had the objective to test our overall approach in four different Nordic countries and to try and select cities with a mix of population sizes. We then identified potential cities based on these criteria and where our previous work in the Nordic Working Group had developed a network with local or regional planning agencies. From this, Funen, Stockholm, Tampere and Trondheim were selected. In Funen, Region Syddanmark had voiced a wish to find collaboration opportunities with Nordregio and the Nordic Working Group. It was a similar situation in Stockholm with the Growth and Regional Planning Administration (TRF), and in Trondheim where the Trondheim Regional Authority is represented within on the working group advisory board. Tampere was selected based on previous cooperation with the Tampere Region, as well as their existing GIS experience in implementing the reachability analysis for the creation of their revised regional development plan.

The personal connections with at least one planner at the regional development authority in each case area served as the stakeholder group for the project. They

were instrumental during one workshop together with the working group in April 2015, as well as during ongoing email and telephone communication throughout the project's implementation. In particular, their input was used during the workshop to define the specific study area, or city-regional delimitation, in each case area (see next section for further elaboration of this process). They also helped us determine which public and private services to include in the accessibility analysis and supported us with collections of basic population and public transportation data.

GIS methodology

The methodological core of this urban spatial analysis is that of network analysis, or its subfields of service area / market area analysis. Network analysis is the study of relations between discrete objects, rooted in graph theory (See for instance, Alekseev et al. N.D.). In the field of geographic information systems (GIS), network analysis typically concerns relations of objects in a "graph", typically based on a traffic system network and corresponding spatial data (Fischer, 2004). Network analysis is the basis of many common GIS analysis and processing tasks, the most important being possibly that of routing, used e.g. in web map services and

navigators. Simple routing analyses can be further refined into analyses of service or market areas, or of accessibility to any spatially defined object, among others. Typical GIS-based service area analyses are almost always based on graph theory.

Open GIS and open data (especially open spatial data) has enabled an increasing utilization of spatial analysis in planning tasks. In this project, the network used in the analysis was created from spatial data on local traffic networks, acquired from OpenStreetMap (OSM), a collaborative open database project for creating a free map of the world. The data was downloaded from GeoFabrik, a company who create regular extracts of the latest OSM data (which by nature is continuously updated) for free download.

In order to be used in network analysis, raw OSM network data must be converted into a routable network (a graph, its nodes and edges/paths and different rules between these). This can be achieved in multiple ways, but here the open osm2po converter was used. Its algorithm stores the graph as spatial SQL data. A project specific Python programming script was created that utilizes the open PostgreSQL database system, its spatial extender PostGIS and pgRouting extension to calculate routing algorithms using OSM data. The script was run in the open GIS software Quantum GIS (QGIS). The routing algorithm used here was a variant of Dijkstra's algorithm¹, possibly the most used routing algorithm for calculating shortest paths between graph nodes. The algorithm can take into account different "costs" along the network, based on which a so called cost distance can be calculated. Distance is then the property of the traffic network used as a "cost" parameter. As a fundamental aspect of urban sustainability involves non-car forms of mobility, we selected a

20 minute time/distance threshold based on an average walking speed of 4 km/h. The 20 minute threshold was decided upon during meetings with local stakeholders in each of the case areas. Also, it was necessary to have a single accessibility measure, as our method was not able to straightforwardly incorporate multiple forms of mobility, such as cycling, public transportation alongside walking. This is not to discount the importance of multi-modality in cities, but is instead a limitation of the study. Likewise, our rationale for extending the walking time-distance threshold to 20 minutes was to indirectly account for the fact that many short trips can include these other forms of mobility.

Put simply, the routing algorithm calculates shortest paths from a given set of points, in this case locations of services, and finds the paths and nodes of the network that can be reached within the given cost limits. As we were interested in the areas that can be reached, so-called alpha shapes were created for these nodes of reachability; in other words, these shapes were minimum enclosing polygons for the furthestmost reachable network nodes from each given service.

Data on service locations was primarily collected as address listings, subsequently geocoded into spatial point data. The main data sources were OpenStreetMap, municipal and other authority sources, open data portals and portals for specific commercial services. Many of the addresses were double-checked against commonly used service directory web maps, especially Yellow Pages (GS, fonecta.fi). In total, 19 987 service amenities were mapped: 2 408 (Funen), 13 808 (Stockholm), 2 056 (Tampere) and 1 715 (Trondheim). Specific data source(s) for each service or amenity in each region are shown in Appendix 2.

¹ Dijkstra algorithm. M. Hazewinkel (originator), Encyclopedia of Mathematics. URL: http://www.encyclopediaofmath.org/index.php?title=Dijkstra_algorithm&oldid=11354

3. Defining city-regions

While planning decisions and subsequent actions are usually defined in the context of some sort of political or administrative scale (e.g. municipalities or regions) these boundaries are not necessarily representative of the areas in which flows of people, goods, services and resources through a city take place. By contrast, the term city-region reflects associations of multiple municipalities and scales of government in which responsibility for urban development is distributed, both formally and informally.

Yet the decisions by private sector actors on where to make investments that strongly influence the development of urban form are perhaps even more vital to spatial impacts of urban development. These decisions are driven by many powerful factors that are not always within the reach of steering by formal (public) planning strategy. As a result, a holistic analysis of urban form should also include the spatial scale of city-regions, which accounts for the daily interactions between people and places in the urban network, irrespective of political borders. This is increasingly acknowledged in the policy community as a principle that could or should help to define successful urban governance and policy-making (Pugalis & Townsend 2014). Thus, defining what constitutes the city-region in the context of four case studies is important for both delimiting the study areas of our analysis as well as providing context for the authorities that are involved in strategic decision-making processes (Diş et al 2014).

The term “city-region” generally refers to a functional urban and economic agglomeration that is often calculated in terms of accessibility to urban centre(s). This is defined primarily through detailed data on land use, population density and commuting patterns, which allows the urban structure to be visualised vis-à-vis the municipal and regional structures of cities.

Within policy and scientific communities, there are different conceptualisations of city-regions, which in turn define the spatial extent of the city differently. Therefore, to define the study areas of the four case areas researched in this project, we analysed each area according to three common spatial delineations of city-regions:

1. Functional Urban Areas (FUA): Developed by the

OECD. Shown in dark grey in Map 1.

2. Local Labour Markets (LLM): Developed by Nordregio. Shown in light grey in Map 1.
3. The stakeholder perspective: This is the delineation of city-regions by members of the working group from each case area, utilizing information from FUA and LLM applications, as well as the definitions of Urban Morphological Zones (UMZ). These stakeholder perspectives became the study area for our work and are marked by the green boundaries in Map 1.

Urban Morphological Zones (UMZ) are also shown as the assemblages of gridded data in Map 1. Developed by the European Environment Agency (EEA), a UMZ is “a set of urban areas laying less than 200m apart” (EEA, 2015: <http://www.eea.europa.eu/data-and-maps/data/urban-morphological-zones-2006>). Those urban areas are defined purely from the EEA’s CORINE land cover data from 2006, in terms of the following land cover types:

- Continuous urban fabric
- Discontinuous urban fabric
- Industrial or commercial units
- Green urban areas
- Port areas
- Airports
- Sport and leisure facilities

The UMZ therefore offers a strictly spatial delineation of the specific urban areas within a city-regional perspective. This is in comparison to the FUA and LLM delineations, which identify the city-regions according to assemblages of administrative areas (municipalities).

OECD Functional urban areas

The OECD’s definition of functional urban areas (FUA) uses population density to identify urban cores and travel-to-work flows to identify the hinterlands – whose labour market is highly integrated with the cores (OECD, 2013). The methodology consists of three main steps:

1. Core municipalities are identified through gridded population data, which define high-density clusters. A threshold of 1,500 inhabitants is applied for Europe in contiguous 1 km² grid cells. A municipality is then defined as being part of an urban core if at least 50% of the population of the municipality lives within the urban cluster.
2. While urban cores defined in step 1 provide good approximations of contiguous, highly built-up surfaces, not all the city-regions are characterised by a contiguous settlement pattern (that is, as simple core-periphery settlement patterns). Consequently, polycentric urban structures are identified by relationships among the urban cores, using the information contained in the commuting data. Two urban cores are considered integrated, and thus part of the same polycentric metropolitan area, if more than 15% of the residence population of any of the cores commutes to work in the other core.
3. The urban hinterland is then defined as the “worker catchment area” of the city-regional labour market, and is delineated as any municipality where at least 15% of the employed residents commute to the urban core. Notably, however, only the contiguous core municipalities identified in step 1 are included, while the non-contiguous polycentric cores are dropped.

Local labour markets

Nordregio’s definition of local labour markets (LLM) is similar to the OECD’s approach to functional urban areas, except only administrative data on commuting patterns is used, and lower commuting thresholds are applied (Roto 2012). Centres of LLM are identified if they meet one of the following three conditions: the municipality’s share of out-commuters is less than 20% of its employed residents; there are more places of employment than employed residents; or the highest single out-commuting flow to another municipality is less than 10% of the sending municipality’s employed residents. The objective in defining LLM centres is therefore to identify populous municipalities where people are

mainly living and working in the same municipality.

Secondary LLM centres are also identified if the share of out-commuters is below 25% of the municipality’s employed population AND the highest single out-commuting flow to another municipality is below 7.5% of the employed population. Hinterland municipalities are then defined as belonging to a LLM when their single out-commuting flow to another municipality that is over 7.5% of the employed population.

Applying and delimiting in practice: The project study areas

The application of the UMZ, FUA, and LLM to the four case areas (see Mapset 1, pg. 9; Table 2, below; and Figure 1, pg. 8) was used by local stakeholders, who defined their own delimitation of each area.

Urban land cover represents a distinctly low percentage of the total area of each FUA – from 6.6% in Trondheim to 11.4% in Stockholm. At the same time, there are incredible differences between the shares of urban land cover at the municipal scale within each FUA. For example, while 83.9% of area of Danderyd is within the UMZ in Stockholm, this is as low as 1.1% in the peripheral municipality of Gnesta.

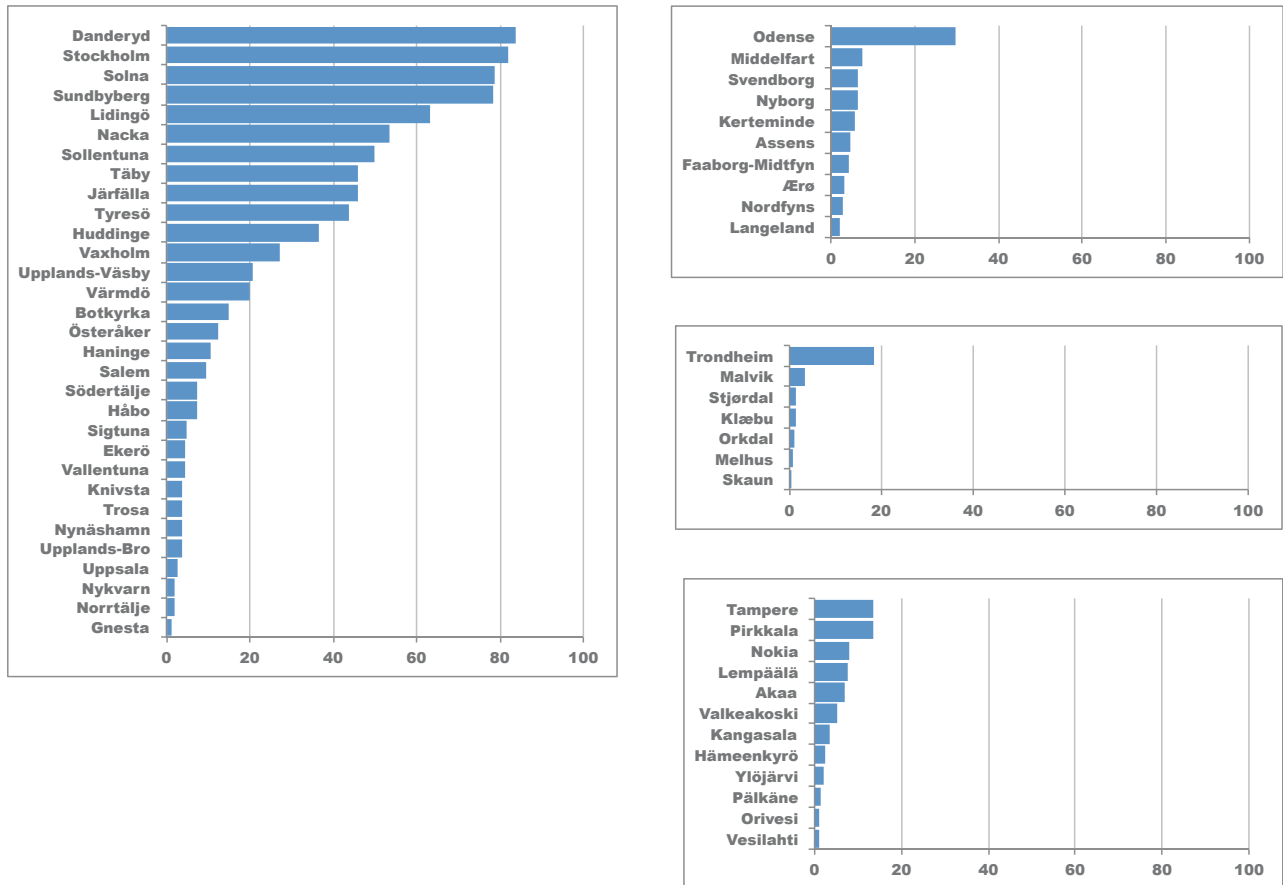
The delineations of the UMZ, FUA and LLM provided a basis for the regional stakeholders participating in the project to identify the study area for the following accessibility analysis. These delineations are also shown as the green border in Map 1. Like the quantitative definitions, they should not be seen as necessarily being representative of a (most) accurate definition of a city-region. For instance, in some cases municipalities were included in the study because the stakeholders thought “they (the municipalities the outside of the FUA or LLM) would be disappointed if they were left out”.

Seen together in Mapset 1, the three city-regional delineations (FUA, LLM and the stakeholder definition), coupled with the UMZ data, reveal strikingly different interpretations of the city-regional boundaries within our study. For instance, in no case does the FUA and the LLM completely overlap; the LLM includes addi-

Table 2: Combining two metrics of city-regions: the distribution of UMZ in the FUAs of the four study areas.

Urban Morphological Zone in each Functional Urban Area			
	Share	High	Low
Odense	7,75%	29,12% (Odense)	2,17% (Langeland)
Stockholm	11,40%	83,94% (Danderyd)	1,08% (Gnesta)
Tampere	4,10%	12,52% (Tampere)	0,94% (Vesilahti)
Trondheim	3,59%	17,56% (Trondheim)	0,48% (Skaun)

Figure 1: Share of each municipality accounted as UMZ in the four study areas.

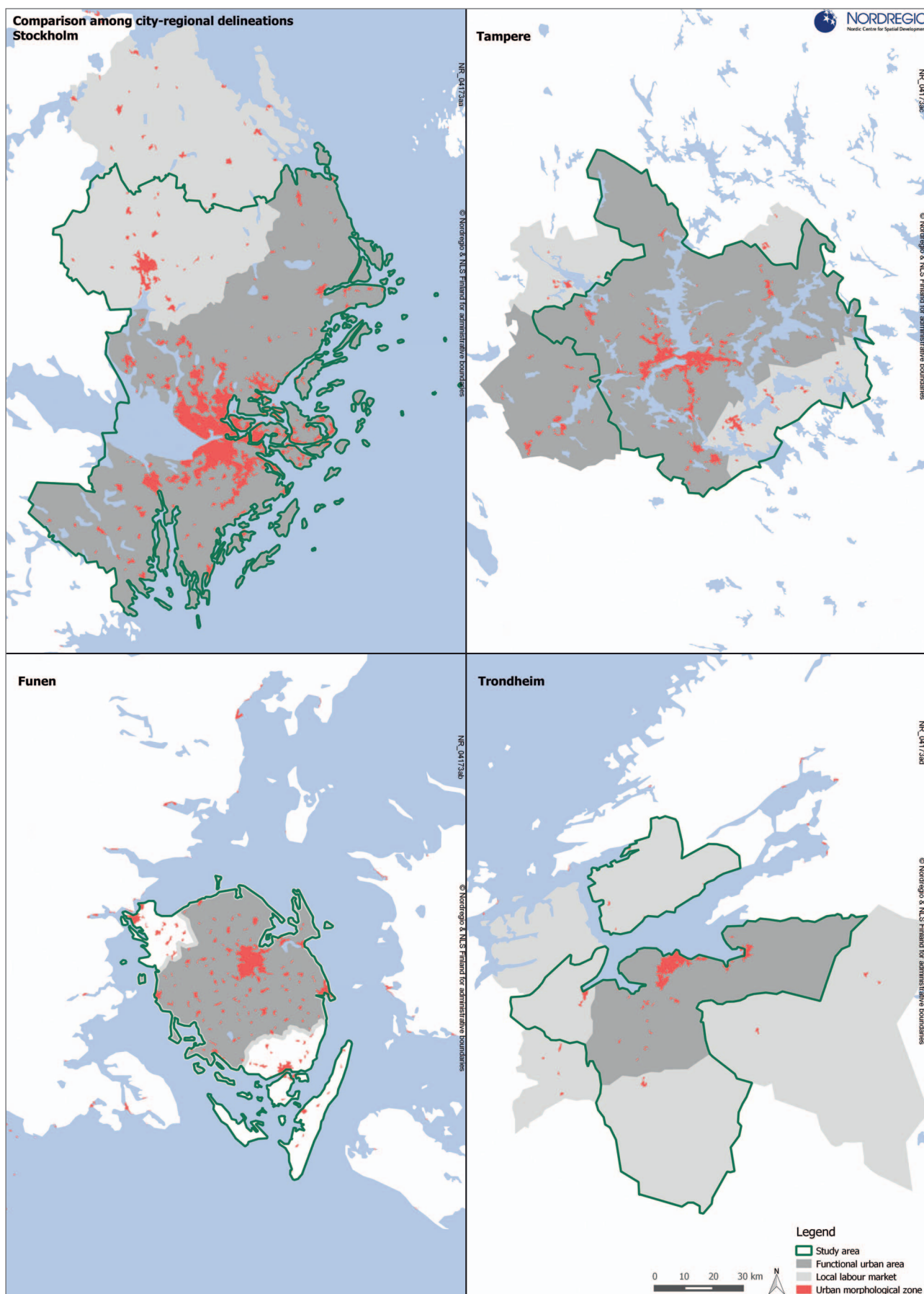


tional peripheral municipalities compared to the FUA. In Stockholm and Trondheim, this results in the addition of a significant area of land. Moreover, the stakeholder definition of the city-region perfectly overlaps with the LLM or the FUA in only one case (Funen). This stakeholder delineation includes more municipalities than are included in the FUA definition in the other three cases. In Tampere, one municipality that is in the FUA is left out of the stakeholder definition.

Two points are also interesting to note based on the share of each municipality consisting of UMZ land cover (see Figure 1). First, there is evidence of the impact of size and scale among the four different sized cities. In Stockholm, there are 12 municipalities in which more than 20% of the municipality is within the city-regional UMZ. In contrast, no municipality in Tampere or Trondheim has over 20% of their area covered by the UMZ, while only one municipality in Odense reaches this threshold. Second, there appears to be a

slightly more balanced share of the UMZ distribution in Stockholm and Tampere (perhaps more polycentric), as compared to Odense and Trondheim, where a vast majority of the UMZ of the city-region as whole is contained in the core municipality.

Put together, the process of breaking down these spatial definitions of city-regions is an integral part of the method, as it shows the interplay between the way cities are seen as agglomerations in a number of different ways – as the gathering of many settlement areas, economic zones, politicised entities, constructions of infrastructure, etc. Likewise, there is no singular or catch-all definition of city-regions. What constitutes a ‘functional city-region’ is thus dependent on the ‘function’ being considered. In the context of this project, we are concerned with the interplay between the physical layout of cities and the distribution of urban amenities that shape peoples’ everyday lives.



Mapset 1: Four delineations of the city-region in the four case areas. The UMZ is shown in red as the assemblages of urban land cover, areas in dark grey show the FUA, the LLM is shown in light grey and, finally, the green outline shows the stakeholder delineation.

4. Population and commuting patterns

A series of maps and information showing population and commuting patterns provides an overview of the physical layout of the city-regions in our study. Table 3 shows the total population and area of each city-region. This shows the wide range of difference in terms of size and scale of the four areas, which was an objective when we decided upon which four city-regions to investigate in our study.

Mapset 2 visualises population density in each city-region using grid data from various sources (see Appendix 1). In terms of urban settlement structure, a number of general results are notable. First and foremost, a more dispersed structure of settlement centres surrounding the “core” is evident in Funen compared to the other regions. These settlements are separated by areas of low population density - mainly agricultural or natural landscapes. The other study areas have smaller settlements surrounding the main core as well, but the spaces between them are more often developed in a linear fashion (i.e. transport corridors and consequent development).

In contrast to the dispersed settlement structure in Funen, the structures of Trondheim and Tampere appear to have a similar overall pattern - a clear city-centre with settlement along main transportation corridors and a relatively scattered settlement structure of low density sprawl and peri-urban settlements. The similarities of Trondheim and Tampere also illustrate the impact of topography as an underlying driver of settlement structure. For example, the interaction between land and water creates clear corridors of development in Tampere and Stockholm, whereas Trondheim is being limited by both their marine and mountainous landscape. In contrast, while Funen is clearly contained

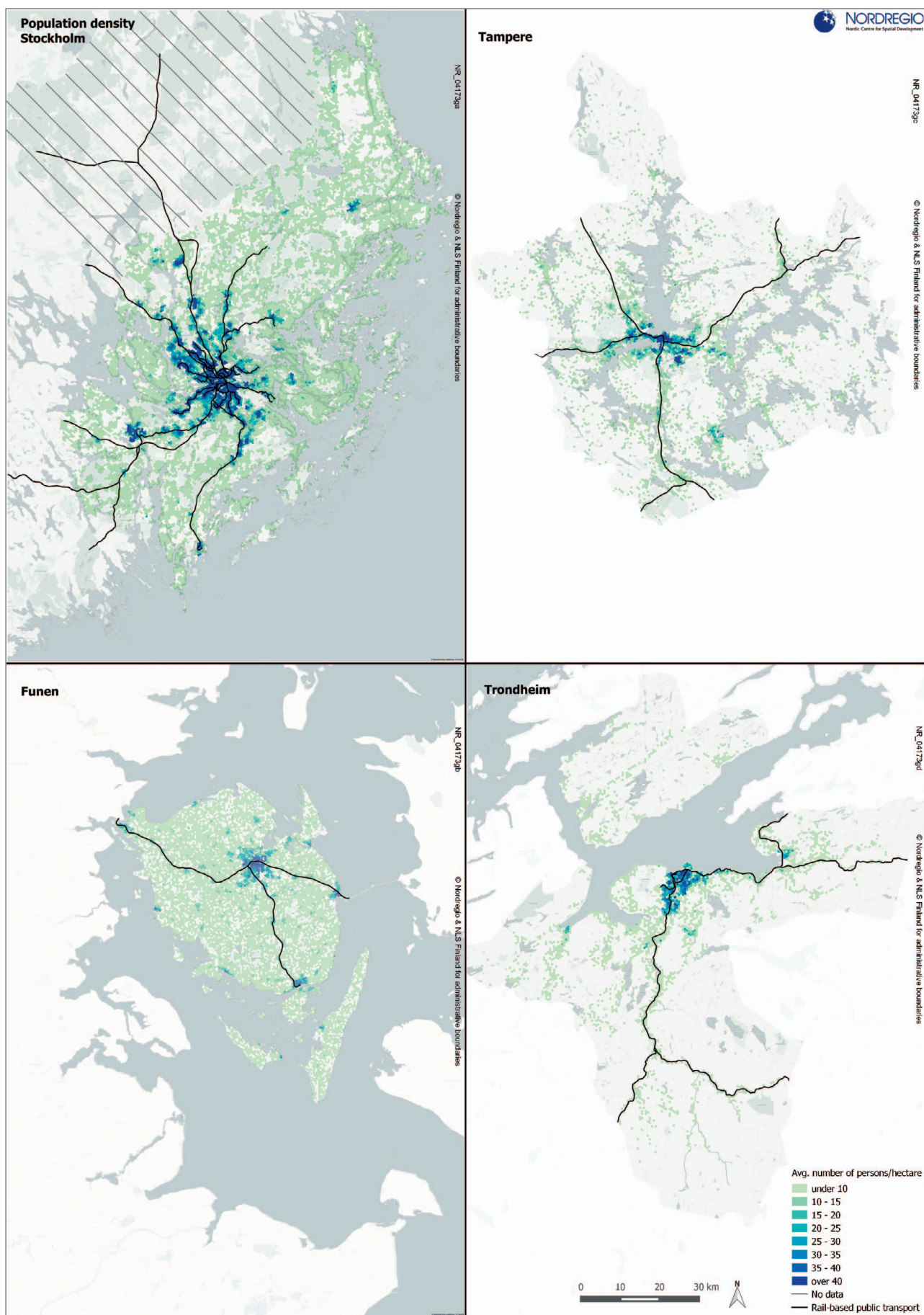
as a main island, there are rather few topographical landscapes to impede settlement development. This has been an underlying basis for its agricultural and farming economy that has also supported a more dispersed or scattered population structure compared to the other study areas.

In the case of Stockholm, we clearly see the impact of size and scale compared the other three city-regions. Foremost, it is the only of the four study areas that has rail-based local public transportation, such as trams or a subway (not including regional or national train service). While Stockholm indeed has a significant amount of urban sprawl (of low-density, single family homes), the series of high density nodes outside the city-centre are clearly visible. Likewise, these nodes are connected to the city centre via high-quality, rail-based public transportation, which is reflected in the radiating corridors. The presence of trams, subways, light rail, etc. thus acts as an important driver of the urban settlement structure.

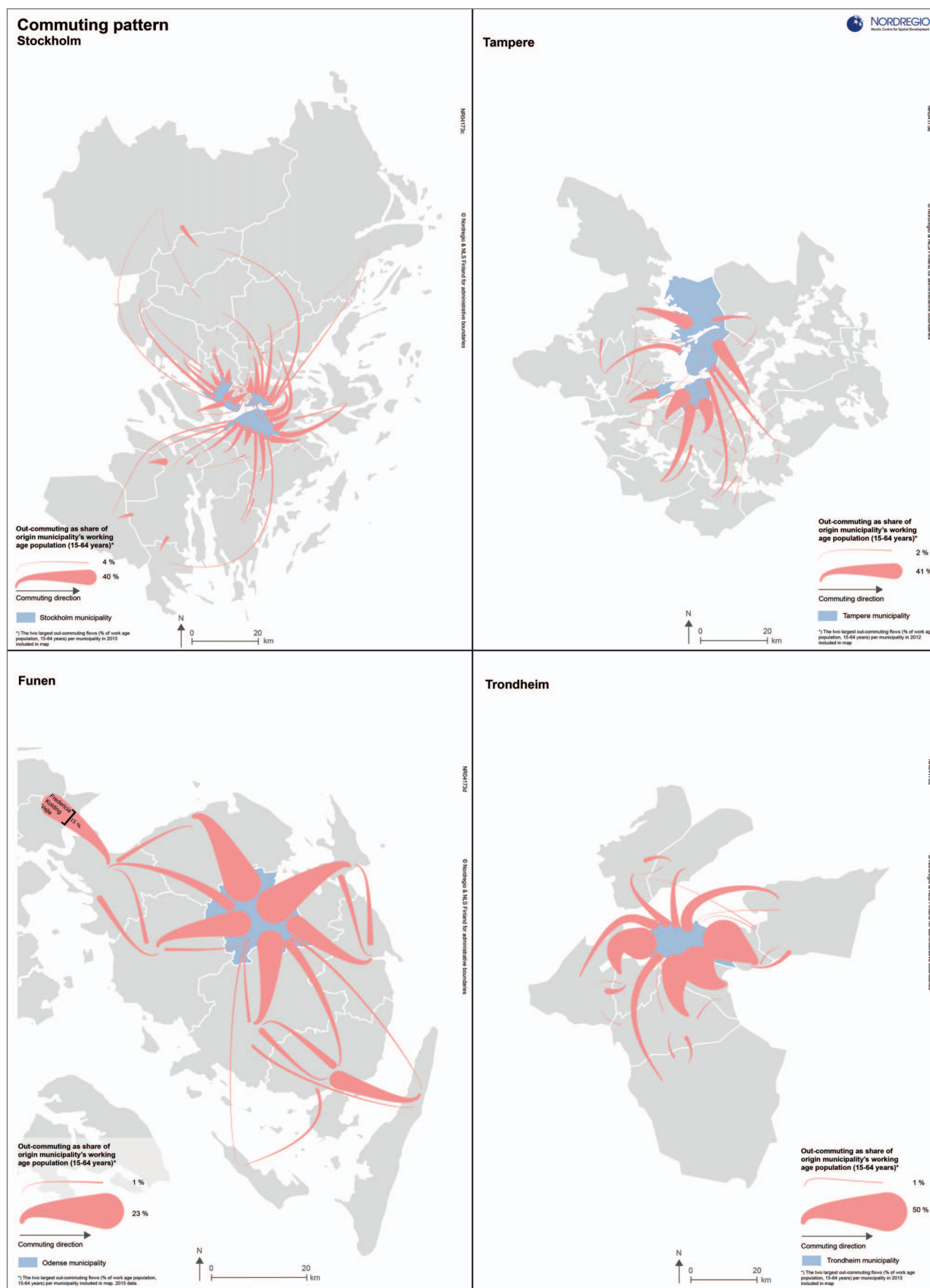
Lastly, Mapset 2 shows evidence in all four study areas of peripheral nodes functioning as their own urban centres (as compared to nodes within a larger urban configuration). For example, Södertälje and Uppsala (population data not available) are included in the city-region for Stockholm, but both towns have their own degree of autonomy from Stockholm. This is similar to Middelfart and Svendborg in Funen and a series of small settlement areas in Tampere (i.e. Valkeakoski) and Trondheim. (i.e. Hjerkin). This phenomenon is important in returning back to the very definition of city-regions, particularly in terms of the spatial arrangement of (and accessibility to) services of public interest, which is analysed in the next section.

Table 3: Population (2014) and total area of the study area in the four city-regions. Source: NSI's.

	Population (2014)	Area
Funen	486,709	3,560 km ²
Stockholm	2,399,523	9,989 km ²
Tampere	427,178	7,194 km ²
Trondheim	279,515	7,326 km ²



Mapset 2: Population density in the four study areas of the project (persons per hectare, averaged at a 250m² hexagonal grid). Break values in each map are selected using a common set of thresholds. Full size maps are available in Appendix 3.



Mapset 3: Main commuting flows for the municipalities within each study area. Clockwise from top left: Funen, Tampere, Stockholm and Trondheim. Each map shows the two dominant out-commuting flows as a share of the origin municipality's working age population (15-64). This highlights whether a certain municipality has a high rate of commuting in relation to its potential work force. The municipality with the dominant level of in-commuting is highlighted in blue.

Mapset 3 profiles each city-region in terms of commuting patterns. In all cases, the core is a dominant recipient of commuters from surrounding areas. In Trondheim and Tampere, for instance, all municipalities have their dominant commuting flow to a single (main) urban core. In Tampere, Tampere municipality is the most important commuting destination, where six municipalities have commuter shares of at least 26% of their working age population. Out-commuter flows to other municipalities are generally small, with a few exceptions: Vesilahti to Lempäälä (8%), Hämeenkyrö to Ylöjärvi (6%), and Akaa to Valkeakoski (4%).

However, in Stockholm and Funen it is clear that city-regional sub-centres are operating as individual labour markets/commuter catchments. In Funen, the dominant flow from Middlefart (in the Northwest), is out of the city-region, towards towns such as Fredericia, Kolding and Vejle. In the south, Svendborg appears to act as its own commuter catchment and labour market, as it receives the dominant share of out-commuters from Ærø and Langeland.

In Stockholm, the municipalities of Gnesta, Trosa and Nykvarn have their principal commuting destination to Södertälje, thus identifying as its own commuting cluster. The same is notable for Knivsta in the Northwest, which has its main commuting flow to Uppsala. The importance of both Södertälje and Uppsala as their own local labour markets is even more evident when it is considered that a majority of their resi-

dents work locally as well. Solna constitutes not only the principal destination for Stockholm municipality's out-commuters, but is also the secondary destination for ten out of 31 municipalities located within the region.

Apart from the large flows to Stockholm municipality from the surrounding municipalities, it is striking that all other major out-commuting flows go to a bordering municipality. This is the case for Vallentuna to Täby, Österåker to Täby, Värmdö to Nacka, Salem to Södertälje, Upplands-Bro to Järfälla, Nykvarn to Södertälje, Sundbyberg to Solna, Nynäshamn to Hanninge, Knivsta to Uppsala, Gnesta to Södertälje, and Trosa to Södertälje.

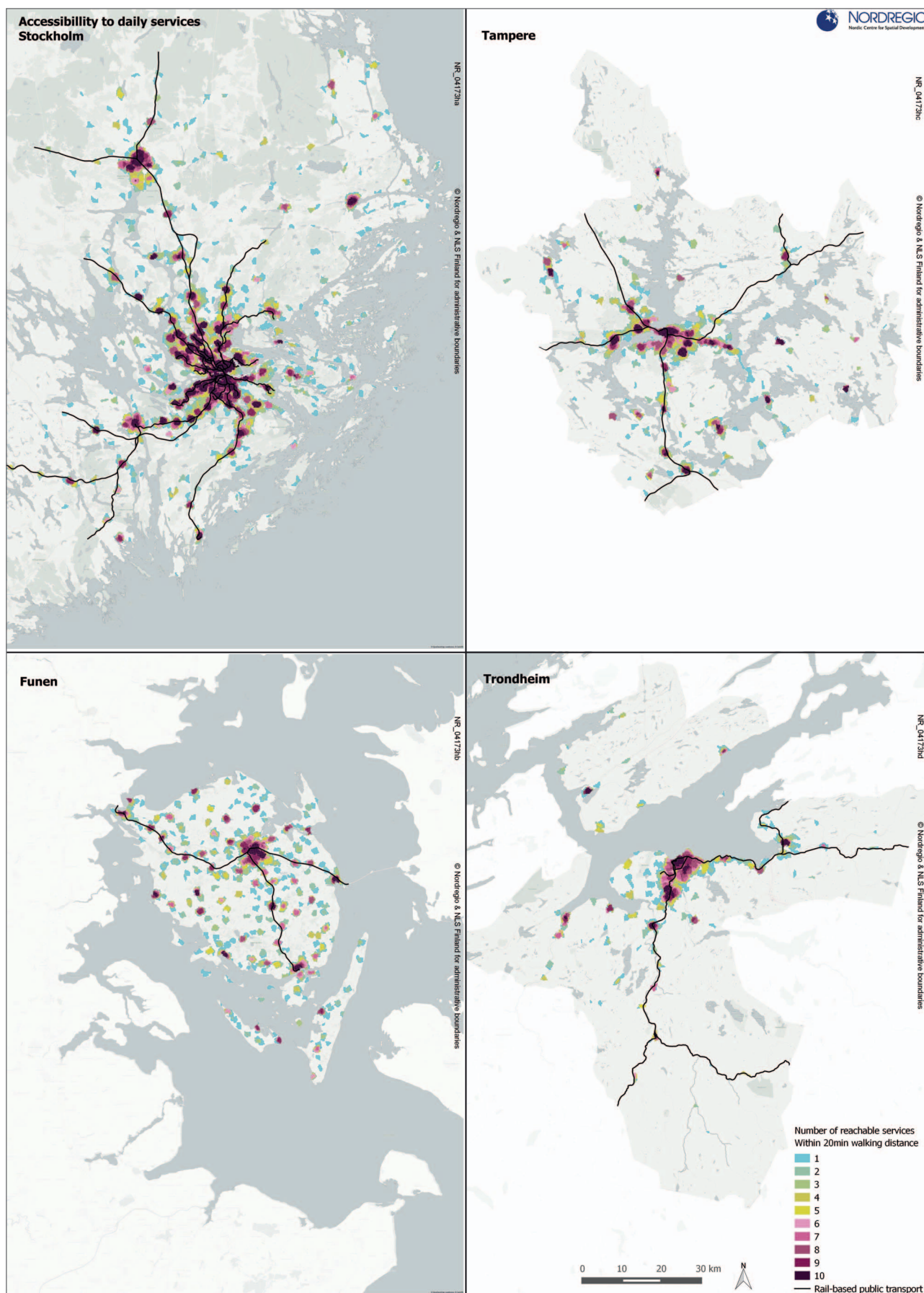
Trondheim municipality is the principal commuting destination in its area; perhaps only with the slight exception of Leksvik (Leksvik has 10% commuting flow of the working age population to Trondheim, but also 6% to Rissa). Likewise, the four municipalities neighbouring Trondheim (Melhus, Skaun, Klæbu, Malvik) have significant flows of commuters to Trondheim (between 38-50% of their working age population). The remaining municipalities have significantly lower values, between 10-15%, due to their distance (Midtre Gauldal, Orkdal and Stjørdal) or relative isolation (Rissa and Leksvik) from Trondheim. There are also some notable connections between neighbouring municipalities, i.e. from Skaun to Orkdal and Malvik to Stjørdal, 8% and 6% respectively.

5. Service accessibility

Mapset 4 shows the results of the service reachability analysis in the four study areas. When visually comparing the results to population density (Mapset 2), urban service nodes are clearly more visible and defined than the distribution of population density, particularly in Tampere, Trondheim and Funen. This particularly includes the main or central main service node in each case area. These more distinguished service nodes are not surprising given the fact that many suburban communities tend to have monofunctional land uses, consisting of low density settlements with little or no service mix. Rather, service areas are agglomerated in central commuter catchments. In these cases, areas of relatively good service provision do not coincide with an “urbanesque” settlement structure, consisting of good land use mix that promotes non-car forms of mobility. This implies that outside the main urban cores, service nodes do exist, but these are mainly seen as catchments for relatively large surrounding areas of low density settlements. From this evidence, we suggest that areas outside city-regional centres that have high service intensity could offer possibilities for strategic densification if demand warrants it.

While multiple nodes with nine or ten of the service groups present are visible in each case region, spatial differences in their distributions are also evident. In Funen, service centres appear as isolated nodes, where areas of little or no service accessibility separate these nodes. These same broken-up patterns are also notable in the other three cases, but in each case there is more of a linear or corridor-like distribution pattern, extending along main thoroughfares and transport corridors. This insinuates the dependency of private car transport as a realistic necessity for many people to use these everyday services in Funen.

At the same time, Funen may present a case where there are a number of smaller functional urban areas rather than one larger functional urban area. This is confirmed by the commuting data in Mapset 3, which shows Svendborg (southeast) as having its own commuter catchment / settlement area while Middelfart also has its own commuter catchment as well as having the majority of its out-commuters going out of Funen. Similarly, the areas of isolated service centres in the other cases (i.e. Uppsala, Norrtälje in Stockholm, isolated communities in Tampere, etc.) also represent their own functional urban areas, regardless of their classification within the larger functional urban area or local labour market they belong to. This is important when referencing back to the overall definitions of city-regions based on different statistical approaches or data sources. City-regional definitions using population and commuting data at administrative scales have a default tendency to identify large functional areas, which are important for planning infrastructure investment, especially for areas outside urban cores. In contrast, spatial data at grid level (land cover data used to define urban morphological zones) or locational level (absolute locations of services) provide significantly enhanced views of the spatial perspective of city-regions. This more detailed view provides a complementary perspective on how urban areas function as a complex arrangement of urban spaces within a larger metropolitan area. This can have a range of uses for planning city-regions within and across traditional administrative borders. Key examples would include: mobility infrastructure such as cycling networks, provision of public services such as education and health care or, as mentioned, identifying service gaps or promoting strategic development of existing urban nodes.



Mapset 4: Accessibility to daily services in the four study areas of the project. Shades in the map correspond to the number of service groups that are accessible within a 20-minute walking distance from each 250m² grid cell. Full size maps are available in Appendix 3.

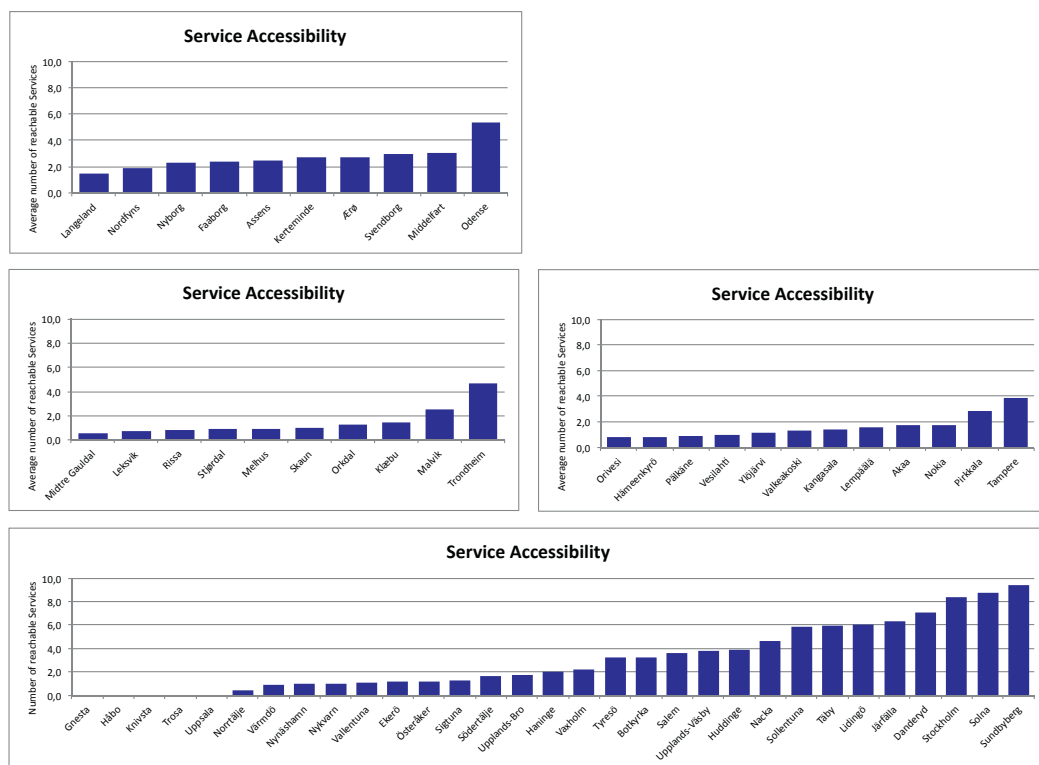


Figure 2: Average number of reachable service groups per municipality, within 20 minutes walking distance from all populated areas. All cells where people live are classified based on the number of reachable services, and these are averaged for each municipality. The results therefore describe the spatial equality of service reachability within the municipality. Note that the five municipalities on the left are missing population density data and are therefore not included in the municipal analysis results.



Figure 3: A population-weighted average number of service groups per municipality that are accessible within 20 minutes walking distance from populated areas. Being population-weighted, figures are calculated as follows: first, the “number of reachable services” is multiplied by the “total number of people” in each populated grid cell. Then, the average from these is calculated on a municipal level and divided by the average population per grid cell. This in turn gives a view to the demographic equality of service accessibility within each municipality. Or, in simpler terms, it shows the service reachability as experienced by the majority of people living in the municipality. Note that the five municipalities on the left are missing population density data and are therefore not included in the municipal analysis results.

A number of additional findings can be made by combining the service accessibility results shown in Mapset 4 with the results aggregated to the municipal scale in Figure 2. Stockholm's larger scale produces higher service accessibility. Larger shares of the populated areas in the municipalities of the Stockholm case study are also covered by situations of good service accessibility. For example, in Stockholm there are three municipalities (Stockholm, Solna and Sundbyberg) where all populated areas have, on average, eight service groups within a 20 minute walking distance. This highlights Stockholm's more extensive infrastructure development and more common development of medium to high density, mixed-use residential areas. This is in comparison to the other three cases where the highest average total is between 4 and 6 services accessible to all populated areas.

Next, while the core-periphery dynamic is evident in all cases, the municipal results show a more balanced spatial development pattern in Funen, as compared to Trondheim and Tampere. Even in Stockholm, the core-periphery dynamic is evident in the municipal results, although there are more services within a greater number of municipalities, with roughly six times as many services mapped as compared to the other cases. However, the situation appears different in Funen. While Odense is the dominant centre in Funen, the surrounding municipalities have a more balanced distribution of service level, with 8 out of 10 municipalities having an average of at least two service groups

accessible in all populated areas. This gives the impression that there are a number of second-order nodes where ample service accessibility is evident in Funen compared to Tampere and Trondheim, which supports the information shown by the population density and commuting maps.

The former point can be elaborated further when analysing Figure 3. Instead of considering service accessibility for all populated areas, the population-weighted measure focuses on where a majority of people live in each municipality. This accounts for the fact that much of the physical area of municipalities outside the centre are often populated by few people living in a rural setting, even though most of the people in these peripheral municipalities are actually agglomerated in specific areas. When considering this fact, we see that people living in all ten of the municipalities in Funen have, on average, four service groups within an accessible distance. It therefore shows a quite balanced situation in Funen, as well as in Stockholm. There is also more balance notable in Tampere, but in this case Trondheim especially sticks out for the very low shares of average service accessibility. While people living in Trondheim proper have almost 8 service groups accessible to them on average, this immediately drops to nearly 4 in Malvik and Orkdal, and it drops even further in the remainder of the municipalities. This implies that, compared to the other cases, a high share of the people in the Trondheim city-region are living in a peri-urban or rural setting with few services located close to them.

6. Public transport accessibility

The number of accessible service groups gives a picture of service distribution and accessibility via a reasonable walking distance. It does not, however, consider that multiple forms of mobility exist in cities, which affects the reachability to services for the population. For example, someone living close to public transportation can easily travel to other locales where other constellations of services are available. Therefore, service accessibility by the walking metric can be supported by analysis of public transportation accessibility.

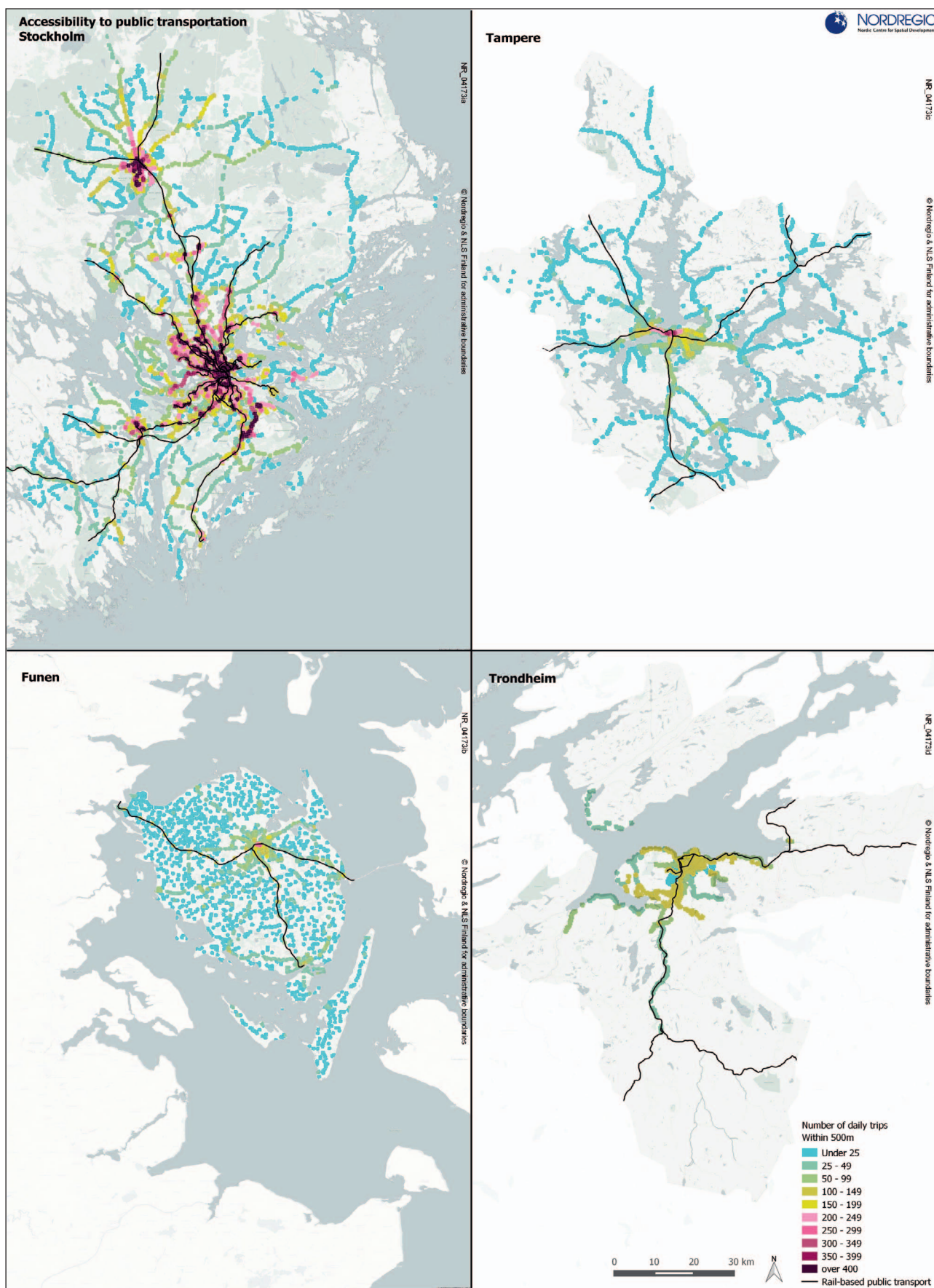
Mapset 5 shows the number of daily (Monday-Friday) public transport trips (to any available direction) at designated stops/stations that are accessible at within 500m. Figure 4 aggregates these results to the municipal level. Mapset 6 refines the results of Mapset 5 by combining the public transportation accessibility data with population data to show cases where population density and public transport accessibility are mismatched. Here, population points are shown for locations with an average of more than 10 persons per hectare, and the transport network excludes the lowest threshold from Mapset 5 (<25 trips/day in all directions).

Stockholm is the only city-region that includes rail-based public transport as a competitive commuting service. As a result of the increased frequencies of Stockholm's rail based public transportation, coupled with the basic urban planning and development principle of developing service areas and public transport nodes in close proximity, it is the only case where the public transportation network closely resembles the distribution of services. The sheer size and scale of Stockholm's network is also evident in Figure 4, where an average of nearly 500 daily trips are available to residents in the Stockholm municipality. In contrast,

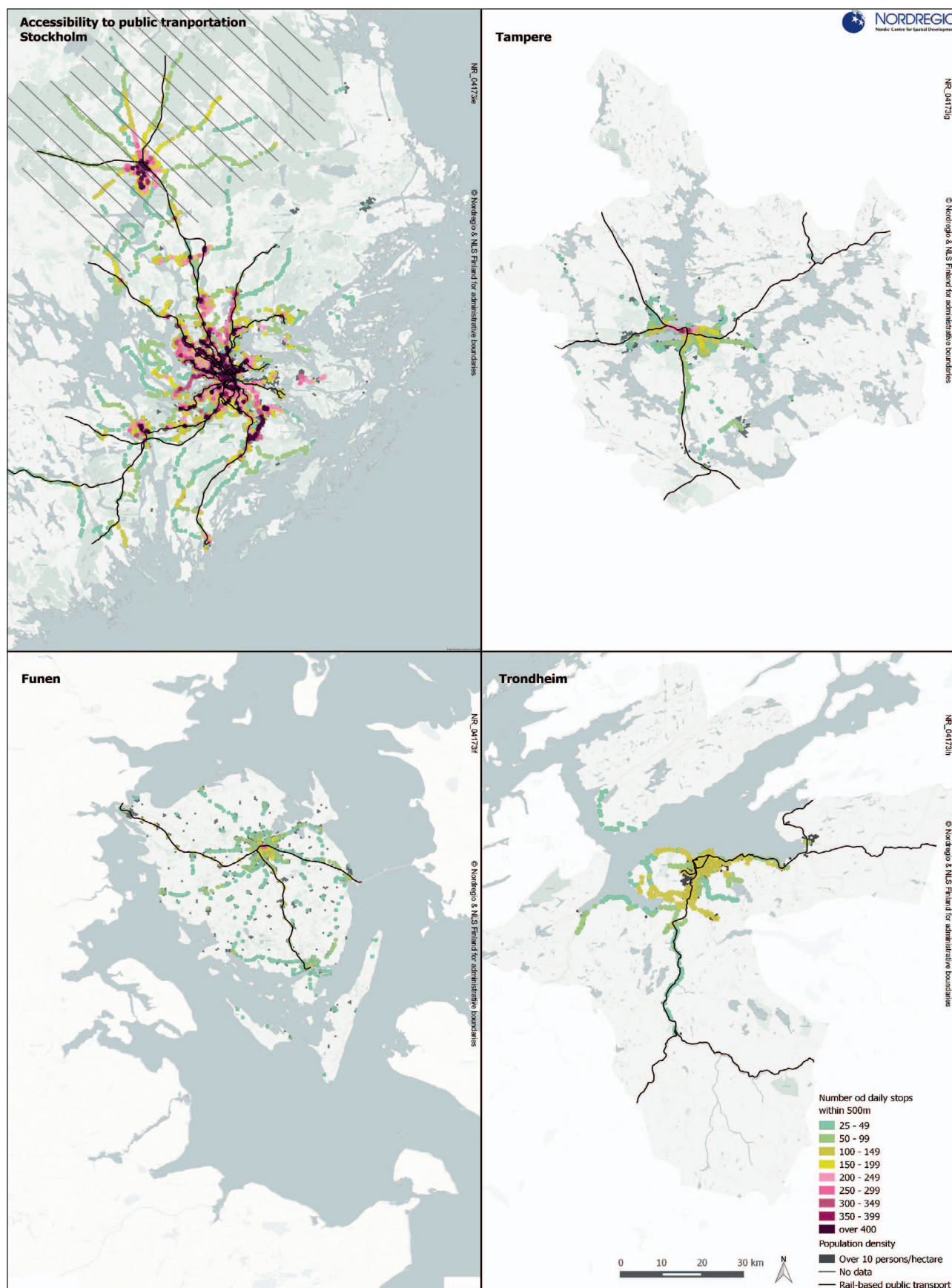
the core municipalities of Trondheim, Tampere and Odense have maximum averages of 80 trips per day accessible to their population. Likewise, there are 15 municipalities where the population has access to over 80 trips per day on average in Stockholm.

In Funen, it appears as if there is a distinct lack of sufficient public transport service to support non-car commuting to and from the smaller communities. This is also notable in Tampere, where a reasonable service appears to be provided in and around the city-centre (between Tampere centre and other municipal centres and major suburbs in the urban area, as well as on the southern corridor) but then immediately drops off to only periodic service outside of these areas. Yet, a slightly different situation appears to be the case in Trondheim, where a relatively wider distribution of 100-200 daily trips is spread across the main areas of residential settlement. This is especially notable when observing the transportation corridors in Mapset 6. One should however consider a higher potential error margin in the results as well, since the Trondheim data was not based on GTFS.

Finally, Mapset 6 shows that, in comparison to Stockholm, Tampere and especially Funen include settlement areas that are outside the network of reasonable public transportation. These appear to be settlements that in some ways are 'caught in the middle', meaning that they are not 'rural' settlements per se, yet they do not have the density threshold or historical tract of implementing suitable public transport as a realistic substitute to private car commuting. A key urban development question should likely focus on these areas and how we can ensure that they provide adequate services and can attract/retain residents, especially from the perspective of efficient public transport provision.



Mapset 5: Accessibility to public transportation in the four study areas of the project. Classes in the map correspond to the number of daily public transport trips at designated stops/stations that are accessible at within 500m of the given grid cell. Note that the trips are typically in both directions. Therefore, a value of 48 would theoretically correspond to a daily average of one trip per direction per hour, at one stop or station. Full size maps are available in Appendix 3.



Mapset 6: Accessibility to public transportation, combined with population cells with more than an average of 10 persons per hectare. Classes in the map correspond to the number of daily public transport trips that are accessible at stops/stations within 500m of the given grid cell. The population cells in the map therefore give a view to areas of the city-region where at least 10 people per 100m² live, but do not have access to public transportation stops with at least an average service level of 25 trips per day. Full size maps are available in Appendix 3.

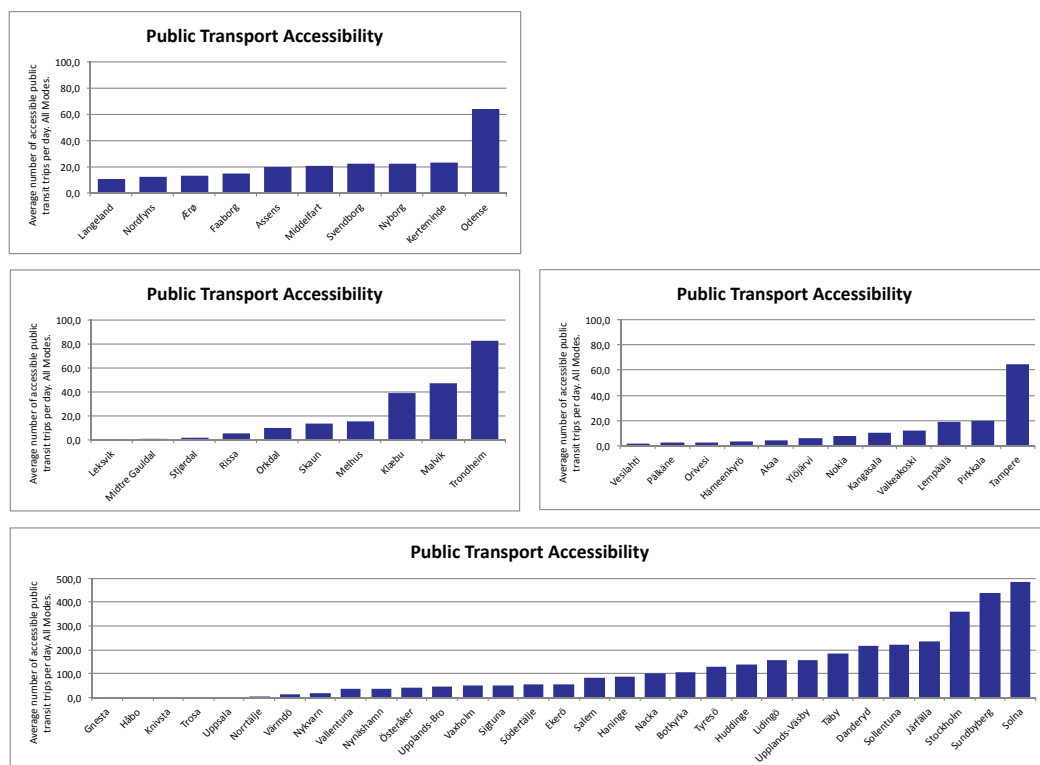


Figure 4: Average number of public transportation trips that are accessible within 500m by each person per municipality. All cells where people live are classified based on the number of public transport trips accessible at all stops within 500m and these are averaged for each municipality. This provides a clear indication of the spatial equality of public transport reachability within the municipality.

7. Conclusions

Our results describe the current service distribution and settlement structure in the four case study areas. From the perspective of sustainable urban development in general, a point of departure has been that densification (and development) policies that do not consider existing urban structures are irrelevant (and potentially dangerous) to any comprehensive planning approach for sustainability (Batty, 2008a). Based on these two principles, we have aimed to analyse the patterns of comprehensive service reachability in this study, as well as test the feasibility of such analyses in a multinational research setting - including the initial phase of data acquisition. This paper can be seen as a pilot study for our methods, which could be further utilized to provide more specific, targeted information for planners and other public actors.

Defining city-regions: No one-size-fits-all approach

It was clear that the two approaches to defining city-regions based on standard population and commuting pattern criteria at the municipal scale provide only a basic definition of city-regions. These approaches, including the ones developed by the OECD and Nordregio, can be useful for investigating city-regional patterns at a wider scale; for instance, for comparing or benchmarking city-regions in a national or an international context. However, more detail and nuance is needed when investigating patterns within individual city-regions, which was exemplified when interacting with the project stakeholders in defining the local study areas. Furthermore, the addition of high resolution UMZ, population density and service accessibility spatial data complements the administrative-based definition of city-regions. It does so especially by providing a picture of the underlying complex arrangement of many urban structures within a greater urban system. As a result, there is no unanimous way to spatially define the city-region, and a more detailed scale of analysis is likely to require a more tailor-made approach.

Testing and developing a new approach for analysing service accessibility in cities

The analysis we conducted has provided new knowledge into the urban structures of city-regions, which can facilitate new planning strategy within or between municipalities. This deeper focus on urban spatial structures can particularly support planning strategies towards diversifying the service or amenity base in the areas experiencing a mismatch between services and population. For example, a clear evidence base concerning strategic densification opportunities is provided by distinguishing areas that experience rather good local service reachability but have little or no local population. This helps to identify areas for infill development – this is a topic that is increasingly gaining importance in light of the ongoing demographic gravitation to urban areas.

On the other hand, this type of analysis can be used for identifying service gaps – in other words, areas of relatively high population settlement and relatively poor service offering. This is highly relevant from the planning perspective, considering that land use and service distribution patterns (public transportation especially) often follow patterns of traditional land use zoning by municipalities. Further to this, the trend of mid-sized Nordic city-regions currently pursuing rail-based public transportation development (tram networks are currently in the planning phase in both Tampere and Funen) creates a strong need for a detailed and local understanding of current population as well as service distribution patterns alongside public transport development. In other words, the more that strategic public transport investment can be matched by an understanding of service and settlement development opportunities, the better the chances are for a successful overarching process of public transport oriented urban development.

One unique characteristic about our approach to measuring the reachability of services and public transportation has been the application of high resolution spatial data. Here we noticed a number of relevant findings that can shape future work. Foremost, there

are vast differences in the availability and openness of data both between different types of services (i.e. public versus private services), different countries, and even between regions within a country. In general, we were able to utilize open source data from OSM for a majority of the services used in the study, but detailed spatial data on public transportation was inconsistently developed in the four case areas. For population density data, we especially noticed differences in the quality of the basic data, which even limited our ability to include grid level population data for all of the four case study areas. And not least, we lacked a more up-to-date UMZ data set defining the study areas in the four city regions. To enable widespread, up-to-date research, planning and monitoring of the urban structures and their linkages to the people, urban form and accessibility, there is potential for greater Nordic cooperation on common spatial data infrastructures, open data and the principles underlying. There are indeed many steps to be taken before geodata becomes a means and not only a goal.

Future opportunities for measuring service reachability

In terms of our work as a pilot project, there are relevant findings regarding further applications. First, it is important to recognize that the comparative or benchmarking aspect of this pilot project, across four case study areas of very different sizes and local contexts, seems to provide limited information in terms of action-oriented results. We would therefore not encourage expanding the analysis in an effort to compare more city-regions throughout the Nordic Countries. For instance, conducting such a benchmark could lead to the situation where the results are translated into some kind of “urban spatial performance” monitor, which in turn could lead to an over emphasis on promoting densification around existing service or public transport nodes. This issue is more widely discussed within critical analyses of the compact city, an issue that is discussed at more length in a preceding report by the working group (Diş et al 2014). The key point here is that while urban form certainly does matter for achieving urban sustainability, place-based economic, societal and environmental conditions, rather than the compact city ideal, must be considered to achieve long-term development success.

Instead of the benchmarking perspective, the focus

of additional work should be on expanding the analysis within specific administrative jurisdictions. For example, this was the focus in the Tampere Region when using the service reachability analysis in their development of their Tampere Regional Land Use Plan 2040. In particular, they were able to identify specific areas of service gaps and develop planning strategies to ameliorate them. A deeper analysis of local socio-economic phenomena mentioned above is another example, both of which highlight the need for the combination of an objective service reachability analysis with local knowledge of underlying development patterns.

Second, we also realize that it is not only basic population distribution that we should focus on when drawing conclusions from the results. Socio-economics also play a major role in the formation of spatial patterns of services and amenities. Although we were not able to properly assess this issue within our paper, further studies could advance our methodology by incorporating socio-economic data and/or in-depth knowledge about geographical context. For example, our approach could be integrated with Neutens et al’s (2010) approach to measuring social equity in public service delivery. Visual maps of service distribution and transport intensity could provide an engaging way to frame broader discussions on segregation or urban inequality.

Lastly, a major opportunity for future application involves the upscaling of the analysis to larger areas, but still within some sort of continuous area - either in terms of a single urban structure or within a single regional or national planning jurisdiction. For example, Nordregio is currently implementing this type of analysis to address the state of urban structure in cross border regions, and for identifying service accessibility patterns across a number of urban settlements within a larger macro-regional structure. Likewise, the service patterns are effectively analysed in relation to grid level socio-economic data, which provides detailed information of socio-economic process driving and responding to changes in urban structure. At the same time, deeper implementation of the approach can also take place at the national scale, especially in terms of the distribution of individual comprehensive service types such as health care or education. This appears to be a highly relevant field for further work, especially regarding the issue of service accessibility in peri-urban and rural areas as the entire Nordic Region continues to concentrate its people and services around its existing main urban areas.

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Appendix 1

Metadata for population density data.

	Year	Scale	Source
Funen	2013	100m ²	Statistics Denmark
Stockholm	2010	100m ²	WSP Group & Statistics Sweden (SCB)
Tampere	2013	250m ²	Finnish Environment Institute & Statistics Finland
Trondheim	2014	250m ²	Statistics Norway (SSB)

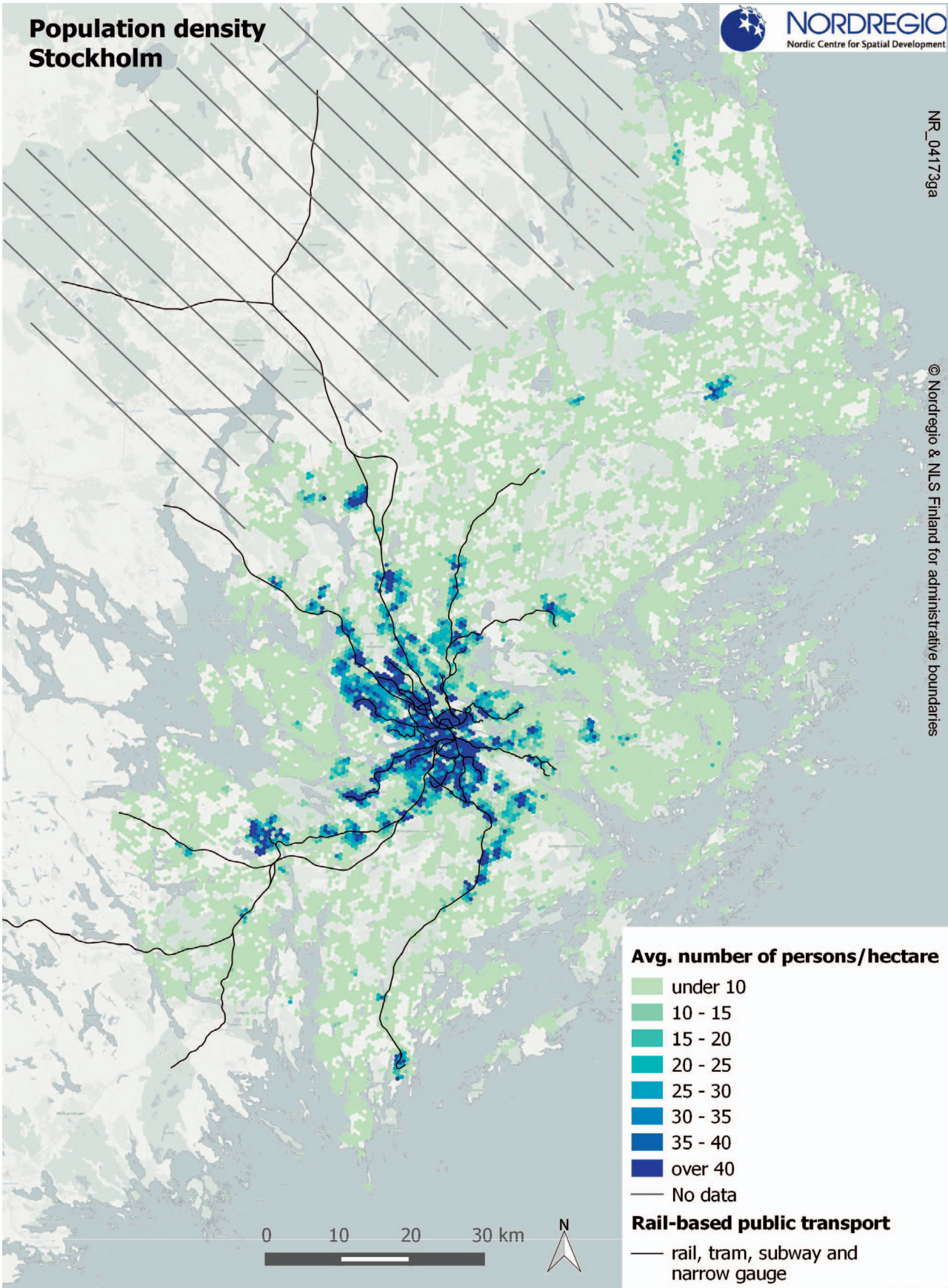
Appendix 2

Data sources for amenities and services in each study area. DST = Danmarks Statistik, OSM = OpenStreetMap, GS = Yellow pages (e.g. Gule Sider, Gula Sidorna), mun.web = municipal web pages, CTR = Council of Tampere Region.

Amenity/Service	Funen	Stockholm	Tampere	Trondheim
Restaurants	DST / OSM	OSM / GS	OSM / eat.fi / fonecta.fi	OSM / GS
Bars	DST / OSM	OSM / GS	OSM / eat.fi / fonecta.fi	OSM / GS
Cafes	DST / OSM	OSM / GS	OSM / eat.fi / fonecta.fi	OSM / GS
Grocery stores	DST / OSM	OSM / GS	Retail chain GPS locations	OSM / GS
Convenience stores	DST / OSM	OSM / GS	Retail chain GPS locations	OSM / GS
Fitness gyms	DST / OSM	OSM / GS	LIPAS WFS (University of Jyväskylä)	OSM / GS
Swimming halls	DST / OSM	mun.web	LIPAS WFS (University of Jyväskylä)	mun.web
Cinema	OSM / DST / GS	OSM / GS	CTR	OSM / GS / mun.web
Theatre	OSM / DST / GS	mun.web	mun.web / CTR	OSM / GS / mun.web
Library	bibliotek.dk / mun.web	mun.web	piki.verkkokirjasto.fi / kirjastot.fi	mun.web / OSM
Hospitals	sundhed.dk / DST	OSM / 1177.se	CTR	mun.web / OSM
Clinics	sundhed.dk / DST	OSM / 1177.se	CTR	mun.web
Pharmacies	DST / OSM	OSM / GS	apteekki.fi	OSM / GS
Day-cares	DST / OSM	utbildningsguiden.nu / OSM	mun.web / CTR	mun.web
Kindergartens	DST / OSM / frie.dk	utbildningsguiden.nu / OSM	mun.web / CTR	mun.web
Primary	statweb.uni-c.dk / InstReg	skolverket.se	CTR	utdanning.no / skole.no
Secondary	statweb.uni-c.dk / InstReg	skolverket.se	CTR	vibli.no
Tertiary	statweb.uni-c.dk / InstReg	studeravidare.se / OSM	CTR	utdanning.no / OSM
Bank	OSM / DST	OSM / GS	finanssivalvonta.fi	OSM / GS
ATM	OSM	OSM / GS	otto.fi	OSM / GS
Post offices or kiosks	postdanmark.dk	posten.se	posti.fi	posten.no

Appendix 3

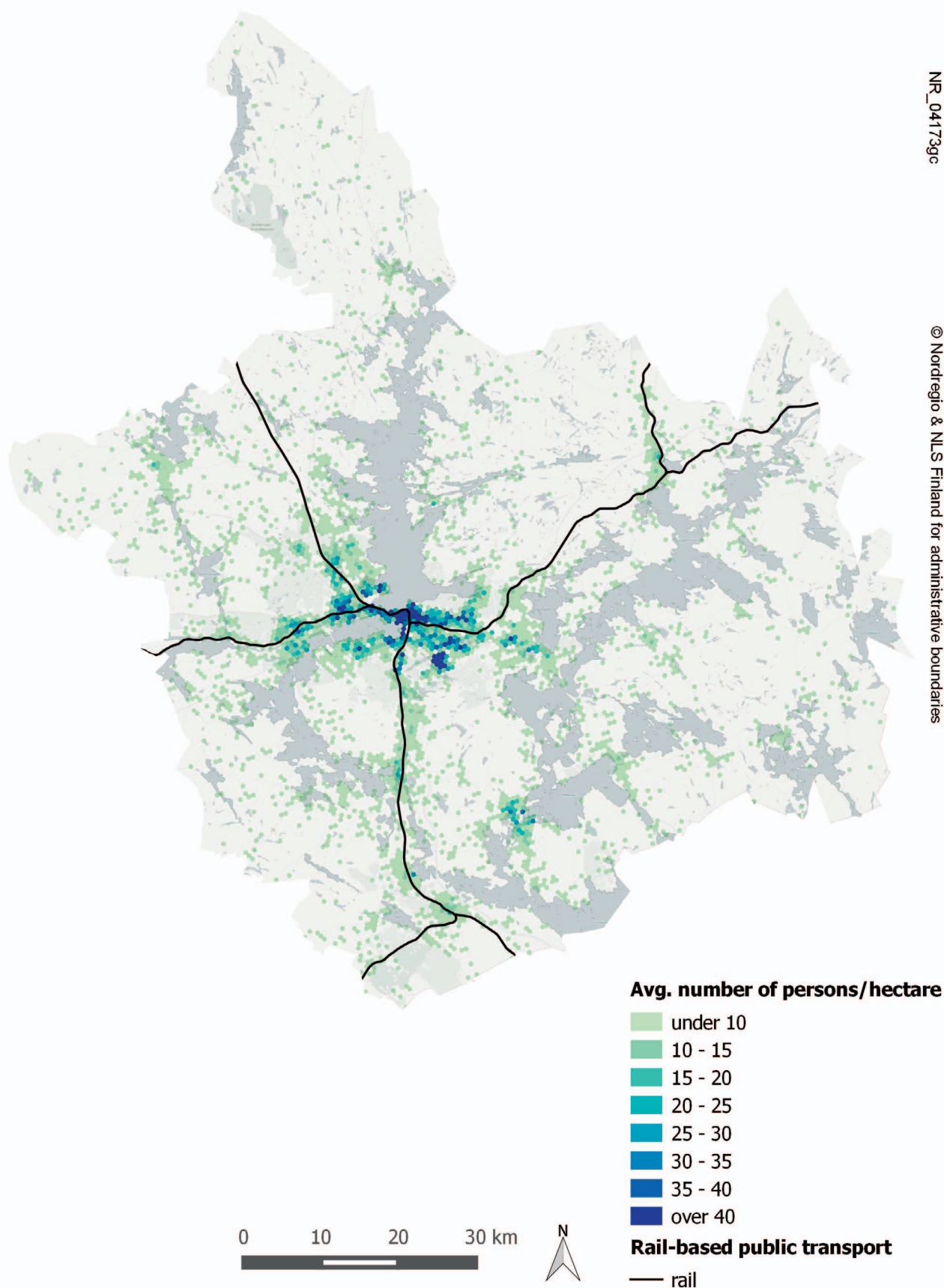
Population Density Maps



Population density Tampere

NR_041739c

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Population density Trondheim



NORDREGIO
Nordic Centre for Spatial Development

NR_04173gd

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Avg. number of persons/hectare

- under 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- 35 - 40
- over 40

Rail-based public transport

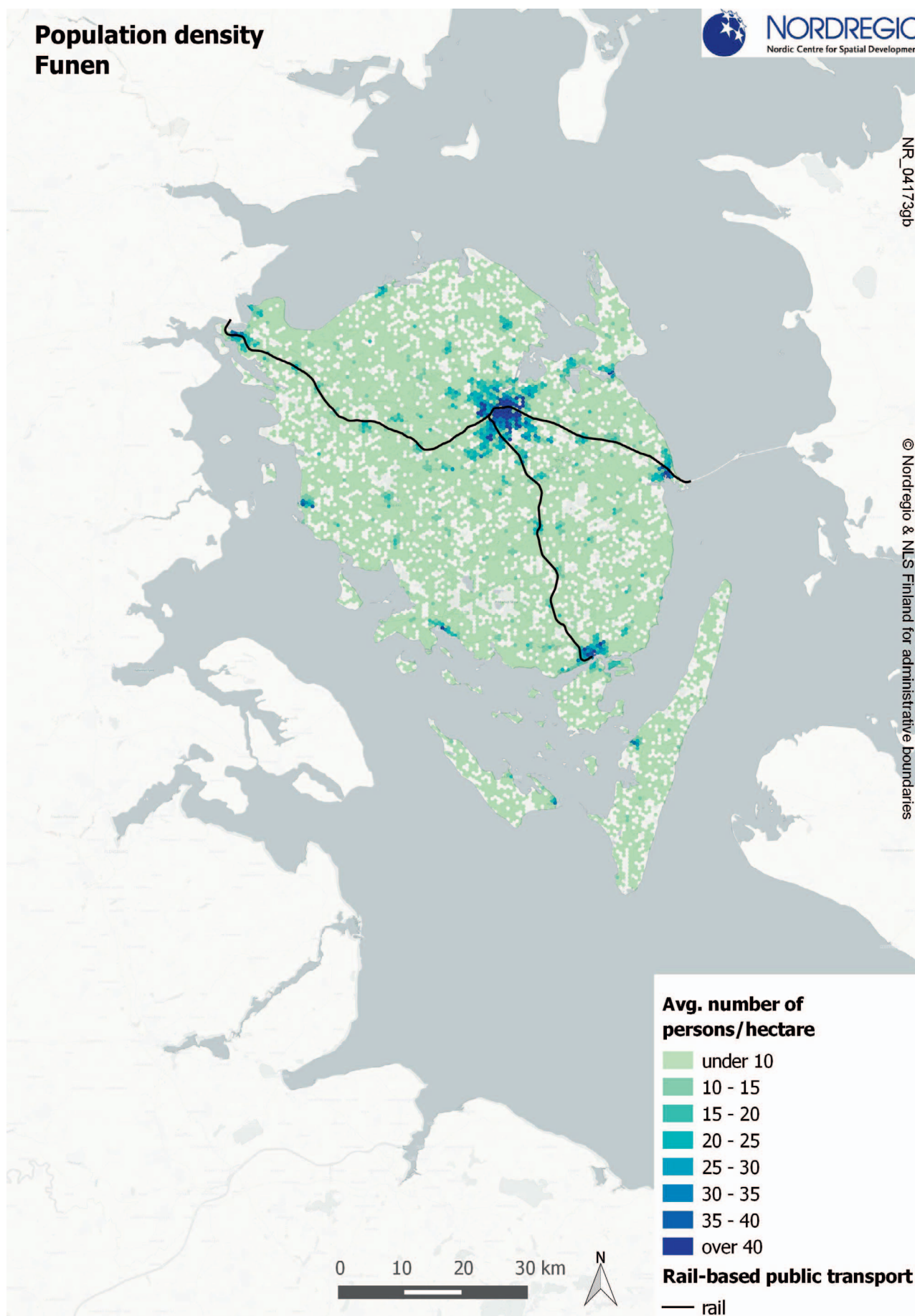
— rail and tram

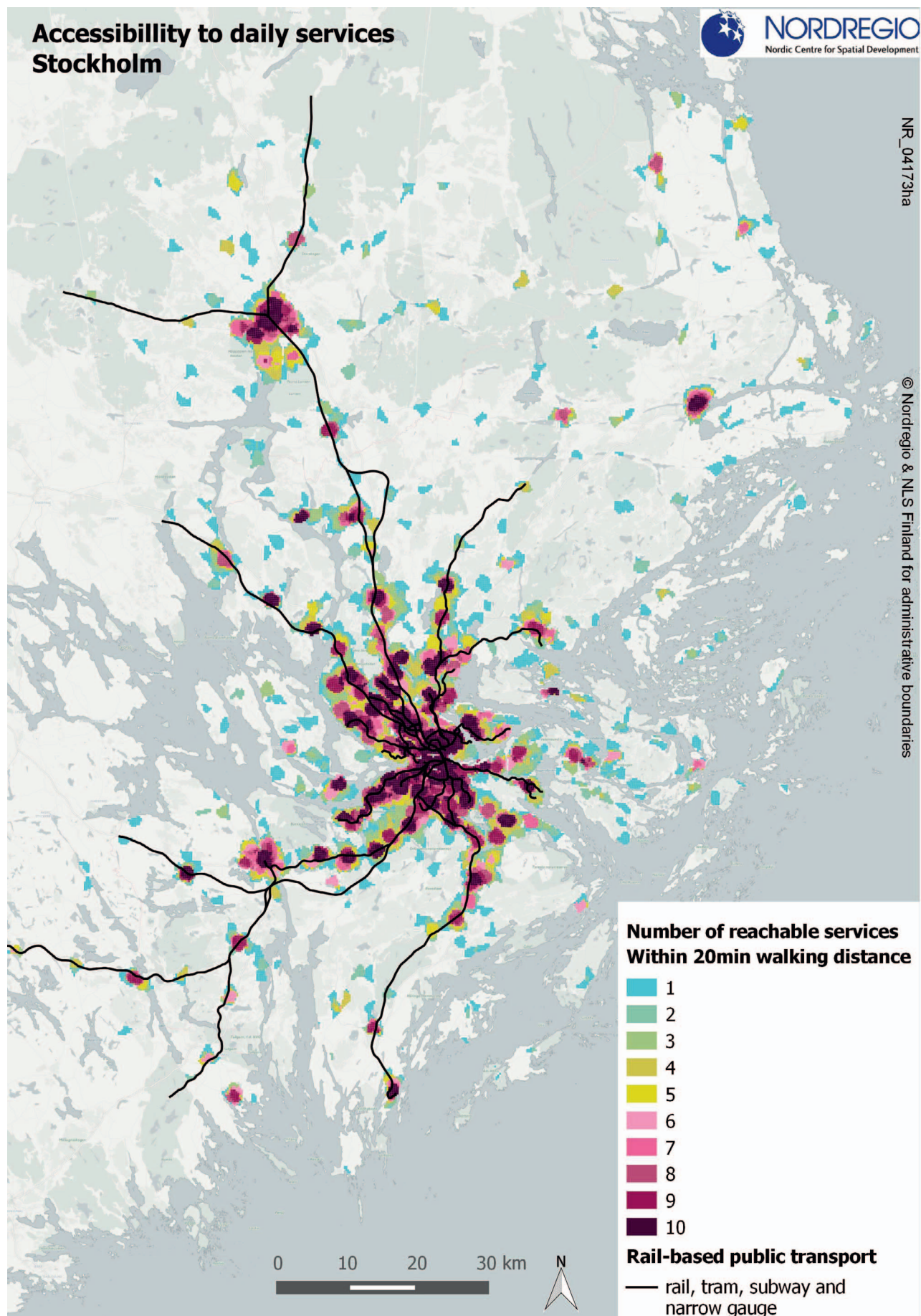


Population density Funen

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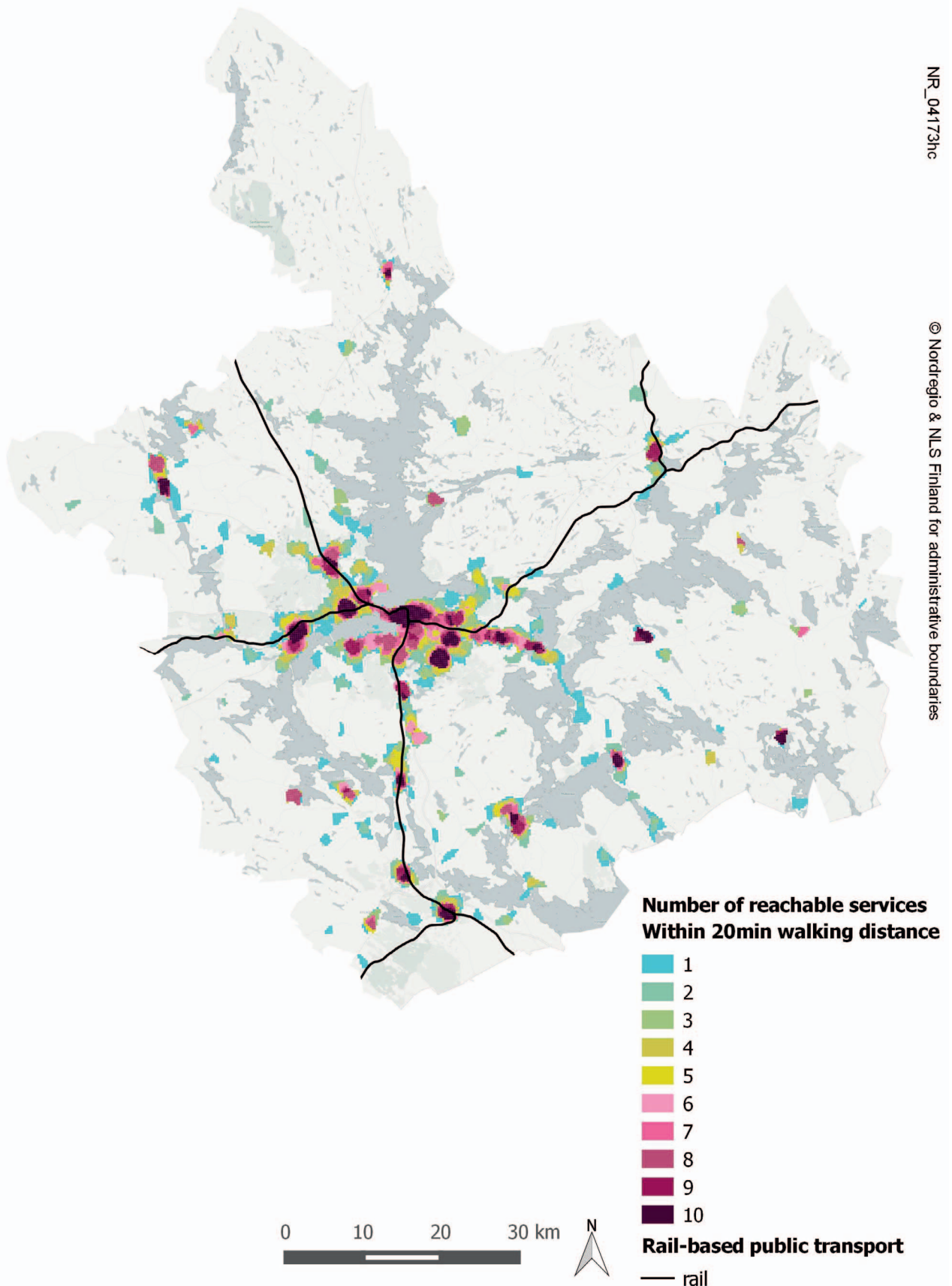
Accessibility to daily services Tampere



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Accessibility to daily services Trondheim



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**Number of reachable services
Within 20min walking distance**



Rail-based public transport

— rail and tram

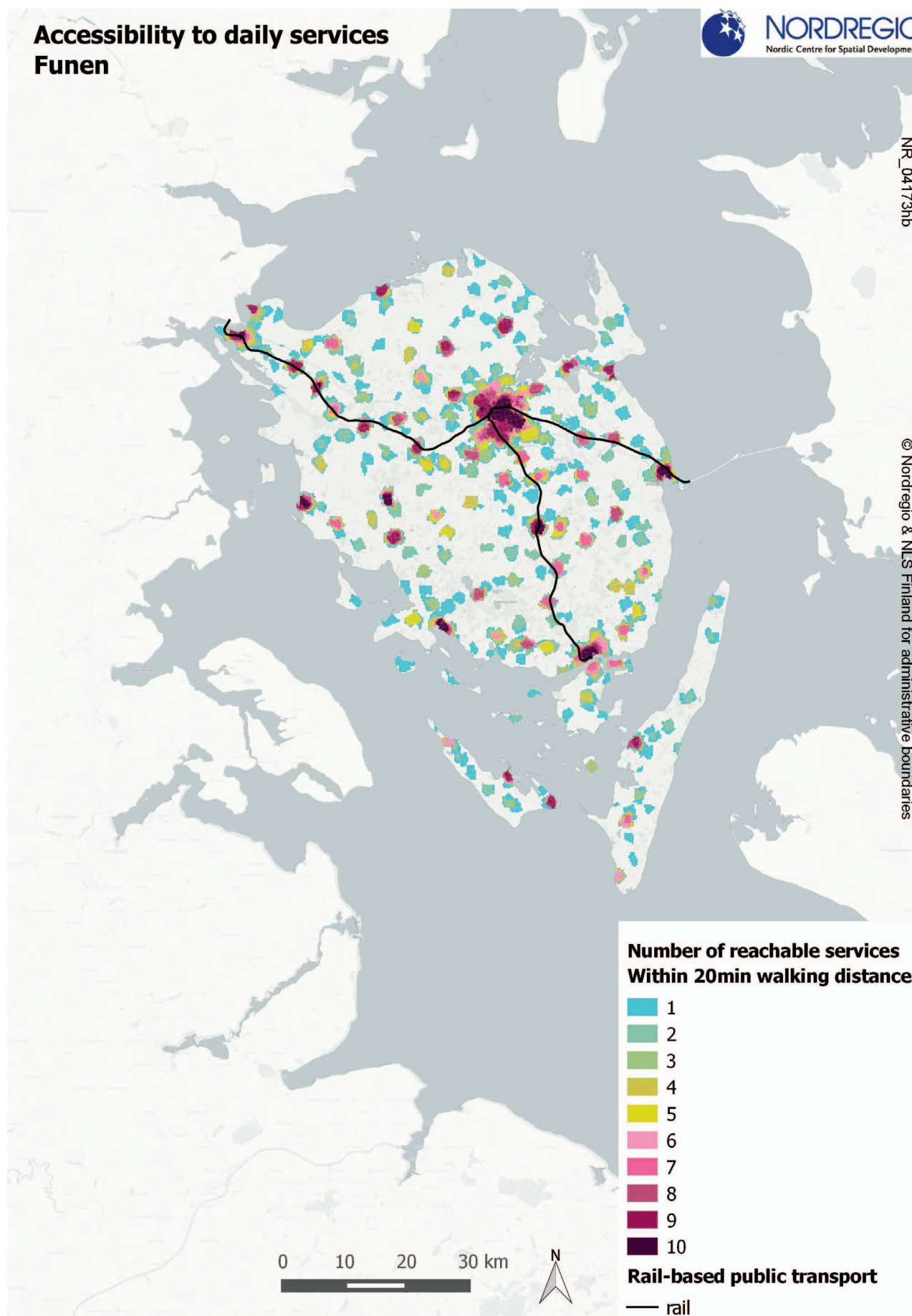
0 10 20 30 km

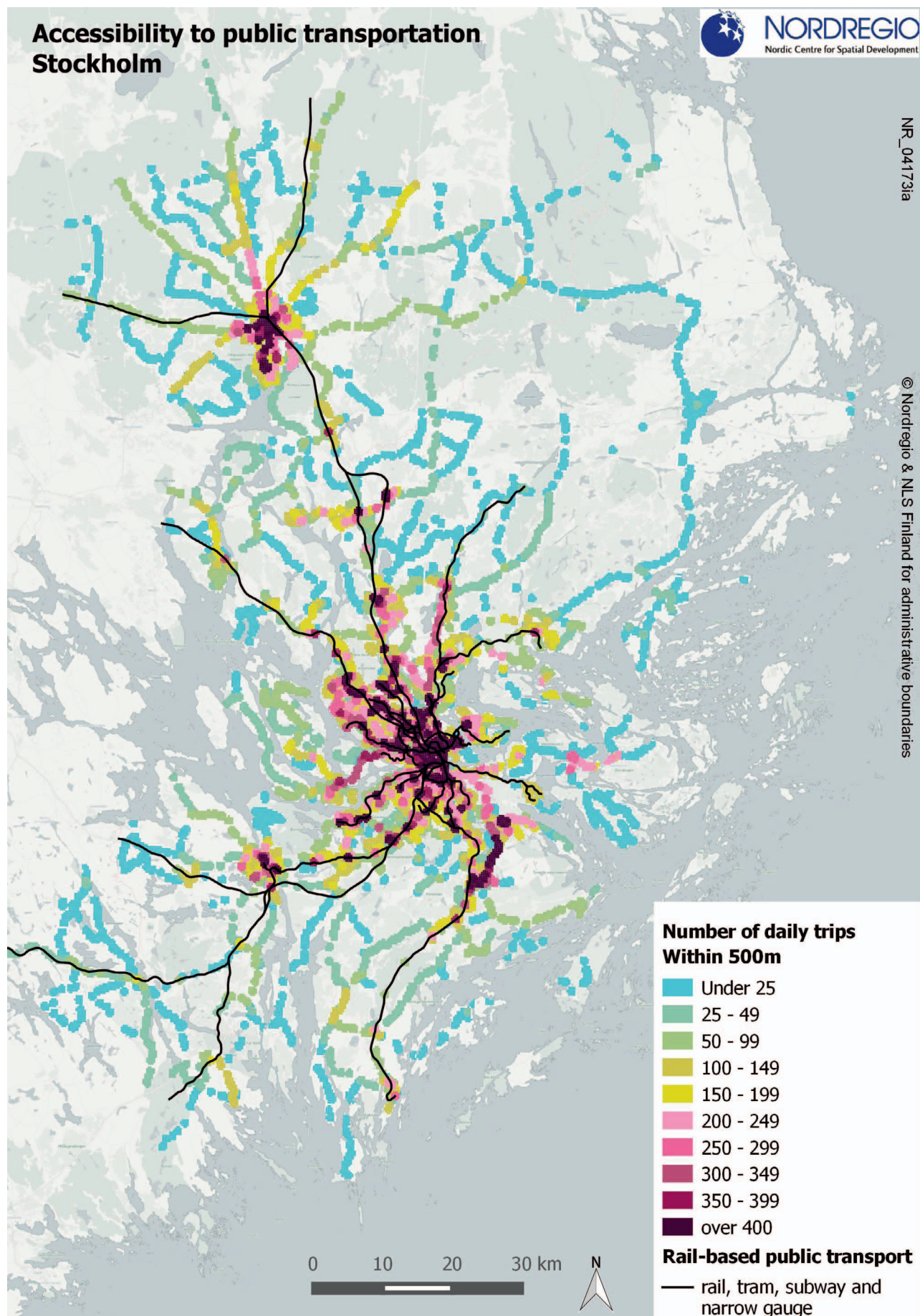


Accessibility to daily services Funen

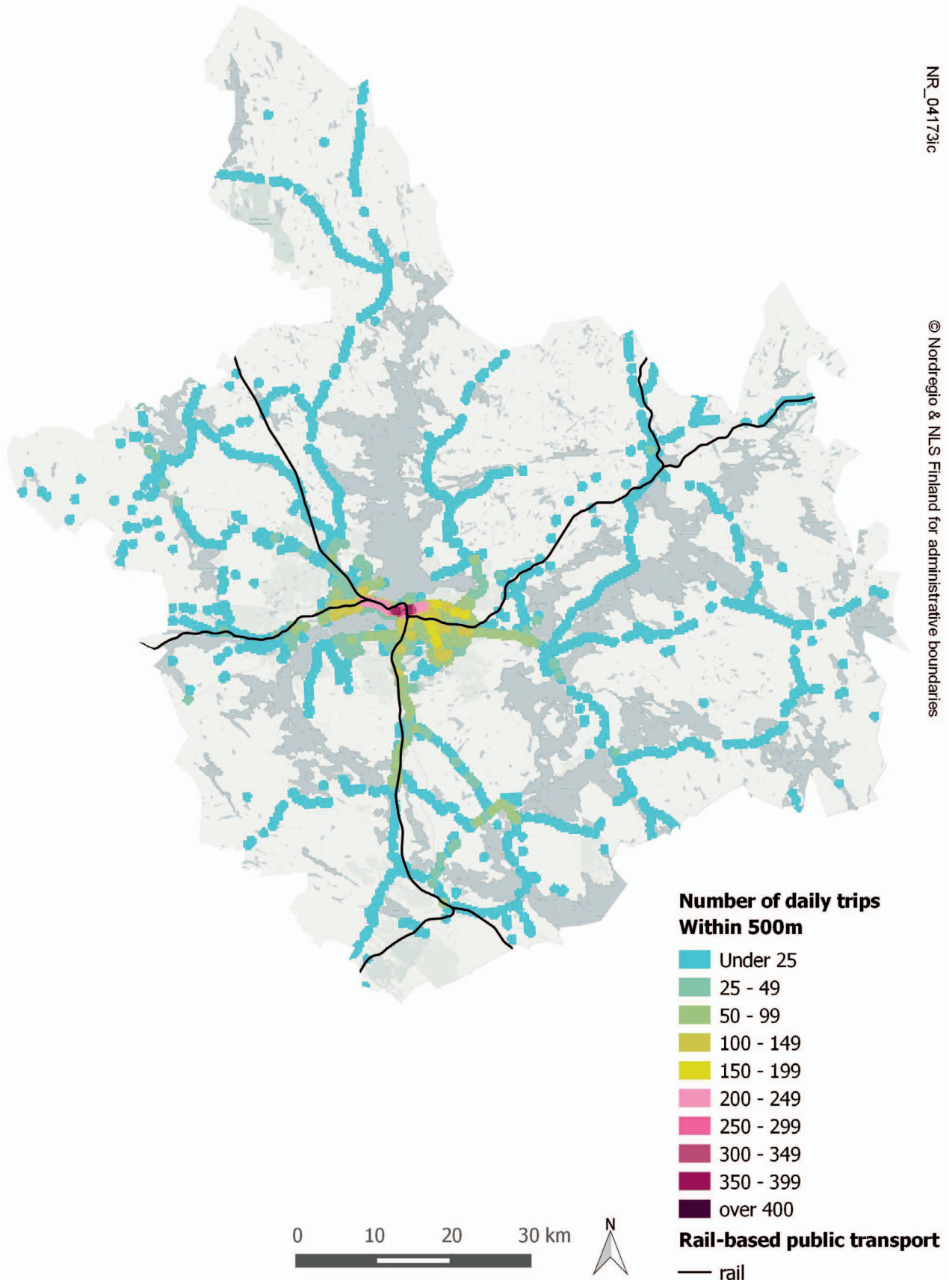
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Accessibility to public transportation Tampere



Accessibility to public transportation Trondheim



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Number of daily trips Within 500m

- Under 25
- 25 - 49
- 50 - 99
- 100 - 149
- 150 - 199
- 200 - 249
- 250 - 299
- 300 - 349
- 350 - 399
- over 400

Rail-based public transport

— rail and tram

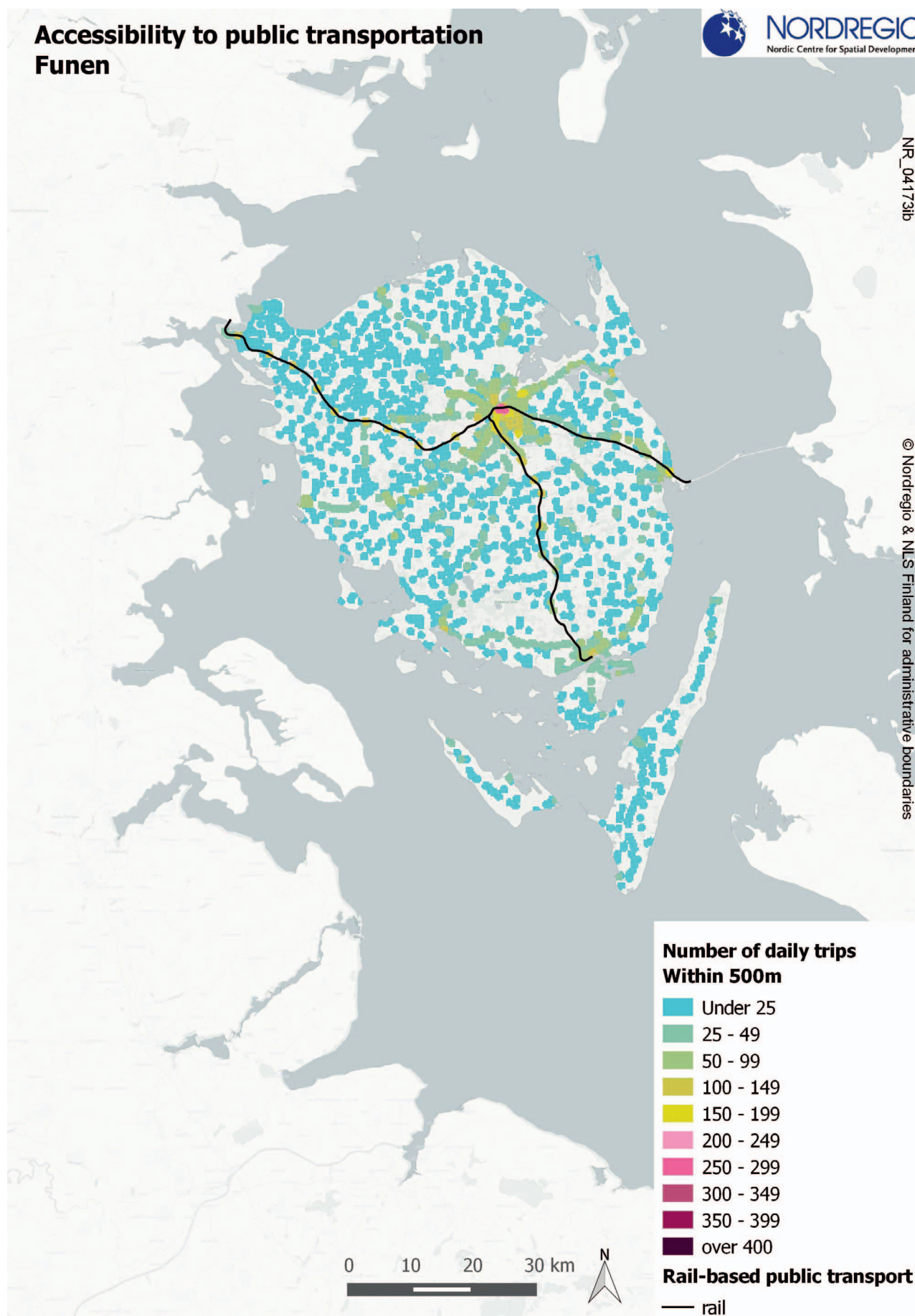
0 10 20 30 km

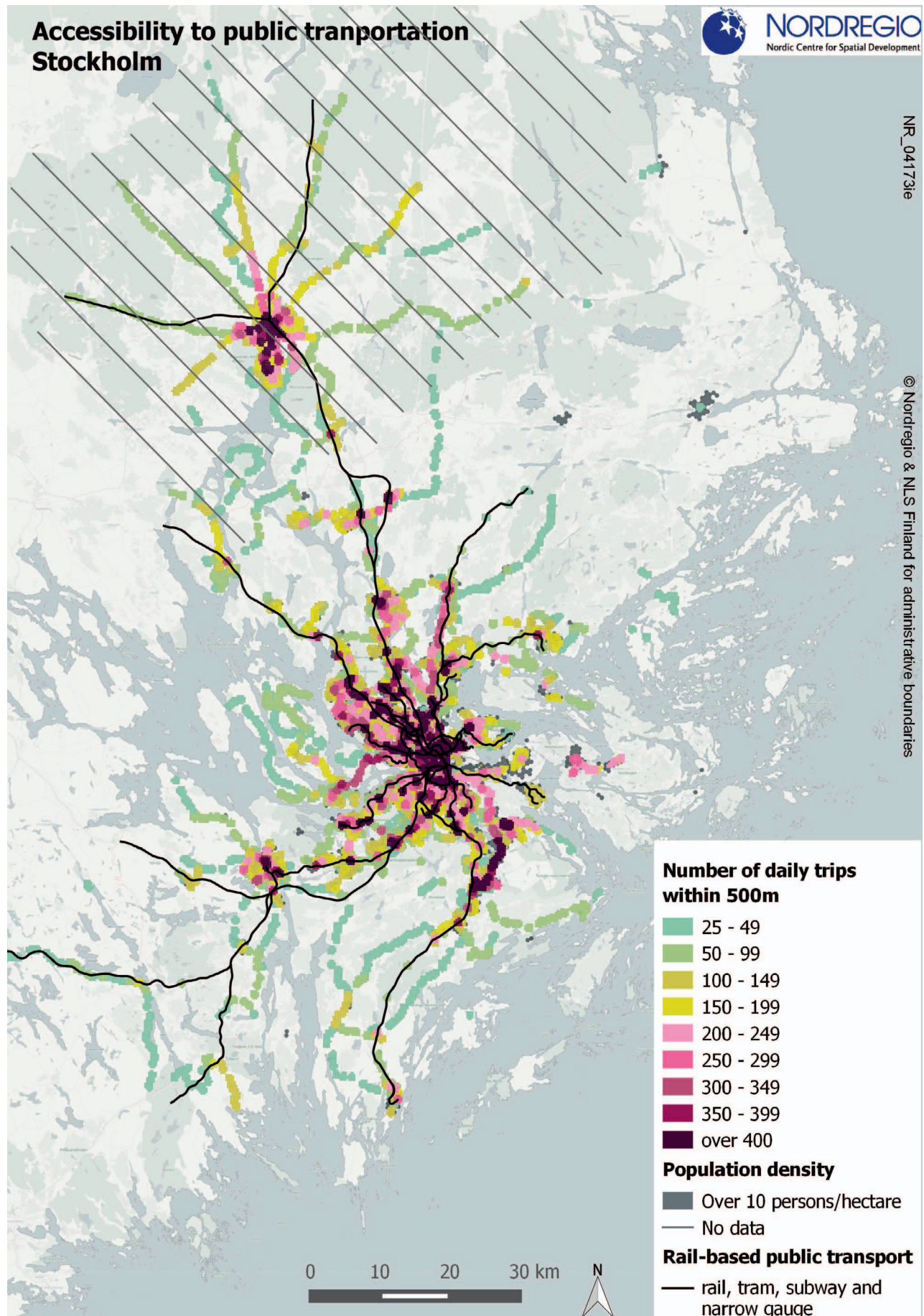


Accessibility to public transportation Funen

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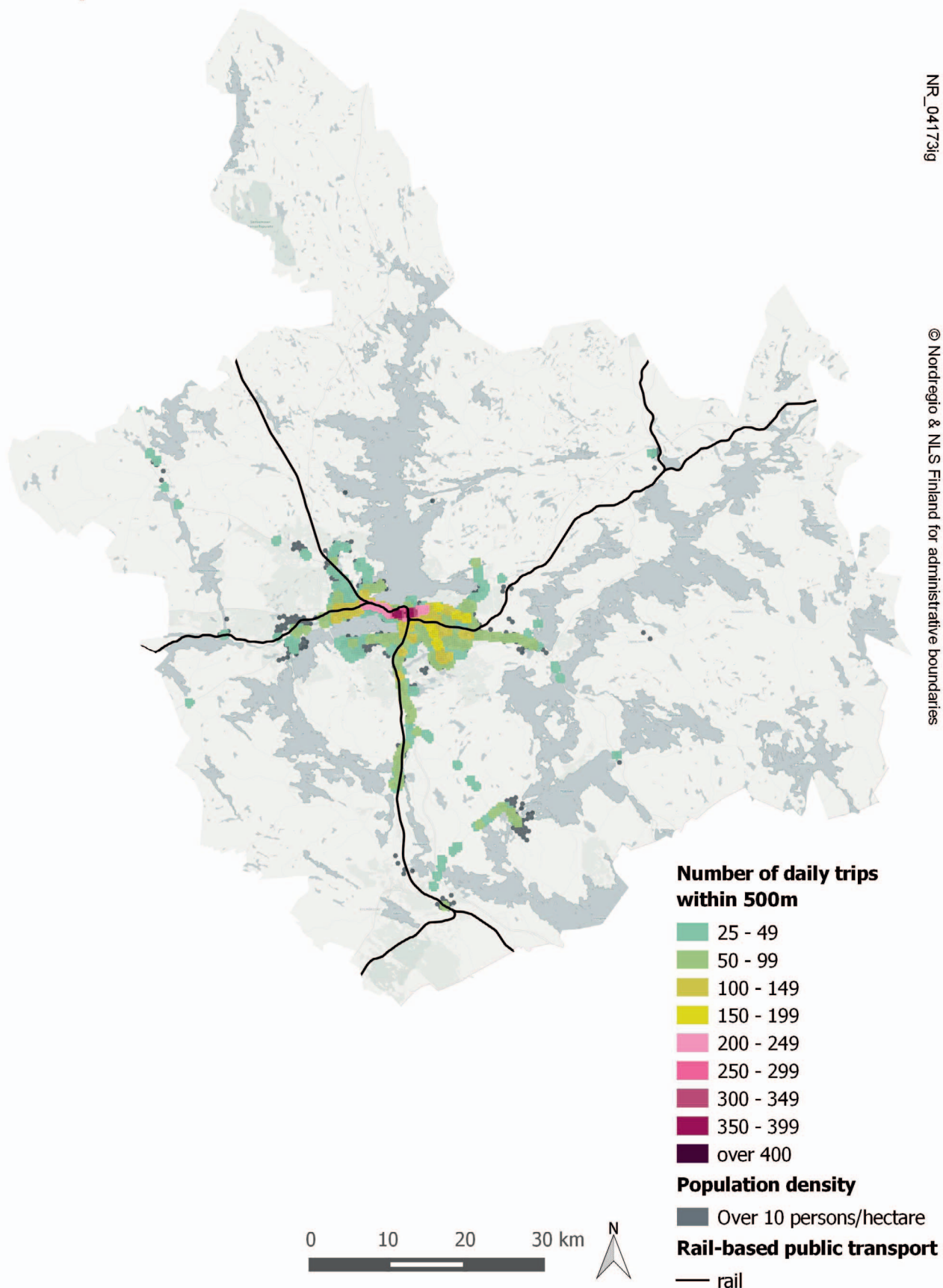




Accessibility to public transportation Tampere

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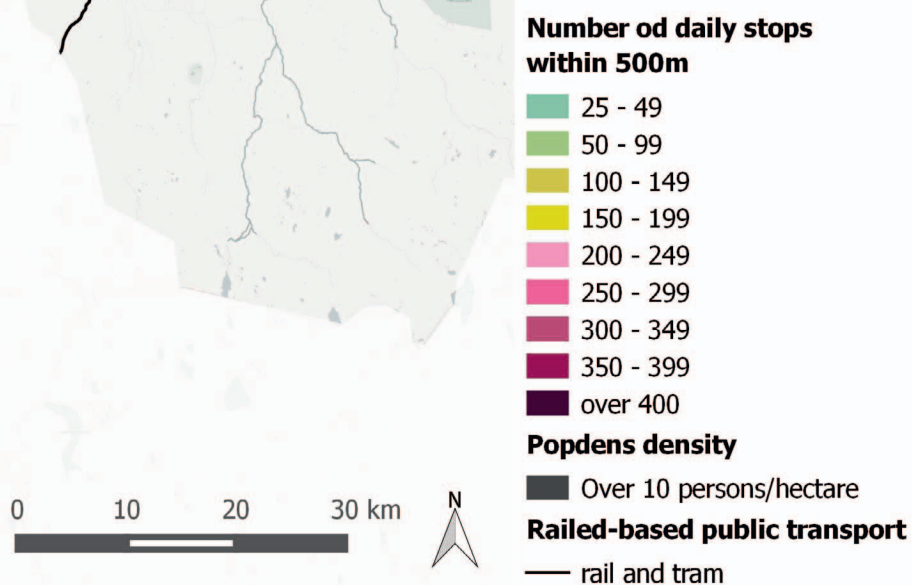
Accessibility to public transportation Trondheim



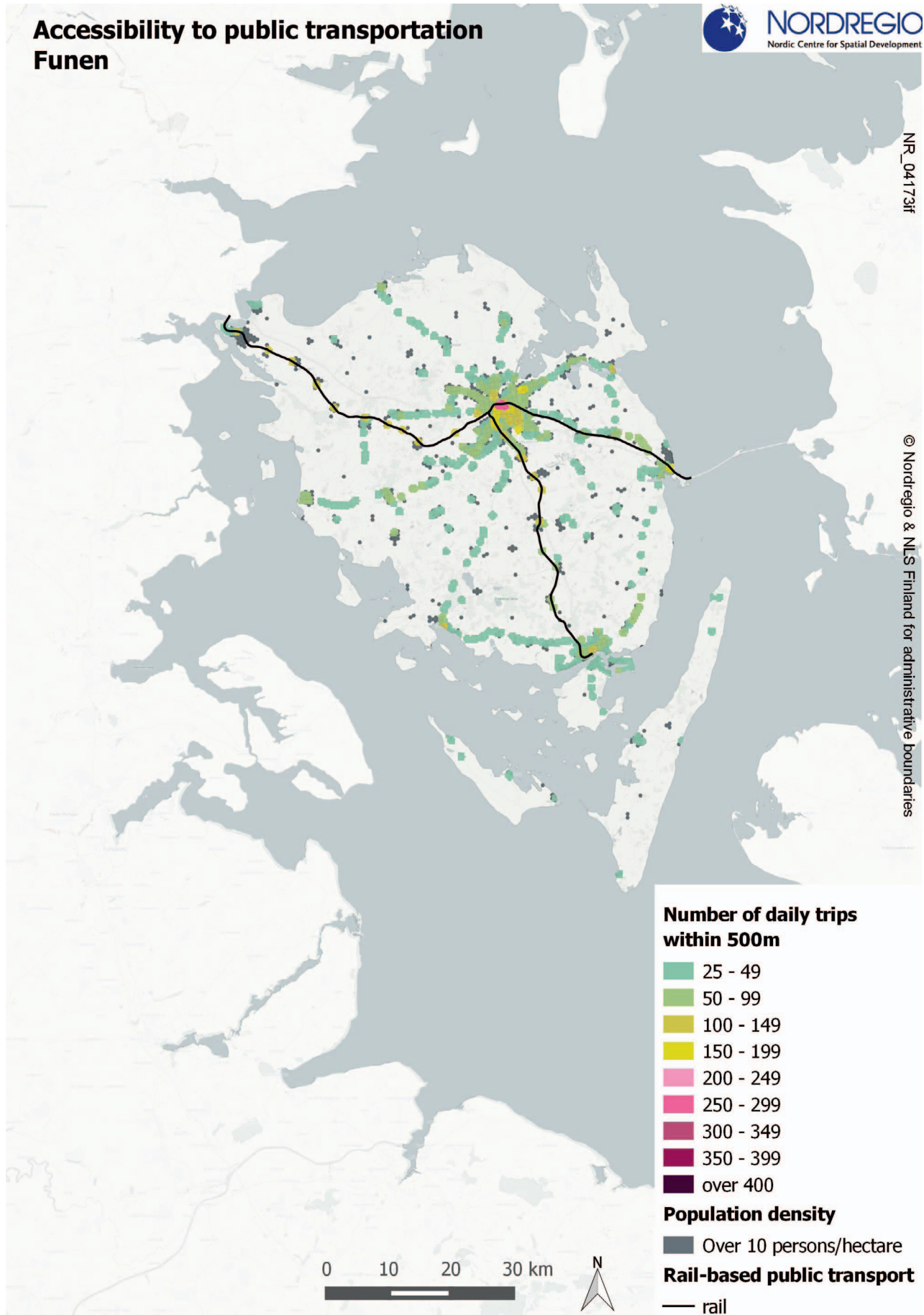
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Accessibility to public transportation Funen



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