Multifunctional Suburban Networks

A Case Study on Social-Ecological Synergies and Conflicts of Dense Corridor Development in the North Eastern Suburbs of Gothenburg

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Supervisor: Ioanna Stavroulaki | Examiner: Meta Berghauser-Pont Chalmers School of Architecture | Department of Architecture and Civil Engineering Today, many suburban areas of Gothenburg are facing multiple obstacles related to their disconnected position in the urban street network including social exclusion, unjust resource distribution, and increased car dependency. An urban development approach that has recently gained ground in Europe is the 15-minute city (15mC), advocating for denser cities with all essential services within a 15-minute walk from each household. The Evolutive Meshed Compact City (EMC2) is a response to the 15mC model, addressing its limits outside urban cores and in relation to peripheral areas. By acknowledging the periphery's relative position in the street network, the EMC2 proposes strategic dense corridor development of existing suburban main streets where the driver for densification is highest. However, development in urban peripheries comes with additional, ecological challenges. Studies have shown that biodiversity is declining with intensified urbanization and increases along the urbanrural gradient. For some species groups, the species richness has proven to peak at intermediate levels of urbanization, implying density forms characteristic of suburban settlements. Many of the bigger cities of Sweden, including Gothenburg, have been established on woodlands, indicating that future

urban development will continue to encroach on remnant urban woodlands, putting accessibility to nature and red-listed species at risk. Suburban development without taking the green and blue networks into consideration could therefore result in habitat fragmentation and consequently, push the urban nature and ecosystem services further away from the cities, affecting quality of life and the resilience of cities negatively. Through data-driven analyses, this thesis work seeks to address the suburban street network's role in providing proximity, connectivity, and various services as well as the suburban green/blue networks' role in supporting ecosystems and linking habitats on a city scale. The result is a social-ecological case study of potential suburban main streets, showing synergies and conflicts in the ecological and sociospatial overlaps.

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Chapter 1: Introduction

1.1 Introduction and Problem Description

Many of today's suburban areas in Gothenburg were designed and developed during "The Peoples' Homes" initiative of the Swedish welfare state from the 1940s and onwards, following the neighborhood-unit planning ideals of that time (Legeby, et. al, 2014). The spatially demarcated urban expansion was characterized by enclaves consisting mainly of housing units and differentiation of traffic - a design that later has been pointed out by researchers to pose obstacles to social processes and integration processes. Furthermore, it is a design in which many are facing particular challenges coupled with social exclusion (Ibid.). Besides the social obstacles deriving from the suburban areas disconnected position in the street network, including the uneven distribution of resources and limited people exchange, the sprawl of people in urban planning comes with a multifaceted array of other effects on a macro scale, including increased car-dependency and transportation of goods, reduction of the viability in services and public transport and the fragmentation of ecosystems. All of which result in greater space, biodiversity loss, and energy consumption of cities (Berghauser-Pont & Haupt, 2021).

In urban cores, the 15-minutecity (15mC) concept is an urban development approach that recently has gained ground in both policy and practice around Europe. One dimension of the 15mC is "walkable neighborhoods", meaning inhabitants should be able to access basic essential needs within reach of a 15-minute walk or bicycle ride, to promote healthier lifestyles by minimizing the dependency on cars (Moreno, et. al, 2021). However, a transition to the 15mC is much more complicated for peripheral areas of a city. such as suburban areas. as these lack the key morphological preconditions and demographic drivers for densification. The Evolutive Meshed Compact City (EMC2) is a model aiming to include the loose structural networks of peripheral and suburban areas by proposing compact corridor development utilizing existing main

streets where the driver for densification is highest. (Fusco, et. al, 2023). Concentrating development along peripheral main streets that already exhibit relatively high movement flows and increase internal connectivity appears more feasible than attempting to transform the legacy of modernist planning mediated by open space through extensive densification (ibid). Such dense corridor development, aiming to strengthen internal connectivity, could increase accessibility between spread-out urban amenities by connecting adjacent neighborhoods and, in the long run, benefit from the multiplier effects of the generative movement economy (Klasander, 2008). However, there is a potential conflict in the densification of suburbia as land use interests may come into conflict in regard to what is already there in terms of ecological values, such as remnant forests (Hedblom & Söderström, 2007) and what needs to be developed in terms of social values, such as accessibility (Legeby et al. 2014).

As the acquisition of natural reserves and protected nature areas has plateaued internationally, the habitat heterogeneity and relative species richness of the suburban mosaic have been pointed out as increasingly important to conserve (Lintott & Douglas, 2021). Development of periurban areas might cause fragmentation of species dispersal corridors (Dearborn & Kark, 2005), potentially leading to declining biodiversity and ecosystem services in cities if not properly addressed in planning and management actions (Hedblom & Söderström, 2007). Just recently EU adopted a new law with the aim to increase, secure, and restore the preconditions for all ecosystem services. In urbanized areas, the goal is "no net loss of green urban space and an increase in the total area covered by green" (https:// environment.ec.europa.eu/topics/natureand-biodiversity/nature-restorationlaw_en). It is of great importance to find a balance between density, biodiversity, and thresholds regarding what kind of social services and ecological services the urban form can provide for (Colding et al, 2022). This calls for a cautious social-ecological approach in the implementation of the EMC2, in which the social and ecological systems of suburban land use must be understood both separately and in relation to one another. This dual perspective is essential to identify potential synergiesas species richness correlation to ecological systems ability to mitigate climate impact, which is highly relevant in the dynamic changes of cities and climate change (P M L Anderson, 2020), and biodiversity's impact on human health and well-being (Ode Sang & Hedblom, 2021)—as well as possible conflicts.

Today there is a lack of coherent measurements comprising the relationship of density, urban form, and social and ecological values (Colding et al, 2022). Attempts to link human activity and ecological processes in urbanization can be found in the developing field of urban ecology and research done towards establishing a unified spatial morphology, combining



Figure 1. A simplified diagram illustrating species richness along a rural-urban gradient. It shows urban biotas (groups of species at a specific location) related to impervious surface area, as well as suitable conservation strategies in relation to urban sprawl. Suburbia is located in between the conservation strategies of preserving remnant natural habitats and restoring ruderal habitats, meaning the site-specific preconditions need to be evaluated. The suburbia's relative position in the middle of species richness and groups is pointing it out as an important stepping stone for habitat connectivity in urban nature. The diagram has been remade from the original version made by Michael L. McKinney (2009).

urban morphology and landscape ecology's different means of description (Marcus & Berghauser Pont, 2019). By mapping such overlapping dynamic connections of social and ecological entities in a dense suburban corridor development, questions emerge on how, and to what extent, spatial integration and street configuration can create co-presence and movement among humans from different areas, but also among humans and nonhuman species.

1.2 Chosen Fields and the **Thesis Starting Point**

The Evolutive Meshed Compact city model serves as the starting point of this thesis, offering a strategic framework for addressing the integration of peripheral areas through a more sustainable urban form that is meshed compact main streets. The effects of the successful implementation of such a mesh would enhance human-scale movement while preserving the continuity of green and blue networks within the mesh (Fusco et al. 2023). While pointing out the 15 Minute City-frameworks limitations outside the urban core, the EMC2 model similarly advocates for denser, mixed-use neighborhoods with reduced need for motorized traffic, but through a model that acknowledges the networked pre-requisites of these functions and is applicable on the loose suburban street network (ibid). By combining complex social and ecological systems through urban form, the EMC2 model aligns with the principles of Social-Ecological Urbanism.

The 15-minute City concept

The 15-minute city (15mC) is an urban planning concept rooted in chronourbanism, emphasizing time as a key determinant of quality of life (Moreno et al., 2021). Although the framework gained widespread attention through its implementation in Paris, its underlying principles can be traced back to influential urban thinkers such as Jane Jacobs, Jan Gehl, and Torsten Hägerstrand, who have long advocated for more human-centered urban environments (Elldér, 2024) as well as to the original ideas of social and self-sufficient Neighborhood units (Fusco et al, 2023, Klasander 2008). At the core of the 15mC lies the ambition to enable people to access all essential services, such as work, housing, commerce, healthcare, education, and entertainment. within a 15-minute walk or bike ride from their homes. The model presents a strong critique of the car dependency of modernist planning, instead promoting a more compact, multifunctional, and socially inclusive urban form. To support this city planning concept, Moreno (2021)

identifies four key planning principles: density, proximity, diversity (including mixed land use and sociocultural diversity), and digitalization through smart city technologies.

Social-ecological urbanism

Social-ecological urbanism (SEU) approach is a theoretical framework positioned at the interface of urban ecology and urban design and dwells on the academic discourse of resilience science and the space syntax theory to link resilience building to different variables of urban form (Colding et al. 2019). As a discourse, social-ecological urbanism can be seen as the evolution of the smart growth/socio-technical "sustainable urbanism"-paradigm as it goes beyond design for mitigation of carbon emissions impact on climate change and brings in the measurement of adaptation to urban design and planning by incorporating ecosystems (Barthel et al. 2013). Thus, socialecological urbanism derives from the idea of social and ecological systems' multi-scalar interconnectedness (Berkes et al., 2003, Marcus & Colding, 2014) where resilience thinking is linked to the systems' ability to absorb disturbances through social-ecological synergies (Barthel et al. 2013).

The thesis positioning

The EMC2 model, the 15-Minute City framework, and the principles of Social-Ecological Urbanism form the conceptual foundation and starting point for this thesis. Together they underscore the importance of overlapping social, and ecological dimensions to achieve synergetic multifunctionality within urban form, positioning the thesis within these themes.





Metapopulations

Figure 2. The 15-minute city applied on the urban core in relation to a suburban area. Applying the 15-minute city without taking the peripheries into consideration could increase polarization between the gentrified urban core and peripheral neighborhoods (Fusco et al. 2023).



guestion of this thesis is how social-ecological dynamic of suburbia can inform the design of dense corridor development to avoid fragmentation of species' metapopulations

Aim

The aim of the thesis is manifold.

First, the thesis aims to assess what the suburban street network provides for in terms of proximity, connectivity, and different services and what the suburban green/blue networks provide for in terms of functioning ecosystems and linking habitats and biodiversity.

Secondly, the thesis aims to highlight the synergies and conflicts that can emerge when overlapping the two systems' networked nature in a meshed main street development.

Finally, the thesis aims to address identified similarities and differences between the social and ecological systems, contributing to the strives towards a joint social-ecological morphology (Marcus et al, 2019).

Purpose

The purpose is to contribute to a methodology of identifying potential multifunctional networks with socialecological potential for compact corridor development, in accordance with the EMC2 and SEU.

Delimitations

Both social and ecological systems of urban form are complex fields within themselves (Berkes et al., 2003), meaning it is necessary to limit the scope of these separate fields. Furthermore, it is important to point out that this is not a design project thesis, but an applied case study addressing the challenges and opportunities of implementing an urban form concept in a suburban context. Below is a graph aiming to capture what the thesis is about and what it is not about.



1. How can potential synergies and conflicts of overlapping social-ecological dynamics inform the design of dense corridor development in the Northeast suburbs of Gothenburg?

2. What does the suburban street network provide for in terms of connectivity, proximity, and different services and what does the suburban green/blue structure provide for in terms of linking habitats and functioning ecosystems?

Sub questions:

• What are some examples of significant spatial factors and land uses for selected species in the suburban landscape?

• How can different spatial configurations and urban types of the dense corridor development of the EMC2 affect human and non-human movements in a suburban landscape?



Figure 4. Delimitation graph



Figure 5. Gärdsås Mosse is one of the multifunctional habitats of the case study area. This area has human access through gravel paths and consists of source habitats (dead/decaying wood, small waters, and sandy substrate) for all studied species. It includes biotopes with high quality for the species and humans, for instance, pastures with grazing animals, allotment areas, and deciduous remnant forest, all of which has a positive impact on both human and nonhuman species.

Chapter 1: Introduction

This chapter introduces the reader to the problem, background, and context of the project.

Chapter 2: Discourse

Theories and research relevant to the thesis.

Chapter 3: Method and process

The reader is presented with the research design (the overall structure of the thesis) and the main principles of the methodology based on the aims of each analysis. This is followed by the presentation of the data used in the thesis and how it has been processed through different methods and tools. The methods and processes for the spatial analysis and ecological analysis are presented separately.

Chapter 4: Analysis and results

This chapter introduces the reader to the analysis and results of the potential of the existing suburban networks. The analysis and results for the ecological analysis and spatial analysis are first presented separately, and then jointly as a social-ecological analysis. The overlaps give insight into the synergies and conflicts of the spatial and ecological networks combined.

Chapter 5: Design Implementing the EMC2 Model with a Social-Ecological Perspective

In this chapter, the reader will be presented with a social-ecological strategic mesh design on a city scale. The strategic design illustrates spatial and ecological key interventions based on the analyses. From the strategic design, one identified main street comprising different social-ecological challenges and opportunities is selected to further elaborate on different design strategies on a local scale.

Chapter 6: Discussion

In this final and concluding chapter, the reader will be presented with the answers to the thesis questions, followed by a discussion, suggestions for further research, and concluding remarks.

Gothenburg

To better understand the spatial conditions of suburbia and its relative position within the city, the street network and the blue/green network need to be analyzed from a city scale. For this reason, Gothenburg municipality forms the context of this project. Adjacent municipalities are included to some extent as the networks are not necessarily spatially defined by administration borders.

NordOst/North East

To be able to apply the analyses on a suburban context the North Eastern suburbs of Gothenburg was selected as a case-study area. The area of the selected case study is spatially defined by the river Göta Älv in the West, the valley Lärjeåns Dalgång in the North, the stream Säveån in the South and the border of Partille Municipality in the East. Within this area, the neighborhoods Gamlestan, Utby, Södra Kortedala (Southern Kortedala), Norra Kortedala (Northern Kortedala), Västra Bergsjön (Western Bergsjön and Östra Bergsjön (Eastern Bergsjön) are located. Other than being a spatially segregated area of Gothenburg, the chosen area is an interesting case-study area in regards to the ecological aims of this project, as it has important urban nature, such as Lärjeåns dalgång, which just recently became a nature reserve (Göteborgs stad, 2024), and Säveån. Another aspect of the choice of the case study area is the current developments of Gamlestaden, which is the connector between the Northeast neighborhoods and the urban core (Göteborgss Stad, n.d.a)

Kortedala and Bergsjön

In this project, particular emphasis will be on Kortedala and Bergsjön as these were developed during the neighborhood unit paradigm (Klasander, 2008) and are considered particularly disadvantaged based on social-ecological factors (Göteborgs stad, n.d.b.) This is in contrast to adjacent Utby which is considered to be among the least disadvantaged of Gothenburg neighborhoods (ibid.). Kortedala was established in the 1950s and Bergsjön in the 1960's. In accordance with the planning ideal



Figure 6. Map showing particularly disadvantaged areas based on socio-economic factors in different neighbourhoods of Gothenburg, ranging from most disadvantaged (1) to least disadvantaged (6). (Source: Göteborgs stad (Stadsledningskontoret), Göteborgs-Posten)

of this era, the peripheral housing estates have services concentrated to poorly spatially defined local squares, differentiated from global scale movement (Klasander 2008).







Figure 8. Differentiation of traffic is characteristic for the modernistic neighbourhood unit development. This pedestrian path located in Bergsjön is submerged in 'green', but has no particular social-ecological values.

Chapter 2: Discourse

2.1 Theoretical Framework

This section presents the framework of theories used as the discourse of this thesis work, which is largely theories, approaches, and expert areas within urban morphology and landscape ecology.

Urban morphology

The interdisciplinary field and research output of urban morphology is vast and has a varied definition within research. The field stems from schools within both geography and architecture (Klasander, 2008) and can be described as the study of how urban form shapes, structures, and transforms the city's processes (Oliveira, 2016) and as a field that "studies the process of city building and its products" (Vernez Moudon, 1998 p. 141).

Elements of Urban morphology

Vernez Moudon describes the field as consisting of three main principles, that is:

Urban form is defined by the elements: streets, plots, buildings, and open space;

urban form can be analyzed in multiple scales including building scale, block scale, city scale, and region scale, and;

studies of urban form need to have a time perspective (Vernez Moudon, 1997).

Spatial segregation

Legeby (2010) argues that urban life is a process shaped by urban form, which in turn influences the degree to which public space can be shared by different social groups. This perspective adds a spatial and structural dimension to the concept of residential segregation, which typically focuses on the geographical distribution of neighborhoods and the separation in how and where people live often measured through relative and relational indicators such as socioeconomic status, demographics, and ethnicity within administrative boundaries like municipalities. According to Olsson

(2005), the presence of diverse groups in public spaces is not only a fundamental principle of public life but also essential for counteracting social segregation. The notion of interplay segregation highlights whether different socioeconomic groups can interact, depending on factors such as the built environment, population density, and the flow of non-locals through an area. This reframes segregation as a question of movement and accessibility, suggesting that access to "the other" and the city's resources is an issue of the spatial configuration and urban form (Legeby, 2010).

Space syntax theory

Space syntax is a methodological and theoretical framework used to analyze spatial configuration in built environments to be able to understand and create intelligible systems of integrated and segregated space in a street network. It focuses on understanding the relationship between spatial design and social, economic, and environmental processes as an outcome. Overall, space syntax provides a set of tools and concepts for analyzing the spatial aspects of urban and architectural planning and design, offering insights into how physical space can influence human behavior and social dynamics. A theory within space syntax theory is the theory of natural movement. The theory refers to the street integration's ability to attract pedestrian and vehicular flows in an urban network. A wellintegrated street naturally attracts more movement, creating a multiplier effect (Hillier et al, 1993). A conceptualization of cities based on this theory is cities as "movement economies", pointing out movement as generated and generative. In a mixed-use regular urban grid where destinations are spread out, movement roughly goes from everywhere to everywhere (Hillier 1996). The deformed grid creates asymmetries that create a hierarchy in the level of integration of streets in the network, causing attraction



Figure 10. Four grid systems joined in one network. The orthogonal regular is most integrated, meaning it has shortest mean length from one cell to all other cells in the network. Figure is from Hillier. B, Centrality as a process: accounting for attraction inequalities in deformed grids (1999)

inequalities (Hillier, 1999). Hillier (1999) argues that the uneven distribution of movement and activity in a city derives from the spatial configuration, which is driven by the movement economy process, rather than land uses. Consequently, in a suburban context, neighborhoods with a high density of people can still have low accessibility to different destinations because of their disconnected position in the street network. Klasander (2003) argues that the lack of regularity in the grid reduces the movement economy to a monofunctional 'origin-destination system'.

Spatial morphology

Spatial morphology is a theoretical endeavor of combining the analytical dimension of spatial analysis, such as the analytical measurements found in space syntax, and the descriptive dimension of urban morphology, such as typologies of the urban form (Marcus & Berghauser Pont, 2015).

Typo-morphology

Typo-morphology is a field within urban morphology and can be related to both descriptive and functional dimensions

of the urban fabric and its built form and how it has evolved with time. Berghauser Pont et al. (2019a) manage to explain both spatial performance and morphological function of built form through two urban types developed through the spatial properties of street centrality and built density. The two urban types are divided into key morphological forms, essential for urban design practices capturing 1) movement (street types) and 2) occupancy (density types). The urban types have proven to structure pedestrian flow (Berghauser Pont et. al 2019b) The combination of both high centrality values of street type and high density correlates to higher pedestrian flows (ibid.).

Landscape ecology

Landscape ecology is an interdisciplinary field incorporating theories from social, biological, and geographical sciences and can be compared to urban morphology as it describes the dynamics of space (in this case landscapes) through spatial form (Marcus & Berghauser Pont, 2015). The field is concerned with the spatial variation of landscapes across multiple scales and how such spatial patterns are shaped by both natural processes and human actions (Alberti, 2008). Because it perceives humans as an integrated part of ecological processes, the field of landscape ecology can be of use in planning for nature conservation and urban planning. The spatial components addressed in landscape ecology include both biotic (living) and abiotic (non-living) forms that are analyzed through landscape elements such as patches, corridors, and matrixes (ibid.), explained below.

Elements of Landscape ecology

Matrixes are described as "a surrounding area that has a different species structure and composition" (Forma & Gordon, 1986, p. 83) and describes the functioning landscape (ibid) as a composition of biotic and abiotic forms. A city, including both built form, hard surfaces, and green areas could for instance be a matrix, where the green areas, such as urban parks, could be perceived as patches (Marcus & Berghauser Pont, 2015).

Patches are defined as "a nonlinear surface of land which differs from the matrix on each side" (Forman & Gordon, 1986, p.83) and describe the horizontal structure of ecosystems (Alberti, 2008), which is in extension built up from what in ecology is called biotopes (Marcus & Berghauser Pont, 2015).

Corridors are "narrow strips of land which differ from the matrix on each side (Forman & Gordon, 1986, p 123) usually forming linear strips of a specific land use forming a pathway of dispersal for species (Forman 1995).

Urban ecology

A field within landscape ecology recognizes the co-presence of human and non-human species in the urban landscape (Alberti, 2008) The field recognizes the similar characteristics of the studied elements of urban morphology and landscape ecology (Marcus et al, 2019). Marcus et al. (2019) take important steps towards forming a joint social-ecological urban morphology recognizing these similarities and differences through the elements and geometric descriptions of urban morphology and landscape ecology. Elements compared from the different fields are streets and corridors, patches and plots, as well as urban blocks and matrixes. While these elements may share comparable geometric forms, they often support distinct ecological and social processes. The primary focus, therefore, lies in the shared relational dynamics between patterns, form, and function in social-ecological systems (Marcus & Berghauser Pont, 2015). These dynamics can be simplified to the geometric shape of polygons (Marcus et al. 2019), comprising the elements constituting both human and/or nonhuman habitats and flows. For humans, streets facilitate such flows; however, understanding the specific dynamics of this connective patchwork depends on what is analyzed as moving through (Ibid.) More urbanized landscapes are

expected to exhibit greater spatial separation between these flows (ibid.) as the degree of landscape connectivity (Douglas, 2021) and surface permeability influence biodiversity and species richness, which becomes more fragmented and decreases towards the urban core (McKinney, 2009).

Fragmentation and Habitat networks

Biotopes and habitats are fundamental structural components of ecosystems and ecological dynamics. As urbanization and densification often encroach upon natural landscapes (Hedblom & Söderström 2007; Kindvall et al., 2024), new methods are emerging to map habitat networks and fragmentation as tools for ecological restoration and enhancing the ecological functionality of cities. Kindvall et al. (2024) recently developed a Habitat Network Analysis Tool (HNAT), which applies a species-specific approach to support the survival of targeted species within urban environments. The tool utilizes raster-based biotope data to assess habitat quality, friction, connectivity, and functionality. This modeling approach has demonstrated the capacity to integrate human habitats and movement patterns through the assignment of friction values relative to the species under study, offering a shared framework for analyzing both social and ecological impacts on social-ecological flows.



Figure 11. Polygons of social and ecological entities are viewed separately and overlap, forming what Marcus et al. refer to as the "configuration of patches" as it inhibits the functional dimensions of both biotic (ecological entities) and abiotic forms (social entities) (2019). In this way, a street with trees might serve as both human and non-human habitats and thus inhibit social-ecological dynamics, depending on what species is analyzed.

Chapter 3: Methodology

3.1 Research Design

The thesis falls into the category of research for design and uses a mixed-method research design, including desk research, qualitative and quantitative research, and research by design to describe the multiple processes of urban form and landscape patterns. The research design is divided into four phases:

1. Finding the foreground network

In this initial phase, most time was spent gathering data for the spatial and ecological analysis and analyzing the existing situation of the studied context.

2. Finding synergies and conflicts

In the second phase, the functioning of the spatial and ecological networks of the existing situation was assessed separately to identify multifunctional street networks and multifunctional green networks of the studied context. From these results, a social-ecological overlap analysis of spatial and ecological networks was conducted.

3. Implementing the EMC2 with a social ecological perspective

In the third phase synergies and conflicts of spatial and ecological networks were assessed through a strategic design of a multifunctional mesh. Social-ecological design interventions were applied on a local scale design of an identified case-study main street.

4. Conclusions and suggestions for practice

In the final phase, the constraints and opportunities of the implementation of the EMC2 in a studied suburban area are discussed from a social-ecological perspective.



3.2 Introduction to Methodology

The analytical methodology for this thesis follows a systematic, three-part structure designed to achieve the research aims. In principle, the approach first identifies the key social (street network) and ecological (habitat network) systems, and then synthesizes these findings to reveal their social-ecological overlaps. The required analyses were as follows:

1. Identification of the EMC2 mesh for the foreground streets, assessing its potential for pedestrian movement by ensuring it is Multiscalar, Multimodal, and Multifunctional. This requires the following analyses:

A Spatial Analysis to quantitatively evaluate the street network's social function, which includes:

• A multiscalar betweenness analysis combining the motorized and non-motorized networks.

• A multimodal analysis based on the proximity to public transport stops.

• A multifunctional analysis based on the accessibility of non-residential functions within a 500-meter walking distance from the streets.

• A systematic streetscape photography analysis to provide a qualitative understanding of the physical character and pedestrian environment of the potential foreground network.

2. Identification of multifunctional ecological corridors and patches, based on a multi-species approach. This is achieved through:

A Multi-species Habitat Analysis to quantitatively evaluate the 'green' network's ecological function, which includes:

 Separate habitat connectivity analyses for the three specific species with different mediums for movement and dispersal capabilities in the landscape; Lesser Spotted Woodpecker, Amphibians (Common frog), and the Small Scabious Mining Bee. • An overlap analysis of the species specific dispersal probability to identify multi-species dispersal corridors, i.e green corridors.

• An overlap analysis of species specific habitat functionality to identify multifunctional patches for multiple species, i.e functioning ecosystems with multiple ecosystem services.

3. Identification of socialecological synergies and conflicts. This final step of the methodology synthesizes the previous findings and requires:

A Social-ecological overlap analysis where the identified EMC2 foreground network (the social layer) is systematically overlapped with the identified multifunctional ecological patches and corridors (the ecological layer).

• As part of the method is the implementation and evaluation of minor interventions to improve internal connectivity and multifunctionality of the meshed suburban networks, including both spatial and ecological networks.

The following sections will now describe the specific social and ecological data, tools, and step-by-step procedures used to carry out each of these required analyses.

3.3 Spatial Analysis

As an initial step of the spatial analysis, the foreground network and current functioning of the suburban streets needed to be assessed. For this, data significant for the EMC2 model was needed. Such data would need to be both configurational and morphological, in accordance with the aims of the EMC2. In this section, realworld vector data used to identify the current potential of different streets is presented and shown in maps of Gothenburg and the Northeast suburbs of Gothenburg. First, suburbia's networked nature within the street network was identified through the urban types; streets, and built density types. As a complement to the suburban forms' performance in terms of centrality, the multifunctionality of suburban streets was evaluated through the currently built functions of the area, public transport, and accessibility to different attractions.

3.3.1 Multiscalar Centrality Street Types

Street types is an urban typology capturing human movement in urban planning and design. Multiscalar centrality street types are developed by Berghauser Pont et al. (2019a) and combine the street's descriptive form (typology) with its functional performance (the street's configurational properties) measured through angular betweenness centrality in multiple scales. Angular betweenness centrality is a measurement of how often a street segment is part of the shortest path in angular turns, meaning that streets with less angular deviation are likely to have more throughmovement (Stavroulaki et al. 2023). The shortest path of angular betweenness centrality can be measured through different scales of movement and has been associated with both pedestrian and vehicular flows (e.g. Berghauser Pont et al 2019a, Stavroulaki et al. 2019, Hillier and Iida 2005) Hence, the multiscalar centrality street types captures how the centrality of each street changes from local to global scales of movement and how the different streets' centrality profiles relate to each other in the street network (Berghauser Pont et al 2019a, Berghauser Pont et al 2019b).

Non-motorized (NMS) centrality street types

The non-motorized (NMS) centrality street types consist of four street types created from the streets accessible for pedestrians, including streets that are shared with bicycles and cars (in this thesis called multimodal streets from now on). The multiscalar NMS centrality street types are calculated through angular betweenness centrality for the pedestrian movement and are therefore limited to the more local scales, ranging from 500m to 5km (Berghauser Pont et al 2019b) City streets represent the main streets, that is streets that have high centrality in most scales, and are similar to what is called the foreground network of the city, with high centrality across scales (Hillier, 2009) Neighborhood streets have slightly higher centrality in the local scale, but drop in centrality in the higher scales. As Berghauser Pont et al. (2019a) point out, Neighborhood streets are important streets in connecting adjacent neighborhoods. Local streets have the highest centrality value on a very local scale but drop quickly on larger scales. The fourth street type is the background street, which has low centrality values in all scales, these streets are not included in the method as the aim is to find the foreground network of the studied context.





Motorized (MS) centrality street types

The motorized (MS) centrality street types are like the NMS centrality street types but for larger scales, as it is calculated for vehicular movement. Here, highways are included, while pedestrian-only paths are excluded from the analysis. The MS centrality street types consist of four street types calculated through angular betweenness centrality, but for movement scales up to 30km (for Gothenburg). Due to the larger scale, the MS types include the Metropolitan street type as the most central street type, mostly representing the highways. This is followed by the City street type, which forms the vehicular foreground network, and the neighborhood street type, which has high centrality on a lower scale (Berghauser Pont et al 2019a). Data sources

Spatial Morphology Group (SMoG) at Chalmers.

3.3.2 Denisty Types and Built Land Uses

Built density types

The built density types are an urban typology based on two density measures (FSI & GSI) and consist of six built density types, where the three lower types are more associated with suburban development. While street types capture the distribution of movement in the street network, the built density types capture occupancy and have been shown to correlate to the intensity of pedestrian flow (Berghauser Pont et al, 2019b). In many Swedish cities, the Spacious low-rise with low FSI and GSI values is the density type taking up most land use (Berghauser Pont et al, 2019a), occupying more than 80% of the land use in Stockholm (Berghauser Pont et al 2019b). Another prevalent building type is the Spacious mid-rise. These two building types are characteristic of villa development and urban sprawl and have the lowest associated





pedestrian flow, whereas the Spacious low-rise has a slightly lower. Compact low-rise is another typical built-density type of suburban development and has a slightly higher associated pedestrian flow

Data sources

Spatial Morphology Group (SMoG) at Chalmers.

Building functions

Central for the 15mC framework and the aims of the EMC2 is the diversity of functions (Moreno et al. 2021, Fusco et al. 2023) The suburban areas of the Million Programme in Sweden are largely monofunctional residential enclaves with planned local centers where most mixed building functions are concentrated (Klasander, 2003). Data sources

Spatial Morphology Group (SMoG) at Chalmers, OSM

Tram infrastructure

Long-range transportation networks are another important aspect of the EMC2 (Fusco et al. 2023), as light railway connects distant local centers where the mixed-use functions are

concentrated (Fusco et al. 2023, Klasander, 2003, Göteborgs Stad, n.d) Data sources Lantmäteriet, Trafikverket, Göteborgs stad

3.3.3 Origins and Destinations

The hierarchical tree structure of suburban streets simplifies complex movement patterns to an "origindestination system" (Klasander, 2003). To be able to assess the distribution of origins and destinations in suburbia, different attractor points were mapped.

Addresses

The origin of the local population in the area. Data sources Spatial Morphology Group (SMoG) at Chalmers.

Bus and tram stops

Long-range transportation hubs. Connects to adjacent neighborhoods and the urban core. Data sources Spatial Morphology Group (SMoG) at Chalmers.



ACEX65 - Chalmers university of technology





24 Scale: 1:50 000 (A4)

Education Universities, schools, and kindergartens. Data sources OpenStreetMap, Spatial Morphology Group (SMoG) at Chalmers.

Commerce

Local markets, e.g. retail, restaurants, cafes, and services. OpenStreetMap, Spatial Morphology Group (SMoG) at Chalmers.

Entertainment

E.g culture houses, playgrounds, sports facilities. Data sources OpenStreetMap, Spatial Morphology Group (SMoG) at Chalmers.

3.3.4 Streetscape and Urban Interfaces

In the 15mC framework, the EMC2 model, and the discourse on socialecological urbanism, the human eye-level scale of the streetscape is emphasized as an important factor influencing the use, cognitive experience, and social processes of urban space (Moreno et al., 2021; Fusco et al., 2003; Colding et al., 2019). To capture this dimension, systematic site visits were conducted on foot and by bicycle. Photographs were taken at 100-meter intervals along selected street segments, which were identified based on the analysed spatial data, eg. NMS and MS street types with different street centrality profiles (see 3.2.1) built density types and tram infrastructure above ground (see 3.2.2) The geotags of these images were subsequently imported into QGIS, enabling the integration of streetscape observations into the analysis and design part of the





Figure 14. Screenshot from QGIS. The total amount of pictures from the systematic site visits was 309, which equals to 30,9km kilometres of explorations along potential main streets in the studied context. The streets descriptive character works as a top layer of the quantitative data, in this case, on top of the NMS street centrality types and tram infrastructure.

project. Things evaluated was how the urban interface was structured in terms of volumes, setbacks and continuity and how openings in facade were constituting the streets with different profiles.



Figure 15. A street profile diagram, combining descriptive and functional measurements. These diagrams were used for some streets as a method of identifying what potential it has today and what strategic and local scale design interventions could be done to increase the potential of the street.

3.3.5 Spatial Data Processing and Method

All of the spatial data used and presented in the previous section is vector data that has been worked with in QGIS. The data consists of the different geometrical objects of description: points, lines, and polygons. Because of this, the data processing was categorized into 1. Line data processing 2. Polygon data processing and 3. Point data processing. Other than processing (adding/combining/manipulating) the data's spatial representation, the data has also been structured based on attributes. Attributes are assigned to the geometry types and describe the properties of the spatial form, eg. an attractor's coordinates, a street's centrality type, or a building's function. Following is a description of how different data has been processed and how the data's attributes have been structured for the spatial analysis.

3.3.5.a Line Data Processing

Line data is data representing networks, such as street types and tram infrastructure.

Multiscalar centrality street types

The NMS and MS street data were overlapped in QGIS to identify multimodal streets (streets accessible for both pedestrians and cars) possessing high multiscalar centrality values (See 4.1) As the non-motorized and motorized network data often appear as parallel lines, a buffer of 5m was made in QGIS. If the distance between the NMS and MS network lines was greater than the buffer, they were not considered to be multimodal but differentiated.

Tram infrastructure

Tram tracks that go underground were separated from tram tracks that go above ground. This was done manually by looking at the comprehensive plan of Gothenburg. The tram infrastructure that runs above ground was buffered by 100m in QGIS and this was used to do a selection by location of adjacent streets. This was done to find streets that are multimodal in terms of tram tracks and motorized and/or non-motorized networks.



Figure 16.NMS1 (City street) and MS3 (Neighbourhood street) are running parallel to each other at Förstamajgatan, next to City torget in Norra Kortedala. Dashed line is the multimodal street NMS1_MS3 after clip by buffer.



Figure 17. Buffer around light rail infrastructure

3.3.5.b Polygon Data Processing

Polygon data is data that usually gives information about spatial morphology/ land use and area, such as built land use and built density types.

Built land use

The source dataset (see section 3.2.2) was updated to include more recent developments identified through Google Maps or site visits and was downloaded from OpenStreetMap (openstreetmap.org). New buildings of significance for the case-study area were added manually to the data set. New building functions were added manually. The attributes of polygons representing parking houses were changed from Commercial to Parking as these are very prevalent in suburban areas and would be deceiving to perceived as commercial activity. This was done based on overlapping data from OSM and through selection by location.

Built density types

The source dataset of recent developments was identified through Google Maps or site visits and was downloaded from OSM. New built density types of significance for the case-study area were added manually and were based on surrounding built density types.

3.3.5.c Point Data Processing

Point data is data that usually gives information about locations such as origins and destinations. Origins and destinations

Addresses

More recent addresses were identified through Google Maps or site visits and were added manually.

Commerce

More recent local markets were identified through Google Maps or site visits and were added manually.



Figure 19. New important building functions was added, as the new culture house in Bergsjön.



Figure 18. Density types in the studied area (BC1, BC6 and BC6). Black outlined buildings are newly developed and added by author



Figure 20. Addresses

3.3.6 Accessibility Analysis Using the PST-tool

The walking distance between origins (such as addresses or street segments) and attractors describes pedestrian oriented accessibility (Stavroulaki et al., 2023) and is a central aspect of the 15mC framework. The origin and destination data (the processed point data) were used together with the NMS street network (line data from SMoG) to perform accessibility analyses in the QGIS plug in Place syntax tool (https://smog. chalmers.se/projects/pst-plugin-for-qgis/).

Accessible attractions

Attraction reach calculates the sum of all attraction points that can be reached via the network from a set origin within a set distance (Stavroulaki et al., 2023). Attraction reach was performed on the NMS network, and a walking distance of 500m was used as the set distance as this is a distance most people are willing to walk (Gehl, 2010). Based on how reachable the attractors were (via the NMS street network) in relation to the street segments, each street segment was assigned a numeric value based on how many attractors (points) could be reached within the set distance. All the attributes representing different reachable functions (addresses/home, bus/tram stops, kindergartens, etc.) were written as separate columns to the same layer of streets (see attribute table to the right) through the PST tool. From the assigned values, a selection by expression was made in QGIS to find streets that had multiple accessible functions and therefore could be considered multifunctional streets.

The final selection of attributes used to determine what was considered multifunctional streets in terms of accessibility in the set suburban context. To determine the amount and diversity of functions of attractions that was to be reached, multiple itterations were done in the PST tool. Thus, some street segments of the context were more multifunctional in terms of amount of reached attractors and the diversity of functions reached, but were not continuous.



Figure 21. Addresses (points) and the NMS street network (lines) with different values based on how many addresses can be reached within the threshold distance.



Figure 23. Map showing accessible addresses within 500 m from each street segment, categorized through natural breaks in

	ARw500ad *	ARw500hl	ARw500fs	ARw500cu	ARw500sp	ARw500he	ARw500re	ARw500lo	-
9	1342.000000000	3.00000000000	3.00000000000	1.00000000000	0	0	2.000000000000	14.00000000000	
0	1339.000000000	4.00000000000	3.00000000000	0	0	0	0	9.00000000000	
1	1339.000000000	4.00000000000	3.00000000000	0	0	0	0	9.00000000000	
2	1335.00000000	3.00000000000	3.00000000000	1.00000000000	1.00000000000	0	1.00000000000	12.0000000000	
3	1333.000000000	4.00000000000	3.00000000000	0	0	0	0	9.00000000000	
4	1333.000000000	4.00000000000	3.00000000000	0	0	0	0	9.00000000000	
5	1332.000000000	2.00000000000	3.00000000000	0	0	0	0	8.00000000000	
6	1332.000000000	4.00000000000	3.00000000000	0	0	0	0	9.00000000000	-
								•	

Figure 22. Attribute table for all street segments in the NMS network. The rows shows the number of accessible functions within 500 reach from each street segment. Accessible reach was performed for functions such as: public transport stops, kindergartens, addresses, local markets, culture houses, health care, sports facilities and religious buildings. Not all of these functions was included in the final analysis of multifunctional streets, as it excluded too many streets in suburban areas.

3.4 Ecological Analysis

To avoid the decline of vital ecosystem services, the green and blue network's interactions with the meshed network of the EMC2 are pointed out as important (Fusco et al., 2023). To be able to understand the complexity of these networks, this thesis work has a species-specific approach, meaning the analysis of green and blue networks departs from a selection of species. The targeted species approach sets up a framework of habitat requirements that could cater to more species with similar needs (Weisser & Hauck, 2024; Apfelbeck, et al. 2019) and is important to understand the function of green infrastructure (Filazzola, et al. 2019). Qualitative desk research was carried out as an initial step, as this would decide which ecological data to use and work with for the case-study area. The available biotopes of Gothenburg were accessed as raster data and the selected species movement and habitat requirements were modeled through a habitat network analysis.

3.4.1 Species Selection

Species information

Since the ecological analysis is based on species, it was important to select species with significance for Gothenburg. On a regional level, the occurrence of species and biotopes vary, and some populations are tied entirely or predominantly to specific regions. These species are considered species of conservation responsibility to these specific regions (Miljöförvaltningen, 2016). Other species that are of particular importance are the key species, these are species that are important for biodiversity, as they create source habitats that other species need to reproduce (ibid). Finally, there are species that are protected by law and red-listed species, which are species with a declining population (ibid.) Thus, a species list of species occurring in Gothenburg was made based on their importance to biodiversity/ecosystems and/or their juridical protection or redlisted status.

Species list

The species list is based on desk research and is used as a method to address different species requirements of the green infrastructure in the studied context. The method can be compared with Animal Aided Design Studio's method of including wildlife in urban planning through "Species portraits", where targeted species' requirements area are illustrated to inform designers' decisions throughout the whole urban planning process (Weisser & Hauck, 2024).



Figure 24. To get an understanding of the species that are of particular importance to Gothenburg, multiple reports were read from the municipality and region.

- Lesser spotted woodpecker (NT)

A red-listed specialist bird that is considered a key species (Miljöförvaltningen, 2016). All birds, their nests, and eggs are protected by law in Sweden (Naturvårdsverket, 2023).

- Small Scabious mining bee (NT)

A red-listed specialist bee of conservation responsibility in Gothenburg (Miljöförvaltningen, 2016).).

- Common frog (LC)

Represents amphibians as a functional group, as they have similar habitat requirements (Kindvall et al. 2024). All amphibians are protected by law in Sweden. (Naturvårdsverket, 2023)



Figure 25. Species observations of the selected species reported to Artportalen between 2017-06-01 and 2024-10-01 (unprocessed). Data: Artportalen and Lantmäteriet.

HOUSE SPARROW Passer domesticus L.



Figure 26. Species profiles by Animal Aided Design studio (Weisser& Hauck, 2024), Graphic by Sophie Jahnke and Rupert Schelle.



3.4.2 Species Profiles

In this section, the selected species are presented. First, a general summary of the species based on the desk research is presented, this is followed by species profiles, which are simplified presentations of the species in relation to the parameters Quality, Friction, Source habitat (nature elements needed for reproduction), and Dispersal range (scale of movement). These four parameters are used as input data for the modeling of species dispersal and habitat functionality in the Habitat network analysis tool (HNAT) (https:// github.com/SMoG-Chalmers/habitatconnectivity-tool) (see 3.5.1a and 3.5.1b)

Lesser spotted woodpecker

The lesser spotted woodpecker is a small woodpecker depending on deciduous forests with softer woods and deciduous hardwood forests. where the amount of birches and alder is especially important (Miljöförvaltningen, 2023., Artdatabanken, n.d. a) The lesser spotted woodpecker is specialized in mature woodlands, meaning that the species relies on old remnant forests with dead or decaying wood of particular tree species to be able to forage and reproduce (Woodland Trust, n.d). This species has a variation in dispersal range and habitat requirements as a survival strategy, meaning it has the ability to travel further and utilize more habitats in winter than during early and late spring. (Wikander et al. 2001) In general, the lesser spotted woodpecker needs to be analyzed from a landscape perspective, as it needs large areas as a result of its habitat specificity, territorial behavior, and seasonal variation (Miljöförvaltningen, 2023).

Common frog

The common frog occurs in both terrestrial and wet habitats (Kindvall et al. 2023) and is a generalist species as it can thrive in multiple different habitats (Artdatabanken, n.d. b). The species prefers wet environments and needs ponds and small waters to reproduce.

Small scabious mining bee

The small scabious mining bee is a solitary bee specialized in specific plants such as Devil's-bit, Knautia arvensis, Scabiosa canescens, and Scabiosa columbaria (Nilsson 2014., Tiderman Häll, 2023). The species depend on habitat amounts, where flower-rich meadows and moist beach meadows are particularly important. The small scabious mining bee is a sand bee and needs sun-exposed sand with little to no vegetation to dig its nest and reproduce (Tiderman Häll, 2023, Artdatabanken, n.d, c).

Data sources

Almost all species observation data used in this thesis is downloaded from Artportalen (https:// www.artportalen.se/ViewSighting/SearchSighting), which is a website where everyone, both experts and hobbyists, can report observed species. Some species observation data I got from the ecologist Öskar Kindvall on amphibians. The data was downloaded to fit the geographical extent of the biotope map (see 3.3.3), on which the analyses were conducted. The extent of the downloaded species observations is Göteborgs municipality, Lerums municipality, Härryda municipality, Kungälv municipality, Öckerö municipality, and Kungsbacka municipality. The biotope map does not cover the full extent of all these municipalities. so the observations were cut by the extent of the biotope map in QGIS. All observations that were made before June 1st, 2017 were sorted out. The reason for the specific date was that the data on amphibians, provided by the ecologist Oskar Kindvall, dated back to 2017, so there was a need for all observations to cover the same time period. The latest observations included in the data was the starting date of the gathering of the species data, which was October 1st, 2024. More recent data has been excluded from the analysis to make sure all observations are gathered from the same timespace conditions.

LESSER SPOTTED WOODPECKER/ MINDRE HACKSPETT

Dyrobates minor (NT)

Specialist species Ecosystem service: Bird song, create other species' nest

Quality biotopes

Deciduous forests, pastures, deciduous hardwood forest, mixed deciduous forest. deciduous forest with deciduous hardwood forest, parks/graveyards/big gardens, forest wetlands, open wetlands, spruce forests in winter

Friction

Coniferous forests, open fields/ non-vegetated open land, built up areas

Figure 28. Lesser spotted woodpecker Illustration by Victoria Hansson



Source habitat/Reproduction

Dead or decaying deciduous trees/old deciduous forests

Moving distance

~400-1500m (seasonal variation)



Figure 27. Dispersal diagram

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COMMON FROG /VANLIG GRODA

Rana temporaria (LC) Generalist species

Ecosystem service: Pest control

Quality biotopes

Ponds, streams, lakes, coniferous forest, open land, wet open land, artificial surfaces, mixed deciduous forest, deciduous forest, grasslands, wet grasslands

Friction

Highly trafficked roads, railways, the ocean

Figure 30. Dispersal diagram

~500m



Source habitat/Reproduction

Small waters/ponds

Moving distance

~500m

SMALL SCABIOUS MINING BEE/ GULDSANDBI

Andrena marginata (NT) Specialist species

Ecosystem service: Pollination

Quality biotopes

Exposed sandy soil, grasslands, pastures, dry meadows, freshwater beaches, trails, flower rich road verges and sandpits

Friction

Forests and highly trafficked roads

Figure 31. Small scabious mining bee Illustration by Victoria Hansson



Source habitat/Reproduction

Dry sun-exposed sand with little to no vegetation

Moving distance

~200m



Figure 32. Dispersal diagram

3.4.3 Biotopes of Gothenburg

By looking at the species observations, one could start making assumptions that the observed species is likely to have been reported at a location where suitable habitat patches, or biotopes, are located as well. However, this doesn't say much about the configuration of landscape patterns that could explain the species' location in terms of movement through the landscape or urban environments. To find this dynamic, more information about the biotopes of Gothenburg was accessed through raster data from the Swedish Land Cover Map (NMD) (https://geodata.naturvardsverket.se/ nedladdning/marktacke/.). The resolution of this biotope map is 10x10m, where each cell/pixel represents a specific land cover type or biotope. Raster data differs from vector data and works such that each pixel has a value assigned to it. This value can mean different things depending on what the raster data intends to give information about, for instance, raster data can have values saying something about altitudes of terrain, or biotopes of the land surface, which is the case of this map. Thus each pixel of this biotope map of Gothenburg has a biotope code, giving information about what biotope is located on that exact spot.



Figure 33. The

full extent of the unprocessed Biotope map. All biotope data in this map is from Naturvårdsverkets Marktäckedata, except for the raster data of ponds/small waters, which was shared with me by Spatial Morphology Group (SMoG) at Chalmers.

Data sources

For all biotopes, including added biotopes: Naturvårdsverket, Miljöförvaltningen Göteborg, Lantmäteriet, SMoG, Chalmers, Trafikverket, Länsstyrelsen Göteborg, SGU. Buildings with different heights and original data of sandy soil from Amanda Häll's work Planning for Pollination.

3.4.4 Ecological Data Processing and Method

The ecological information/data presented in the previous section is desk research, empirical (point) data, and raster data. In contrast to the vector data of the spatial analysis that consists of the geometric shapes line, polygon, and point, raster data can only be understood as pixels representing different values, in this case, the heterogeneity of landscape in a specific resolution. The data processing of the ecological analysis was similar to the spatial analysis as it was further developed to better match the current conditions by adding biotopes to the raster data. The species profiles, including information about quality biotopes, friction, and reproduction, were related to the biotope codes of the biotope map in an Excel sheet, which is called the parameter table. The processed biotope map and parameter table were then combined in the Habitat Network Analysis tool (HNAT). The output of the HNAT-tool was further processed to evaluate the performance of the modeled species' dispersal.

3.4.5 Input Data Processing

Biotope map

A new biotope map was created based on the Swedish Land Cover Map (NMD), downloaded from (https://geodata. naturvardsverket.se/nedladdning/ marktacke/.) From the desk research of the species, a total of 23 biotopes of significance for the species were added to the biotope map, as the predictability of species dispersal is sensitive to the cartographic representation of the input Biotope map (Kindvall et al. 2024). The development of the source biotopes 'dead/decaying wood' and 'sun-exposed sandy soil' required many steps and was based on shared data from Miljöförvaltningen and data from Amanda Häll (See appendix). The four different motorized street centrality types (see 3.2.1) were added to the biotope map instead of the more generic "road" biotope. This was done as centrality values are expected to correlate to traffic volumes (Serra & Hillier, 2019), and therefore might act as a barrier (friction) to different degrees for different species (Kindvall et al, 2024). As Kindvall et al., the added street centrality types were buffered by 15m before rasterization. Adding of biotopes was done through clipping by mask layer and merging in QGIS.



Parameter table

The biotope map was linked to a parameter table (excel sheet) that assigned different parameters to each biotope code. These parameters differ for each species as will be described in the next section (3.3.6). The assigned parameters were based on desk research, on previous studies ("Kartering av biotoper för, samt inventering av, mindre hackspett i fyra områden i Göteborgs Stad" by Miljöförvaltningen, "Planning for Pollination" by Amanda Häll and, "Predicting habitat functionality using habitat network models in urban planning" by Kindvall et al. (2024) as well as input from experts (ecologist Oskar Kindvall and biologist Ulrika Hamrén).

	Network name	Late_spring_o	leciduous		Sandy_open_	land	
Average dispersal d	istance (metres)	600			200		
Ne	twork threshold	0.01			0.01		
BiotopeName	BiotopeCode	Quality	Reproduction	Friction	Quality	Reproduction	Friction
 Jordbruksmark/Arable land 	3	1	0	2	0	0	1
6. Betesmark/Pasture	6	7	0	1	10	0	1
8. Koloniområde/Allotments	8	6	0	1	10	0	1
9 Sand- Grus- och mineraltag/Sand pit	9	0	0	50	9	0	1
10. Golfbana/Golf course	10	3	0	1	7	0	1
13. Sportanläggning/Sports facility	13	1	0	2	8	0	1
4.1. Övrig öppen mark utan vegetation/	41	0	0	50	5	0	1
4.2. Övrig öppen mark med vegetation/	42	3	0	2	8	0	1

Figure 35. This small section of the parameter table shows how the parameter values of different biotopes (BiotopeName) have different values for two different species. For a bigger section of the parameter table, see the next page or the full one in the Appendix.

Figure 34. A mask layer is used to clip in the default BiotopeMap to add a new raster value representing another biotope. In this picture primarily BiotopeCode 42 (Öppen mark/open field) is cut out and replaced with BiotopeCode 6 (Betesmark/Pasture), as this Biotope has greater significance for all studied species.



Figure 36.Biotope map with 23 added biotopes, including buildings with different heights (Above 10m and buildings below 10m height, received from Amanda Häll) and the buffered street centrality types. This is 1/2 of the input data you need to run the HNAT tool in QGIS. Resolution of the map is 10x10m.



Figure 37.Parameter table. Second indata you need to run the HNAT tool in QGIS. The Biotope code corresponds to the raster data value in the Biotope map and the tool "transfers" the values from the parameter table to the spatial location of all raster cells in the Biotope map.

3.4.6 Habitat Network Analysis using the HNAT-tool

A tool developed to support analyses of species-specific habitat networks and can be used as a tool to estimate movement patterns and habitat functionality in urban transformations (Kindvall et al. 2025). Within the Habitat Network Analysis Tool, multiple species can be analyzed at once by adding parallel network columns in the parameter table, where different biotopes are given quality, friction, and reproduction values depending on what species's network is analyzed (Ibid). The input data is a Biotope map with raster data values corresponding to BiotopeCodes given in a parameter table. The output data is 6 rasters calculated in steps (ibid.), explained below.

Source raster

A map showing the distribution of nature elements/biotopes used for reproduction or nesting. These biotopes are sources of dispersing species.

Quality raster

A map showing the quality of existing biotopes, that are suitable foraging areas or provide shelter to the modeled species, relative to each other. It is calculated based on the column 'Quality' in the parameter table.

Friction Raser

A raster map showing how resistance to dispersing species can vary in the landscape as a result of biotope composition and barriers. High values indicate greater barrier effects. Calculated based on the column 'Friction' in the parameter table.

Cost-Distance Raster

A map showing the cost-weighted distances to the nearest available source biotope which is modelled based on the Friction Raster within the tool.

Dispersal Raster

A map showing habitat connectivity in terms of cost-weighted dispersal probabilities. This shows "corridors" where species are probable to move because of relatively high quality and relatively low friction and is calculated based on the Cost-distance Raster in combination with the 'Average dispersal distance' (moving distance) specified for each species in the parameter table.

Functionality raster

A map made by multiplying the Quality raser with the Dispersal raster, showing the spatial variation in habitat functionality for the modeled species within the biotope maps extent. Indicates areas suitable for both nesting, moving, and foraging.



Figure 38. Rasters generated from the HNATtool, presented in order of the explanations to the left.

3.4.7 Post-processing of the HNAT-analysis Results

For this thesis, the most informative rasters are the Dispersal and the Functionality rasters. As will be shown in Chapter 4. the analysis results were overlaid with the empirical observations to test their validity. To do that, the rasters were first vectorized. The empirical observations (point layer) were sorted based on species and for the woodpecker, they were also sorted by season, as it has seasonal variations in habitat quality and dispersal range. Some of the empirical observation data had very low accuracy, meaning that the georeferenced point associated with a reported observation was weakly related to the spatial location on the site. Because of this, all observations with a lower accuracy than within 100m were sorted out from the data, just like Kindvall et al. (2024) did in their habitat network analysis of amphibians.

scientific

observer

Stig Carlsson, J...

Mikael Sundberg

Jonas Jonsson

Rickard Holmsk.

name

accuracy

Dryobates minor Mindre hackspett 2024-03-20T11:55:00.0000000+01:00

Dryobates minor Mindre hackspett 2024-03-20709:50:00.0000000+01:00

Drvobates minor Mindre hackspett 2024-03-07T08:00:00.0000000+01:00

Dryobates minor Mindre hackspett 2024-03-05T00:00:00.0000000+01:00

source

10 Artportaler

100 Artportalen

100 Artportalen

100 Artportalen

Figure 40. Point processing in attribute tables.

later used to discover multifunctional

for more than one species.

habitats with high habitat functionality

time

layer

100 Winter 202.

100_Winter_202..

100 Winter 202.

100_Winter_202...

Vectorizing of Dispersal raster

Vectorizing of the Dispersal raster was done to assess the model's accuracy in capturing species' dispersal. Three threshold values (25%, 50%, and 75%) were subtracted from the Dispersal raster through the raster calculator in QGIS, the dispersal probability threshold was then vectorized and used to assess the models of all species and seasonal variations by counting points (specie observations) in polygons. **Vectorizing of Functionality raster**

Vectorizing of high-functioning habitats was subtracted from the Habitat functionality raster through the raster calculator for medium to high values of 50-100% habitat functionality. This was

Observations_2017_2024



Figure 39.Vectorized Dispersal raster for amphibians. The raster data is a gradient of cost-weighted dispersal probability, where the dispersal probability is highest around the source raster, which is ponds in this case. The raster is vectorized at three dispersal probability thresholds =>75%, =>50%, and =>25. From these polygons, the models performance could be tested through the analysis tool 'count-points-in-polygons in QCIS.

3.5 Scenario Assessment

As part of the method is the implementation and evaluation of minor interventions to improve internal connectivity and multifunctionality of the meshed suburban networks, including both spatial and ecological networks. To assess different design scenarios, the Urban calculator was used to assess different street configurations, and the HNAT tool was used to assess ecological design interventions and land use changes.

3.5.1 Urban Calculator

To assess possible interventions to strengthen the internal connectivity of the suburban networks, Urban calculator was used. Urban Calculator is a design support tool based on space syntax theory (see 2.1) and the GIS-plug in Place syntax tool (see 3.2.6) suitable to make iterative configurational sketches and get feedback, revise and rerun the analysis until the project's ambitions in terms of eg, betweenness centrality are met (SMoG, n.d). This method differs from the method used to find the foreground network where street types (see 3.2.1 Multiscalar street types) were used to assess the multiscalar betweenness centrality.

In Urban Calculator, Angular betweenness and Angular integration (see 2.1) were calculated in Local scale (1km), Neighbourhood scale (2km), and City scale (5km). These scales correspond to the names of the different street types used to find the foreground network (see 3.2). The three scales of Angular betweenness were imported to QGIS, where the centrality values of each scale were sorted through 'natural breaks (Jenks)' to get medium-high betweenness centrality. To make the new streets from Urban calculator "multiscalar" (similar to the street types), the streets were categorized and grouped in QGIS based on the three calculations of the three different scales.

The internal connectivity of streets was drawn to connect to streets showing potential based on the spatial analysis, and the results of the ecological analysis (e.g., avoiding fragmentation) and following the concept of connecting neighborhoods to create viable public space (Legeby, 2015).



Figure 41. Urban Calculator interface



Figure 42. To create a mesh of main streets, the street's new values were sorted by 'natural breaks' in QGIS. Streets that had the 3 lowest centrality values in classes of 10 were not considered to be a part of the mesh of main streets.

3.5.2 Habitat Network Analysis Tool (HNAT)

To assess possible interventions to improve the connectivity of the species networks the HNAT-tool was used to run a new analysis after the spatial interventions. The biotope map was updated in the same way as in section 3.3.5, however when running iterations of the integrated effect the raster editing tool Serval was used, which is a plug-in for QGIS. The new green interventions were implemented in areas where the effect would be strong within the meshed street network. This includes both areas that are directly affected by the spatial intervention, as well as areas that are not directly affected but were identified to benefit from nature conservation strategies, such as the veteranisation of trees to increase the amount of dead wood in time. This was done with the aim of strengthening global dispersal links of the ecological networks inside and between the mesh of main streets.



Figure 43. Vector data from the spatial and ecological design was imported into QGIS and rasterized, then merged with the biotope map. In this picture, blue pixels indicate added biotopes, while red represents built development.

Green/blue interventions to strenghten corridors between habitats

Figure 44. Sketch of potential areas for social-ecological design interventions and nature conservation strategies in and around the new mesh of main streets.

Chapter 4: Analysis and Results

4.1 Spatial Analysis Results

4.1.1 Streets with Multiscalar and Multimodal (NMS&MS) **Centrality Profile**

The meshed network that is aimed for in this thesis is described as consisting of "pedestrian-friendly, multifunctional and multimodal main streets" (Fusco et al., 2023 p. 86) Because of this, the NMS and MS multiscalar street types (see 3.2.1) were overlapped to find what today works as central, multimodal streets in multiple scales. From the spatial analysis, the motorized network comprises a less fragmented and more comprehensible movement pattern than the non-motorized network, which is characterized by clusters of Local streets and some segments of Neighbourhood streets around the local centers. The result is new multimodal and multi-scalar street types that combine medium to high multimodal and multiscalar streets in different variations and inherit both pedestrianfriendly streets and the more cognitively continuous properties of the motorized network. This is an important street type, as the urban movement economy emerges through the multiplier effect (see 2.1), where the intersection of local and global flows enables the street to function as a public space (Legeby, 2015). Here, an interface between local and non-local inhabitants of the city converges (Hillier, 1996). From this new multiscalar and multimodular centrality street type, two existing continuous potential main streets are identified, marked out in the map to the right (dotted arrows). However, the streets do not connect to each other or form a mesh. These potential main streets are discussed more in section 4.1.3.



Figure 45. Data used for this analysis were: (1) Non-motorized (NMS) centrality street types; and (2) Motorized (MS) centrality street types.

Figure 46. Diagram showing the multimodal combination of different multiscalar centrality street types (NMS & MS). Some of the most central overlaps, such as NMS_2_MS_1, which combines citylevel and metropolitan street types, either did not exist or appeared only in locations like bridges and motorway flyovers, and were therefore excluded from the analysis. The most central existing multimodal streets were considered potential main streets, and two continuous segments based on these types were identified (dotted markings in the diagram and on the map). Below is a list of the relevant multiscalar NMS and MS street types, along with their combinations representing multiscalar and multimodal street types.

NMS

2: City 1: Neighborhood 0: Local

MS

1: Metropolitan 4: City 3: Neighborhood

Multimodal (NMS & MS)

2_4: NMS City - MS City 2 3: NMS City - MS Neighborhood 1_4: NMS Neighborhood - MS City 1_3: NMS Neighborhood - MS Neighborhood

Multi-modal Street types with combined centrality profiles, MS and NMS





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METROPOLITAN CITY

4.1.2 Streets with Mixed use and Multi-functionality Profile

As mentioned in the previous section, multifunctionality is another important aspect of the potential main street. Based on the accessibility analysis using the PST-tool streets mixed-use, in terms of pedestrian-friendly accessibility to different functions (>=190 addresses, >=2 public transport stops, >=1 educational facility, and >= 5 local markets) were combined to create a map of streets with mixed-use. Compared to the continuous grid of accessible functions that can be seen in the urban core, the accessible functions in the studied context are concentrated in clusters in a similar manner as the Local street type, close to the planned local centers. Other than being adjacent to the local centers, the clusters are close to the public transport stops, typical for Neighbourhood unit planning (Klasander, 2008). However, there are two mixed-use streets shown in this analysis that are particularly interesting: Förstamajgatan and Årstidsgatan. These two streets link the clusters between the local centers of Kortedala torg (Södra Kortedala), City torget (Norra Kortedala), and Januarigatan (Norra Kortedala) and follow the infrastructure of the light railway, making them both mixed-use and multimodal in terms of street and tram infrastructure. To not confuse the different types of multimodality that is: Multiscalar and multimodal NMS & MS networks and; Mixed use NMS network & Tram infrastructure, the first is referred to as Multiscalar & Multimodal street, and the latter combination is referred to as Multifunctional streets in this thesis.



Figure 47. The analysis used the following data to identify 'Multifunctional streets': (1) Accessible addresses (within 500 m); (2) Selected attraction points and built functions (within 500 m); and (3) Public transport stops (within 500m) and tram infrastructure (within a 100m buffer).







4.1.3 Overlap of Multiscalarity, Multimodality and Multifunctionality

In this section, multiscalar, multimodal, and multifunctional streets are brought together. Here, mixed-use streets identified in the previous section are selected through a buffer if they are somewhat parallel to the light railway infrastructure (See 3.2.5.a, Tram infrastructure). The buffers in these maps symbolize potential densification in a compact corridor development. From this, two important findings can be concluded. Firstly, the overlap of street multifunctionality and multiscalar multimodal centrality shows that there is a clear distinction between the functioning of streets and the capacity of the street to work as a public space, as described by Olsson (2005) and Legeby (2015), as the accessibility of local amenities (mixed use) are not aligning with the centrality of the local and global scale movement. Secondly, the light rail infrastructure is not parallel to multimodal (NMS & MS) streets. This can be compared to other places in the city such as Gamlestaden, the urban core, and even other suburbs, such as Biskopsgården, where multiscalar and multimodal street centrality overlap with multifunctional streets to a much larger extent.

On the next page, the findings of two current potential main streets in terms of multimodal centrality and multifunctionality are assessed on a finer scale and eye-level scale. The spatial limitations of densification are subtracted from the buffer, to see the actual potential of a compact corridor development along these streets. Spatial limitations refer to areas that cannot be densified, such as graveyards, steep slopes, existing buildings, and watercourses. The streets analyzed are Tideräkningsgatan and Förstamajgatan & Gärdsåsvägen. Both streets show potential in terms of accessible space for densification. Along these streets, pictures are analyzed every 100m.

Tideräkningsgatan - Förstamajgatan (see page 53):

1: 0-100m

From Tideräkningsgatan, a newly developed point building is visible. The entrance faces the street but is set back from it.

2:100-200m

A bridge crosses above the tram tracks. A pedestrian bridge connects the municipal building to Kortedala Torg, both elevated from street level and accessed via stairs

3:200-300m

To the right, the Kortedala Torg tram station lies below street level. To the left, a relatively enclosed parking

garage supports the municipal building above it.

4.300-400m

An industrial building housing a second-hand store is located half a story above ground level and set back behind a small avenue of trees. The tram tracks are now elevated relative to the street.

5: 400-500m

An underpass runs beneath the tram tracks, accompanied by a speed bump on the road.

6: 500-600m

A rocky hill covered with pine forest appears. The tram tracks begin to level out with the street, though a significant gap still remains between them.

7: 600-700m

A residential building with street-facing entrances set back slightly behind decorative street trees. A parking lot is to the right. Contact is lost with the tram tracks. 8:700-800m

Approaching the square Citytorget. The tram tracks are elevated again, and the Allahelgonakyrkan tram station is situated some meters above the square 9:800-900m

Services are located on the ground floor and face the street, though they appear to be closed. Residential buildings face the street with open courtyards and a large park in between. The street continues with a sharp turn to the right.

Gärdsåsvägen (see page 53):

10: 0-100m

The characteristic of the streetscape is that the entrances of villas are facing dead-end streets. Hedges defines the plot as close to the street.

11: 100-200m

The characteristic of the streetscape is that the entrances of villas are facing dead end streets. Hedges defines the plot as close to the street.

12: 200-300m

The facade has a setback and a hedge separates the street from the facade and other openings.

13: 300-400m

A sign that you are not allowed to drive through and an opening to Kviberg Park to the left. Today is the bus the only traffic along this street, other than a thin sidewalk strip.

14: 400- 500m

Deciduous forest, mainly birch.

15: 500-600m

Deciduous forest, mainly birch. Some parts are mixed forests with pine trees.

16: 600-700m

Deciduous forest, mainly birch, some pine trees. At the end of the street, you see the roof of a villa.

17: 700-800m

Deciduous forest, mainly birch, some pine trees. Bus stop Gärdsåsgatan expands the street with a Bus street

18: 800-900m

Villa area to the left, openings are facing the street, with a garden and fence/shrubs closest to the street.



Potential dense corridors, today

- High pedestrian and vehicular centrality
- Accessible services, addresses, kindergartens, public transport & tram infrastructure

Light rail infrastructure

Tram tracks

- 1 Residential
- Education -
- Commercial 6 E

.

Important public transport stops

This map illustrates the current functioning of the street network in relation to accessible amenities. tram infrastructure, and streets with high multiscalar centrality for both pedestrian and vehicular flow. Streets highlighted in purple indicate areas where multiple amenities and tram infrastructure are accessible within a 500-meter walking distance, while red streets represent segments with high multiscalar centrality. For a lively main street, these networks should ideally overlap, but in the suburban focus area, they remain disconnected.

Possible areas for dense corridor development, today

Important bus/tram stops

Picture

Tideräkningsgatan,
 Förstamajgatan,
 Gärdsåsgatan

Existing infrastructure

 Potential existing multiscalar and multimodal street
 Potential existing multifunctional street
 Tram tracks, above ground

Potential densification

Multiscalar, multimodal and multifunctional area Multifunctional area Multiscalar and multimodal area

Google Satellite

Gamlestade

Scale: 1:15 000 (A4)

This map highlights streets with potential to be developed into dense main streets, based on the criteria of the EMC2 model. The area surrounding these potential main streets has been processed to exclude spatial constraints such as existing buildings (with an 8 meter buffer), graveyards, steep slopes (≥20°), and watercourses.

In Gamlestaden, all the potential is concentrated along a single street, whereas in Kortedala, Bergsjön, and Utby, multiscalar centrality and accessible mixed-use areas are clearly differentiated.

Västra Bergsjön Gärdsås T 17 16 15 14 13 12 0 250 500 m P





















Gärdsåsgatan

4.2 Ecological Analysis Results

4.2.1 Species Specific **Movement Corridors and High Functionality Patches**

Lesser spotted woodpecker (Winter) Habitat functionality

The habitat functionality map gives a spatial representation of the species' destinations (quality habitats) in the landscape within reach from home (source biotope, in this case, dead or decaying wood). This is in this thesis called high functionality patches. The map should be read as such that red (10) indicates high habitat value and is in the vicinity of the source biotope. The gradient goes towards blue (0), which indicates that the species has no accessibility to either source habitat or quality habitats. In winter, the lesser spotted woodpecker utilizes coniferous forests, compared to late spring (see next page for a comparison of functional patches). Important areas that can be identified for this specie are: Lärjeåns



dalgång, Kvibergs kyrkogård, the forrest of Kviberg park, Gärdsås mosse, the forest areas around Bergsjön and Fjällbo ängar

Dispersal probability

The vectorized dispersal probability map gives polygons describing the spotted woodpecker's probable movement in the winter. As the lesser spotted woodpecker has a bigger dispersal range and utilizes more biotopes in the winter, this is the season where it is expected to spread on a global scale (U. Hamrén, personal communication, 20-12-2024). Based on this map combined with the empirical observation data, this analysis shows that it is probable that this species has its global spread towards North and East, because of the fragmentation around Göta Älv and the urban core.

Habitat functionality map - Lesser spotted woodpecker, Winter

Legend

Ecological_analysis HNAT_analysis Observations_species Woodpecker_Winter_17_24 Winter_deciduous Raster_Woodpecker_Winter **Functionality Raster** Band 1 (Gray) 10 0 This map shows habitat functionality and is calculated by multiplying the Quality

Raster with the Dispersal Raster (see Appendix). Good quality and highly reachable source habitats result in high functionality of the landscape for the species.

Scale: 1:50 000



Dispersal probability map - Lesser spotted woodpecker, Winter

Top_layers

Legend

Case-study area

Östra Göteborg

Ecological_analysis

HNAT_analysis

Observations_species

Woodpecker_Winter_17_24

Winter_deciduous

Vectorized_Dispersal_Winter

Dispersal probability, 75%

Dispersal probability, 50%

Dispersal probability, 25%

This model shows habitat connectivity for one species in a single season in terms of cost-weighted dispersal probabilities. The Dispersal Probability Raster was calculated based on the Cost-Distance Raster in combination with the average dispersal distance specified in the parameter file (see Appendix). In this map, the Dispersal Probability Raster has been vectorized using three threshold values: ≥25%, ≥50%, and ≥75%. The number of observations within the vectorized polygons was counted to assess the model's performance in predicting the species' dispersal pattern.

SUM_25 TOT_OBS_W PERCENT_25 315 284 0.902 SUM_50 TOT_OBS_W PERCENT_50 192 315 0.61

SUM_75 TOT_W_OBS PERCENT_75 315 0.457 144

SUM_X: Amount of observations counted withing the specific dispersal probability PERCENT_X: Percent of observations counted within the dispersal probability TOT_OBS: Total amount of observations

Scale: 1:150 000

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Lesser spotted woodpecker (Late spring)

Habitat functionality

Compared to the habitat functionality of the lesser spotted woodpecker in winter, late spring marks the period during which the lesser spotted woodpecker is territorial and has greater habitat specificity, which can be seen in the habitat functionality map as more spatially defined, fragmented patches. It can also be seen in the empirical observations of the specie of this time period, as it moves closer to the patches of higher quality.

Dispersal probability

When comparing the seasons in the dispersal probability, the same pattern of "observation clustering" can be seen in multiple parts of the city. It can also be seen that its mobility decreases greatly and forms less continuous polygons of connectivity to more fragmented. From this, it can be concluded that it is important that the species can reach all essentials (quality habitats) during this time period to be able to survive, which should be considered in local planning of



sites of high habitat value. This seasonal model has the least reported observations and possesses the least precision of the three models (an additional model of lesser spotted woodpecker for early spring can be seen in the Appendix). A reason could be because of data ('dead/decaying wood'), which could be assumed to be prevalent in the vicinity of where the species is observed during this season because of its limited mobility. Another contributing factor could be that the species is not as frequently seen/reported during this season. Thus, a result of more technical character is that with decreased mobility of a studied species, the need for higher precision of source nature elements or biotopes in the landscape is necessary to enable more accurate models in the HNAT-tool.

0

1

2 km

Habitat functionality map - Lesser spotted woodpecker, Late spring

Legend Ecological_analysis **HNAT_analysis** Observations_species Woodpecker_LateSpr_17_24 Late_spring_deciduous HNAT_Raster_Woodpecker_LS **Functionality** Raster Band 1 (Gray) 10

0 This map shows habitat functionality and is calculated by multiplying the Quality Raster with the Dispersal Raster (see Appendix). Good quality and highly reachable source habitats result in high

functionality of the landscape

Scale: 1:50 000

for the species.

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Kvibergs kyrkogård

Top_layers Case-study area Östra Göteborg Ecological_analysis **HNAT_analysis** Observations_species Woodpecker_LS_17_24 Late_spring_deciduous Counted_Vectorized_Dispersal Dispersal probability, 75% Dispersal probability, 50% Dispersal probability, 25% This model shows habitat connectivity for one species in a single season in terms of Lundby

Legend

cost-weighted dispersal probabilities. The Dispersal Probability Raster was calculated based on the Cost-Distance Raster in combination with the average dispersal distance specified in the parameter file (see Appendix). In this map, the Dispersal Probability Raster has been vectorized using three threshold values: ≥25%, ≥50%, and ≥75%. The number of observations within the vectorized polygons was counted to assess the model's performance in predicting the species' dispersal pattern.



SUM_X: Amount of observations counted withing the specific dispersal probability PERCENT_X: Percent of observations counted within the dispersal probability TOT_OBS: Total amount of observations

Scale: 1:150 000

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Älvsborg



Amphibians

Habitat functionality

The amphibian habitat functionality map differs a lot from the lesser spotted woodpecker, which indicates its functional patches have a completely different character. Although the amphibians are a more generalist species in terms of habitats compared to the lesser spotted woodpecker, which can be seen in a "smoother"/less patchy gradient towards the built-up area close to the Gärdsås Mosse, three things can be addressed as reasons for the relatively fragmented habitat functionality in the studied context as whole. Firstly, the amphibian is bound to the ground and has a shorter dispersal range. Adding to that, the amphibians are more sensitive to traffic flows than the lesser spotted woodpecker (U. Hamrén, personal communication, 20-12-2024), which is related to the motorized centrality (Serra & Hillier. 2019: Kindvall et al. 2024). Finally, the amphibians source biotopes (small waters/ponds) and quality biotopes such as small streams are limited and a threatened biotope



type in urban development, agriculture, and forestry due to drainage (Suislepp et al. 2011) Important areas for the amphibians are Lärjeåns dalgång, the wet forest of Kviberg park, Gärdsås mosse, Bergsjön and Fjällbodammen.

Dispersal probability

The vectorized dispersal probability of the amphibians relates very well to the small streams and wetlands of the landscape. The most evident connectivity for the amphibian is located East of the case-study area in Partille municipality, stressing this is the most important direction of global dispersal for the amphibians, and that planning for species within urban areas at large requires regional planning.

Habitat functionality map - Amphibians

Legend

Ecological_analysis **HNAT_analysis Observations_species** Amphibians_17_24 Small_waters HNAT_Rasters_Amphibians **Functionality Raster**

Band 1 (Gray) 10 0

This map shows habitat functionality and is calculated by multiplying the Quality Raster with the Dispersal Raster (see Appendix). Good quality and highly reachable source habitats result in high functionality of the landscape for the species.

Scale: 1:50 000

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Dispersal probability map - Amphibians

Legend

Top_layers

Case-study area Östra Göteborg

Ecological_analysis

HNAT_analysis

Observations_species

Amphibians_17_24

Small_waters

Counted_Vectorized_Dispersal

Dispersal probability, 75%

Dispersal probability, 50%

Dispersal probability, 25%

This model shows habitat connectivity for one species in a single season in terms of cost-weighted dispersal probabilities. The Dispersal Probability Raster was calculated based on the Cost-Distance Raster in combination with the average dispersal distance specified in the parameter file (see Appendix). In this map, the Dispersal Probability Raster has been vectorized using three threshold values: ≥25%, ≥50%, and ≥75%. The number of observations within the vectorized polygons was counted to assess the model's performance in predicting the species' dispersal pattern.



counted within the dispersal probability TOT_OBS: Total amount of observations

Scale: 1:150 000

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Small scabious mining bee Habitat functionality

The habitat functionality of the Small scabious mining bee is very different from both the lesser spotted woodpecker and the amphibian, as it needs open flowerrich habitats with sun-exposed sand with little to no vegetation as functional patches. An interesting observation from this habitat functionality map is that the clear-cut of the electricity power lines becomes particularly evident. Other important areas can be noted as the graveyard Kvibergs kyrkogård, the sports field of Kortedalavallen, Bergsjövallen and Kviberg park, and the pasture of Fjällbo Ängar. Especially the sports field is an interesting result of functioning habitat patches, as these are not typically thought of as functioning habitats.



Dispersal probability

The dispersal of the small scabious mining bee is of the most local scale of the studied species. Connectivity is found in open areas with sandy substrates and is prevalent in between buildings, especially around open blocks and detached houses.

Habitat functionality map - Small scabious mining bee

Legend

Ecological_analysis HNAT_analysis Observations_species Other_SandBees_17_24 Sandy_open_land HNAT_Rasters_Sand_bee

Functionality Raster Band 1 (Gray)

Scale: 1:50 000

This map shows habitat functionality and is calculated by multiplying the Quality Raster with the Dispersal Raster (see Appendix). Good quality and highly reachable source habitats result in high functionality of the landscape for the species.



Dispersal probability map - Small scabious mining bee

Top_layers

Legend

Case-study area

Östra Göteborg

Ecological_analysis

HNAT_analysis

Observations_species

- SmallScabiousMiningBee_17_24
- Other_SandBees_17_24

Sandy_open_land

Counted_Vectorized_Dispersal

Dispersal probability, 75%

Dispersal probability, 50%

Dispersal probability, 25%

This model shows habitat connectivity for one species in a single season in terms of cost-weighted dispersal probabilities. The Dispersal Probability Raster was calculated based on the Cost-Distance Raster in combination with the average dispersal distance specified in the parameter file (see Appendix). In this map, the Dispersal Probability Raster has been vectorized using three threshold values: ≥25%, ≥50%, and ≥75%. The number of observations within the vectorized polygons was counted to assess the model's performance in predicting the species' dispersal pattern.



SUM_X: Amount of observations counted withing the specific dispersal probability PERCENT_X: Percent of observations counted within the dispersal probability TOT_OBS: Total amount of observations

Scale: 1:150 000

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4.2.2 Multi-species Dispersal Corridors

Multi-species dispersal corridors, or multifunctional green corridors, are the result of overlapping movement networks of multiple species, based on the dispersal probability raster. When interpreting the map, it's important to note that the dark green color (representing areas utilized by all three species) does not necessarily indicate high habitat quality for each species at that specific location (U. Hamrén, personal communication, 20-12-2024). Instead, it signifies that the area is likely to be 'passed through' by all three species, as it has low friction or barrier effects for movement. An example of this is Kortedalavallen which is a gravel sports field in Kortedala, possessing little to no quality for all species, however, it has little friction to movement compared to the adjacent motorized street Almanacksvägen which has high friction from high traffic flows.

This analysis result shows probable movement corridors based on the species-specific dispersal probability, mapped out as different colored arrows. The multifunctional corridors, mapped out as green arrows, connect to all studied species' movement networks. Thus, these corridors can be seen as the likely 'main streets' from a multi-species connectivity perspective. Other than showing multi-species connectivity in the studied context, this analysis shows gaps where strategic nature conservation interventions would be impactful to further enhance connectivity in the studied context and on a global scale.

Figure 49. A simplified movement diagram showing a generalized movement network for each species, and a multifunctional movement network (green) connected to all species' movement networks.









4.2.3 Multifunctional Patches

Multifunctional green patches result from overlapping species' habitat functionality, indicating accessibility to both source habitats and high-quality biotopes for multiple species, based on the habitat functionality raster. A multifunctional patchwork comprises a set of landscape units that provide both high-quality habitat and strong connectivity for multiple species. In this analysis, multifunctionality is quantified by the number of species that exhibit high habitat functionality within a given area. Multi-species presence is likely to generate a range of ecosystem services (Ekologigruppen, 2024). Thus, these multifunctional patches can be considered particularly important to preserve for the benefit of both human and non-human species.

Important multifunctional 'hotspots' and its natural elements (biotic and abiotic):

1. Lärjeåns dalgång

- Stream
- Remnant old forest

2. Gärdsås mosse

- Pond
- Remnant forest
 Geomorphological conditions (sandy soil)

3. Kviberg park

- Remnant forest
- Pond
- Kvibergsbäcken
- Pond in the residential villa area
- Geomorphological conditions (sandy soil)

4. Fjällbo Ängar/Bergjsön

- Remnant forest of Fjällbo ängar
- Pasture of Fjällbo ängar
- Geomorphological conditions (sandy soil)
- Stream between Bergsjön and Fjällbodammen

Besides these areas, other areas/ elements are important for the individual species, for instance, the riparian zones of streams, sports fields, the clear cut of the electricity power line, the graveyard Kvibergs kyrkogård, open yards between blocks, etc.

Figure 50. Functioning habitat patches (for all species) marked out as 'hotspots' (red dots).











- Medium to high habitat quality and connectivity,
- Medium to high habitat quality and connectivity
 Specie (undefined)
 Medium to high habitat quality and connectivity
- Medium to high habitat quality and connectivity, 2 species (undefined)
- Medium to high habitat quality and connectivity, 3 species (all)

This map shows multifunctional green patches, meaning habitats where high quality and connectivity for multiple species overlap. These patches are likely to support multiple ecosystem services, such as pollination, pest control, bird song and temperature regulation and are important to preserve for both human and non-human well-being.

4.3 Social-Ecological Overlaps, Today

So far, attempts to identify the social and ecological networks have been made through spatial and ecological analysis that has been conducted separately in accordance with the first aim of this thesis: to assess what the suburban street network provides for in terms of proximity, connectivity, and different services and what the suburban green/blue networks provide for in terms of functioning ecosystems and linking habitats and biodiversity. As argued by Marcus et al. (2019), the social and ecological dynamic that constitutes human and non-human flows differ based on what is viewed as the moving agent, which is the case in the analysis of the three different species which largely have different dispersal patterns within the studied landscape.

In this section, the identified social and ecological networks are brought together to assess possible areas for dense corridor development in accordance with the aims of the EMC2 model. This is done through overlapping the multiscalar and multimodal streets, the multifunctional streets, and the medium to highly functioning habitat patches for all species, which is the result of the previous sections in this chapter. Hence, this map shows socialecological overlaps in what, at least in theory, could be seen as a mesh of main streets. However, the streets that have been identified as multiscalar, multimodal, or multifunctional as is today, do not form a connective mesh. This will be addressed through strategic design in section 5.1.

Social-ecological overlaps are in this thesis referred to as where social and ecological dynamics overlap with the meshed network of dense corridor development and align with the second aim of this thesis; to highlight the synergies and conflicts that can emerge when overlapping the two systems' networked nature in a meshed main street development. In this map, such overlap is marked out as 'Ecological conflict' at some places. The ecological conflicts are marked out where compact corridor development overlaps with the high habitat functionality. These patches constitute both source habitats and

adjacent quality habitats for one or more species, which then becomes a conflicting area regarding land use. However, the medium habitat functionality, which also is in the map, is not marked out as a conflict but could instead be perceived as a social-ecological entity where both social and ecological functions could co-exist or even create synergies. From this overlap analysis, it can be concluded that Förstamajgatan does not inherit any ecological conflicts, which could make it suitable in terms of densification. However, the street does not constitute any potential for social-ecological synergies or street centrality, which removes its significance in terms of the aims of this thesis. On the other hand, the social-ecological overlap of Gärdsåsgatan, which also has high centrality values, possesses a significant overlap of ecological conflict and some overlap of potential social-ecological synergies. However, regarding the result from the ecological analysis, the ecological conflict is rather critical as it is part of an important global dispersal link, especially for the lesser spotted woodpecker and the amphibians, that would not only lose important habitat from potential compact corridor development but also the species ability to disperse on a global scale.

Given the rather discontinuous street network that does not form a mesh of main streets today, as well as the socialecological overlaps that are given from the current situation of the separate networks, street interventions to increase internal connectivity for both human and non-human movement are needed. In addition to that, such street intervention should avoid the identified potential fragmentation that could occur if Gärdsåsgatan were the subject of dense corridor development.

Other than assessing the social-ecological overlaps in relation to dense corridor development, the ecological function in relation to built density forms and suburban typologies was assessed which can be seen on page 67. This shows that the suburban form could be used in dense corridor development if strategically oriented in relation to the ecological and social networks around the potential main streets.



vehicular centrality

interventions must support both human and non-human movement.



4.4 Parallels between Spatial and Ecological Analysis

l

The preceding analyses of the social/ spatial and ecological systems, while distinct, reveal a parallel in their shared logic of movement. Both assessments are, at their core, investigations into the ability of living beings to navigate the suburban context to satisfy fundamental needs from a home base. For the social system, the betweenness centrality and accessibility analysis, guided by what should be within reach in the 15-minute city framework, evaluated accessibility between streets and key attractors like homes, local markets, and education. For the ecological system, the analysis assessed the ability of species to move between their home (or 'source habitat') suitable for nesting and guality habitats suitable for foraging and shelter. Both the spatial and ecological analyses, therefore, measure the suburban networks' potential to provide the life-sustaining activities of human and non-human species. However, a critical finding in both systems is the rupture between potential to movement and purpose of movement: a path may be easy to travel due to high connectivity or low

Figure 51. Homes and habitats, food and foraging. Conceptualizaton of social-ecological systems in synergies in urban design.

Homes/habitats

Food/foraging



• Addresses

Suburban typologies

Ecological networks

- Sand bee, high connectivityAmphibians, high connectivity
- Lesser spotted woodpecker, high connectivity

High functioning green patches

- Sand bees, High quality and high connectivity
- Amphibians, High quality and high connectivity
- Lesser spotted woodpecker, High quality and high connectivity

This map shows suburban typologies, such as free-standing slab buildings and open blocks, can support ecological connectivity and multi-species life between buildings. Today, many addresses of these typologies face the private yard, limiting the role of the street as a public space. In a socialecological main street design, these typologies can be used by reorienting entrances to face the street.

friction, but still fail to provide access to the necessary resources, be it accessible services for humans or quality habitats for other species. For the social system, the analysis showed how the disconnected non-motorized street network and hierarchical motorized road structures create barriers and distances in a pedestrian network. These barriers increase travel time for inhabitants seeking daily services, often enforcing car dependency and limiting social interaction. For the ecological system, this same road infrastructure causes fragmentation. Roads and developments separate the landscape into isolated patches, increasing the friction of dispersal and mortality risks. The effect of impeded movement is the same, but the impact is specific to each system.

Furthermore, the need for accessibility is not static. For humans, the need for daily accessible attractors varies with the time of day or life stage (Hägerstrand, 1970). Similarly, for other species, different spatial needs and dispersal ranges depend on time, such as seasonal variation in ability to move and resource requirements for the Lesser spotted woodpecker.

Ultimately, this comparison reveals that an effective social-ecological design must overlap both the potential for movement and the purpose of occupancy, creating a foundation for the design explorations that follow.

5.1 Introduction to Design

This chapter translates the findings from the preceding analysis into social-ecological strategic design proposals. The design process addresses the central challenge of this thesis: how to strategically configure and develop a suburban street into a lively main street, without compromising the highly functioning ecological networks. To achieve this, the design work is structured around two primary, interconnected tasks that directly respond to the social-ecological synergies and conflicts identified in Chapter 4. Finally, this social-ecological dynamic forms the implications for a local-scale main street design.

1. The design of a continuous mesh of main streets for the EMC2

This task builds upon the multiscalar, multimodal, and multifunctional network analysis. Its primary aim is to create a more connected and pedestrian-oriented suburban street network that supports human movement and access to services. This design must strategically navigate and respond to the identified potentials and conflicts with the high-value multifunctional ecological patches to minimize fragmentation and enhance social-ecological synergies.

Figure 52. Diagram illustrating how the functionality of the social and ecological networks is a function of built form. The intermediate suburban density forms can comprise social-ecological synergies such as a decreased need for water management.



Chapter 5: Design: Implementing the EMC2 Model with a Socialecological Perspective

2. The design of multifunctional green corridors and patches within the mesh of main streets

This task is based on the multi-species habitat analysis and aims to strengthen ecological connectivity for the studied species. The design involves proposing specific biotope interventions that enhance habitat quality and connectivity, while carefully considering the constraints and opportunities presented by the proposed EMC2 street mesh.

These two strategic design tasks are interdependent, informing one another to create a multifunctional socialecological configuration of patches in the suburban context. The chapter will conclude by applying the implications for design on a local scale, specifically on a main street, demonstrating how a social-ecological approach can foster both social and ecological values in suburban design and planning.



5.2 Configuring a New Mesh of Main Streets

This section presents a strategic configurational street design. The new street mesh is developed with the aim of connecting neighbourhoods within the study area while avoiding the fragmentation of identified ecological networks. The configuration is based on two main approaches: (1) simplification and rationalisation of the existing structure, and (2) the addition of key links to enhance overall connectivity between neighbourhoods.

5.2.1 Strategic design of new mesh

The street interventions are based on the concept of connecting neighborhoods and improving access to potential main streets from within these areas. The strategic street design has also been informed by insights from the ecological analysis, with the aim of avoiding the fragmentation of species' global movement networks. The proposed interventions can be grouped into two categories:

Simplification and rationalisation

Many of the motorized streets are designed to accommodate high vehicular flows and feature large roundabouts, which contribute to longer distances and disconnections within the pedestrian network. Additionally, many streets in the study area are curved, likely due to the terrain. To develop a more compact and efficient street mesh, several streets would need to be straightened in order to reduce travel distances. All proposed street interventions have been designed with consideration for the existing topography, aiming to avoid excessively steep slopes.

Adding Links

To create new centralities some new links are added. The main additions include a new pedestrian bridge over Kvibergsbäcken, which redirects movement from Kamgatan, and from this bridge, a new street segment connecting to an existing pedestrian and bicycle lane through the northern part of Kviberg Park. These added links reduce the relative centrality of Gärdsåsvägen.

On the next page, the effects of the street interventions are assessed in angular betweenness centrality and angular integration, showing improvement in both 'through'-movement and 'to'-movement of the non-motorized street network. This means that the streets are likely to have higher pedestrian flow after intervention.



Figure 53.The concept of the strategic design: linking neighborhoods to make the street a public space.

Figure 54. Below are the street interventions made in accordance with the concept above, see section 3.4.1 for the methodology. Where street segments are red, they have been straightened up or they have been connected to a new link. A full list of all 17 interventions can be read in the Appendix.





Figure 55. Angular betweeness, 5km (Before)



Figure 57. Angular integration, 5km (Before)



Figure 59. Angular integration, 1km (Before)

5.2.2 Scenario Assessment of Street Network Interventions



Figure 56. Angular betweeness, 5km (After)



Figure 58. Angular integration 5km (After)



Figure 60. Angular integration, 1km (After)

Chapter 5: Design







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Medium-High Multiscalar centrality (1km, 2km & 5km) Potential main streets

Medium-High Neighbourhood-City centrality (2km & 5km) Potential main streets

Medium-High Local-Neighbourhood centrality (1km & 2km)

Medium-High

Medium-High City centrality (5km)

(2km)

Neighbourhood centrality

Public transport stop

Added bus stop 0

Tram tracks, above and underground

Built density

Compact low-rise Spacious mid-rise

Spacious low-rise

Municipality Religious

Built functions

Industry

Cultural

Healthcare

Commercial

Sports facility

Education

Social-ecological interventions Social and ecological development

Ecological interventions Nature conservation

Figure 62. The new configuration of streets with high functioning green infrastructure within the mesh. Proposed areas for land use interventions are presented.



5.2.3 Identifying New Social-Ecological Overlaps

In this section, the identified social and ecological networks are brought together again but about the newly identified main streets after the interventions seen in the previous section. Hence, this map shows social-ecological overlaps in the new mesh of main streets. The new main streets at Kvibergs bäckväg have some ecological conflicts as well, however, it does not cut off the habitat functionality and dispersal between Kvibergs Park and Fjällbo Ängar/Bergsjön. Furthermore, there are continuous corridor segments where there are no spatial limitations for compact corridor development or ecological conflicts. To the right is Kvibergs bäckväg as seen on an eye level scale today. The social-ecological synergies and conflicts of this street will be further assessed in a local scale design.

Figure 63. The streetscape of Kvibergs bäckväg. The street is mainly surrounded by football fields and has a section of birches placed in a row along the street. Surrounding the football fields, is the remnant forest of Kviberg Park. A point house of Kortedala Torg can be seen as peaking up above the tree canopies.

Existing infrastructure

Existing street infrastructure

— Tram tracks

Potential dense corridors,

- after intervention
- New pedestrian centrality
- Accessible services, addresses, educational facilities, public transport and tram infrastructure

Critical social-ecological overlap

Conflict of land use Medium to high quality and connectivity

 High habitat quality and connectivity
 Medium habitat quality and connectivity This map highlights new main streets with potential for dense corridor development. These streets have high multiscalar centrality and connect several suburban neighborhoods, enabling through-movement and better access to viable services. While the proposed corridors are more continuous and avoid fragmentation near Gärdsåsgatan, they introduce new ecological conflicts that must be addressed through local-scale design.



Kvibergs bäckväg

5.3.2 Scenario assessment of Biotope Interventions

5.3 Proposed Green Corridors

Because of the social-ecological aims of this thesis, the spatial interventions aiming to enhance social values are inseparable from land-use interventions aiming to enhance ecological values. The land use interventions are done both to strengthen identified dispersal links and to mitigate the impact of new suburban development.

5.3.1 Strategic Design of Land Use

Nature conservation

The strategic design of land uses is based on the findings of locations where the impact of nature conservation would have the greatest impact on the studied species, as discussed in section 4.5.1. These are areas that already possess medium habitat quality and connectivity but would benefit from being enhanced. To these areas, both quality habitats and reproduction habitats were added.

Mitigation

Other than nature conservation strategies, biotope interventions should be incorporated as natural elements into and close to densified areas to mitigate the

impact of development and create natural values for both human and non-human species. Examples of these interventions that benefit both humans and other species are flower-rich road verges and varying street trees along the streets, and ponds, pastures, and deciduous trees around the streets and in between buildings.

On the next page, a scenario assessment of biotope interventions can be seen. In these dispersal rasters, the built development of the local scale design is included. The result is that the impact of dense corridor development can be mitigated through strengthening the connectivity in the surrounding landscape, and through integrating reproduction and quality habitats in between the built form.

Social-ecological interventions for multifunctional corridors





Figure 64. Dispersal probability, Lesser spotted woodpecker (Before)



Figure 66. Dispersal probability, Amphibians



Figure 68. Dispersal probability, Small scabious mining bee (Before)



Figure 65. Dispersal probability, Lesser spotted woodpecker (After)



Figure 67. Dispersal probability, Amphibians (After)



5.4 Implications for Local Scale Design

This section translates the analytical insights from the preceding chapters into spatial strategies for the local design scale. Specifically, it considers how typologies, densities, land-use functions, and streetscape design can be combined to generate synergies between social and ecological networks. By focusing on the interface between built form and green infrastructure, the aim is to guide design decisions that enhance species movement, support diverse social uses, and define vibrant public spaces. The implications outlined here respond to the potential synergies that could be achieved along Kvibergs Bäckväg, offering a framework for shaping multifunctional, dense corridor development within a suburban context.

Social-ecological Suburban Typology, Density, and Constitution

As the suburban form and lack of defined space have been noted to pose obstacles to social inclusion processes (Legeby et al., 2014; Klasander, 2008), multiscalar movement centrality should be concentrated along a clearly defined main street. This enables the street to function as a multifunctional public space, supporting both the viability of destinations and through-movement along a vibrant street edge defined by buildings. Spacious low-rise, spacious midrise, and compact mid-rise are built density types commonly found in suburban contexts. As demonstrated in this thesis. these typologies can facilitate multispecies movement between buildings. One implication is that the main street should be composed of such typologiessuch as open blocks or freestanding slab buildings, with their closed sides facing the street and their open sides oriented towards functional green infrastructure. With this adjusted spatial constitution of the suburban form, social-ecological synergies can be achieved: the street becomes a more clearly defined public space; courtyards become more private and livable for residents; and species sensitive to centrality are provided with improved conditions to disperse and thrive between buildings. Thus, the main street should be formed by this social-ecological adaptation of suburban typologies in the local-scale design.











Figure 70. Sketches of how typologies, density, and constituition should relate to the street/public spaces and green infrastructure.

Social-ecological Multifunctional Land-uses for a Suburban Context

Given the medium-to-high centrality of the proposed new streets, not all commercial uses will be viable. Instead, the functions already present, and articulated in the vision for Kvibergs Park, such as nature, education, sports, and culture (Göteborgs stad, 2015), should be further developed and integrated. However, not all functions are compatible with species co-presence. For example, sports activities can have both positive and negative ecological impacts depending on design choices. Whether football fields use plastic turf or natural grass significantly influences water management and the potential for seasonal wetlands (Lemieux et al., 2018). Similarly, extensive lawns, commonly found in sports parks and suburban typologies, can become multifunctional if designed as nectar lawns rather than monocultures of short grass. In such cases, the height and composition of







Figure 71. Sketches of nature restoration strategies as part of the social-ecological design and program.

selected vegetation must be carefully considered to achieve the aim for social-ecological synergies (U. Hamrén, personal communication, 2024-12-20). Following is a list of potential design interventions that could be implemented along the street depending on the centrality value and ecological values of the socialecological street interface.

List of potential social use at suburban main street segments with medium-high centrality and low ecological value

 \cdot Cafés, restaurants, and street food hubs

 \cdot Spatially room-bounding pocket parks / microgreenspaces

- Community centres
- Shared mobility stations
- · Flexible street furniture and movable seating
- Residential buildings with integrated seating
- \cdot Sports and cultural facilities
- $\cdot \, \text{Public squares}$
- Public transport hubs
- Urban farming
- Public art/murals / cultural storytelling walls

List of potential low-impact social use at suburban main street segments with medium-high centrality and high ecological value

Recreational sitting opportunities

- · Floating walkways or boardwalks
- Outdoor classrooms & nature playgrounds
- Picnic areas

 \cdot Light structures, eg. bird watching towers, wind shelters, and co-creation hubs

- · Allotments / edible landscapes
- Mountain bike/hiking/running trails
- Nature-based stormwater parks
- Seasonal eco-markets/nature fairs

 \cdot Community stewardship zones eg. flower rich meadows

Social-ecological Streetscape

The street design should comprise a width that allows for green infrastructure and spatial variation for a rich pedestrian experience. As a green transition strategy, the width of the street could include parking lots, which later could be transformed into pocket parks as the accessible multifunctionality of the mesh of main streets develops. For the pedestrian experience, the horizontal scale should be broken down so that pedestrians get a diverse experience in unit scale, building scale, and street/block scale. This can be done through both built, abiotic, and biotic forms (New York City Department of City Planning, 2013).

Kvibergs bäckväg

This social-ecological main street design shows Kvibergs bäckväg after local scale design interventions based on the implications for local scale design which can be seen in the previous section. The new main street integrates both social and ecological design components and takes multiple actors into consideration, both human and non-human species. The result is multi-species presence and a rich exchange of services that increase social and ecological resilience in urban design.



Figure 72. The current context of the proposed main street.





Perspective 1

The streetscape of a street segment close to the public square. The high centrality values and low ecological values make it suitable for development such as residential buildings with integrated sitting and cafés.

Perspective 2

A pedestrian-based entrance to the main street, passing over Kvibergsbäcken from Gärdsåsgatan/ Kamgatan. This street segment has high centrality values and high ecological values and is therefore activated through low-impact social use, such as an outdoor classroom and recreational seating.



Chapter 6: Discussion

6.1 Conclusion and Discussion

This thesis has investigated the potential for creating multifunctional suburban networks in the North Eastern suburbs of Gothenburg by integrating social and ecological perspectives into the dense corridor development as proposed in the EMC2 model. The study used data-driven analyses and design explorations to identify synergies and conflicts, proposing strategies to align with the Evolutive Meshed Compact City (EMC2) model and Social-Ecological Urbanism. In this concluding section, I will reflect upon the results of this thesis and make an attempt to address the answers to the thesis questions which have formed the overall structure of this thesis project. Furthermore, I will highlight the contribution of the methodological approach of this thesis, discuss key implications for local and strategic design, and outline limitations.

1. How can potential synergies and conflicts of overlapping social-ecological dynamics inform the design of dense corridor development in the Northeast suburbs of Gothenburg?

This thesis question is the main question of the thesis. I have addressed the question on two scales: City scale and local scale. Furthermore, it has been addressed based on two scenarios which are:

How streets with potential would generate social-ecological synergies and conflicts if the EMC2 were to be implemented today

and

How streets with potential would generate social-ecological synergies and conflicts if the EMC2 model were to be implemented after configurational and functional interventions, based on the findings of social and ecological networks.

The first scenario is answered in section 4.3 where conflicts are found in the patches of land inheriting potential for densification and high habitat functionality. Potential synergies are found in the patches of land with potential for densification and medium habitat functionality. The analysis of two potential main streets addresses the social and ecological dynamics of different characters. Förstamajgatan, which possesses multifunctional streets, provides an example where there would be no ecological conflicts of dense corridor development but has no potential for synergies either. Gärdsåsgatan, which possesses high multiscalar and multimodal centrality provides another example, where dense corridor development instead poses critical ecological conflicts. These findings form the answer to how social-ecological synergies and conflicts can inform the design of dense corridor development in the Northeast suburbs of Gothenburg as they inform the creation of a new mesh that aims to avoid fragmentation of the ecological networks, while simultaneously strengthening the connections between adjacent neighborhoods, enabling the new streets potential to function as lively main streets in accordance with the aims of the EMC2 model. In 5.1.3 new synergies and conflicts are addressed. From the redesigned mesh, places for conservation, restoration, and mitigation of habitat functionality are established. These interventions become an integrated part of the proposed mesh of main streets. Social-ecological elements, including nature elements, typologies, and streets are implemented in the implications of local scale design together with rules regarding the constitution, mixed functions, and the design proposal of the new main street Kvibergs bäckväg. The new corridor development could be argued to create a social-ecological interface, where the configuration of both social and ecological patches function in a "configuration of patches".

2. What does the suburban street network provide for in terms of connectivity, proximity, and different services and what does the suburban green/blue structure provide for in terms of linking habitats and functioning ecosystems?

To answer this question, analysis of the suburban street network and the suburban green/blue structure is conducted separately. In section 4.1, the foreground network is analyzed, and in section 4.1.2 pedestrian-friendly accessibility to different functions is analyzed. An important finding is that the centrality deviates from the functionality and that light rail infrastructure is designed to follow function, rather than centrality. In 4.2.1 species species-specific movement is assessed and this shows how the ecological dynamic depends on what species is considered as the moving agent. In 4.2.3 multifunctional patches are identified which can conclude that Lärjeåns dalgång, Gärdsås mosse, Kviberg park, Fjällbo ängar provides for the 'hot spots' where multiple ecosystems in the North East suburbs of Gothenburg are highly functioning in terms of connectivity and habitat quality. For the individual species, other places are also valuable, such as the riparian zones, the graveyard Kvibergs kyrkogård, and the clear-cut power lines.

Sub questions:

$\boldsymbol{\cdot}$ What are some examples of significant spatial factors and land-uses for selected species in the suburban landscape?

The significant spatial factors are answered early on in the species profiles in section 3.3.2 and can be concluded as deciduous forests, dead/decaying wood, ponds, streams, wet habitats, open flower-rich environments, sun-exposed sandy soil, pastures, and road verges, which is also implemented in the local scale design. The assessment of significant land uses and landscape patterns can be understood through visualized habitat functionality patches for each species in section 4.2.1 and through the list of landscape patterns identified in multifunctional hotspots in section 4.5.2.

• How can different spatial configurations and urban types of the dense corridor development of the EMC2 affect human and non-human movements in a suburban landscape?

The main finding regarding this question is how urban form can affect both human and non-human movement if placed to constitute the main street for human movement, and openness facing the functional green infrastructure for other species. Another finding is how motorized networks reduce the ability to move/disperse as they increase distances and create barriers for both human and non-human species.



Figure 73. Illustration of identified social-ecological interfaces between street and green infrastructure. From left to right: Decorative, Under, Cut-through, Over, Integrated, and Aligned. Each interface, along with potential street design choices, can influence synergies or conflicts of human and non-human occupancy and movement.

Towards a Social-Ecological Methodology in Research and Design

Beyond the specific findings of the case study, this thesis contributes a transferable method for identifying social-ecological multifunctional suburban networks. This approach advances an integrated spatial-ecological method to support evidence-based planning in complex suburban contexts. Central to this approach is the identification and evaluation of multifunctional street networks and ecological systems, enabling planners and researchers to precisely locate synergies and conflicts between densification and ecological values.

The spatial analysis component of this approach combines multimodal and multiscalar betweenness centrality assessments with accessibility assessments to uncover the driving 'social networks' of the city. By evaluating centrality, multimodality, and multifunctionality, the method reveals the conditions that shape everyday suburban life and highlights the spatial drivers of dense corridor development along potential main streets.

This spatial analysis is made in parallel to an ecological analysis that models speciesspecific connectivity and habitat functionality using the Habitat Network Analysis Tool (HNAT). This produces a nuanced understanding of ecological networks through existing green corridors and where highly functioning habitat patches are located. The real strength of the method lies in the synthesis. By overlaying the identified ecological and social networks, conceptualized here as the implementation of the EMC2 along potential main streets, it becomes possible to spatially visualize conflict and synergies in the social-ecological overlaps. This enables scenario testing and design decision-making that goes beyond intuition, offering a replicable framework that can inform further research and urban design practice aimed at fostering multifunctional and resilient suburban areas.

The Rupture of Suburban Networks

A significant finding of this thesis is that the spatial analysis revealed a distinct rupture between streets with high multiscalar centrality, multimodality, and multifunctionality, meaning that streets with high pedestrian and vehicular flow (local and global scale movement) do not coincide with streets with accessibility to high population density, public transport, and mixed functions. This spatial mismatch of the street's configurational and functional properties poses a critical challenge for the implementation of dense corridor development as stated in the aims of the EMC2, as potential main streets ideally should possess both centrality and access to local amenities to enable the street's functioning as a public space. By establishing means to identify the overlaps of these multifaceted dynamics of the street network and suggesting how they could be strategically improved to enhance public life in a suburban context, this thesis contributes to a research-informed strategic design methodology for sustainable suburban development in research and practice.

Implications for Social-Ecological Design: From Strategic Planning to Local Scale Design

The findings of the research for design presented in this thesis carry several implications for social-ecological design, with relevance that spans from large-scale strategic planning to detailed, site-specific interventions in a suburban context. Centrally, the thesis challenges conventional assumptions that equate green infrastructure with visible greenness. Functional ecological design must attend to the specific needs of multiple species, many of which rely on less conspicuous elements. These natural elements can be seen as critical green infrastructure components that, when integrated thoughtfully, reinforce both occupancy and movement. On a strategic scale, spatial and ecological strategic design interventions are weighed in terms of land-use conflicts, and on a local

scale, potential main streets are designed to be active social-ecological spines with both social and ecological functions. They are carefully situated in relation to the functioning green structure, enabling both ecological connectivity and everyday human interaction. A central insight is the need to reformulate the relationship between built form and green infrastructure in suburban areas. While the planning ideals of the 1960s often placed green spaces as buffers between free-standing residential buildings, the design proposals in this thesis advocate for a more integrated approach to enhance social-ecological synergies.

In sum, this thesis suggests that social-ecological urbanism in suburban settings requires a dual focus: one that recognizes development's potential for improved social processes in suburban areas and between neighborhoods, and one that recognizes the remnant ecological assets and ecosystem services of suburbia in which the suburban form is embedded. This dual approach opens up new possibilities for planning suburban multifunctional networks.

Reflections

The Human

The concept of "over-abundance" in green spaces and its differentiated impact on human health and well-being should get further attention. While this thesis has broadly considered the benefits of increasing centrality and multifunction, future socialecological design should more explicitly address how different socio-economic groups experience, use, and improve well-being from urban green spaces, as noted by Ode Sang et al. (2010). This is especially important in suburban areas.
While three species acted as key non-human stakeholders in this study, informing local design through their habitat and connectivity needs, it is crucial to actively include human residents of the studied context as stakeholders as well. This participatory approach can help create awareness of how existing "green" areas are perceived, identify valued qualities, and foster a neighborhood-centered understanding and appreciation of nature. In accordance with the SEU, this would also create relationships with nature which in the long run will protect nature from being further encroached (Barthel et al. 2013).

• Design proposals are often presented visually but as Hedblom et al. (2017) emphasize, our environment is experienced through all senses (sight, sound, smell, touch, taste). The synergy of these combined sensory inputs are likely greater than their individual contributions. This could further strengthen the argument of social-ecological design if the nature values were to be understood based on all our senses, and not just showing in a map what is preserved and added in terms of biotic or abiotic patterns.

Reflections on Strategic Design and Planning Biases

• Designing for multiple species at a large scale is inherently complex. Efforts to avoid fragmentation for one species might inadvertently create fragmentation for another, or even for the same species in a different context or life stage. This highlights the critical importance of acknowledging and addressing potential biases in the planning process. In this thesis work, a bias towards the Lesser Spotted Woodpecker was noted during the strategic design phase. This may reflect a broader trend where analyses of species dispersal often focus on birds, potentially because humans have a strong affinity for them as vocal and visually present species, often associated with stress reduction (Hedblom et al., 2017; Ratcliffe, 2015).

• A preference for remnant forests as the most important biotope was also identified, possibly stemming from the woodpecker bias or personal affinities. While such biases, if aligned with the quality of habitats for both humans and target species, could be beneficial, it is crucial for planners to consciously acknowledge personal preferences as this is not necessarily what is most crucial. An open mindset is therefore important to be able to recognize the ecological value of patches that may not conform to conventional aesthetics or initial assumptions. An example of this is the clear-cut powerline corridor. While not traditionally viewed as a prime habitat, it was identified as significant for

sand bees. This illustrates how landscapes can possess unexpected social-ecological multifunctionality, in this case facilitating energy transmission and supporting specialist insect populations.

The role and limitations of data in design

This thesis involved rigorous data management. While data offers a crucial means to represent real-world phenomena, it is important to stress that it remains a simplification of complex and intricate systems. Despite attempts within this thesis to enhance data resolution (e.g., through detailed biotope merging and species-specific detailing), it is clear that information gaps persist. Furthermore, when conducting data-driven design, the significance of direct engagement with the real world cannot be overstated. The data analysis in this thesis was consistently accompanied by site visits. These empirical observations proved important, allowing for the cognitive understanding of space and integration of elements into the design that might otherwise have been overlooked or misinterpreted. This stresses the necessity of complementing quantitative data with gualitative, eve-level scale investigation to achieve a deeper understanding of the realworld phenomena we aim to plan and design for.

Future Research and Concluding Words

This thesis has contributed to the emerging discourse on social-ecological urbanism by exploring the synergies and conflicts of social and ecological systems in suburban devel-opment. While the research has focused on a specific set of variables and methods, sev-eral areas warrant further investigation.

Density Types as Ecological Indicators

Further research could investigate the correlation between different built density (e.g., Floor Space Index (FSI), Ground Space Index (GSI), and specific building typologies) and measures of species richness. This could provide valuable metrics for urban planning practice.

Pedestrian Movement and Species Sensitivity

While this thesis used motorized street (MS) network centrality as an indicator for ecological friction (e.g., roadkill risk), future studies could explore pedestrian movement, or human presence, as a barrier. This is particularly relevant for more sensitive species, such as mammals, which may be affected more by a certain degree of human presence, compared to traffic-related disturbances. This could improve our under-standing of how close we can get, and to what extent social-ecological urbanism can create co-presence.

Time-Space Dimensions of Social-Ecological Urbanism

There is potential to deepen the exploration of temporality in social-ecological design. A 'time-space' approach to social-ecological urbanism could involve designing urban environments that accommodate multi-species use across different times of day. seasons, or years. Such strategies may enable spe-cies sensitive to human presence to access and utilize urban spaces during quieter periods an thus increase the multifunctionality of cities land use.

These research directions underscore the complexity and potential of integrating ecological thinking into urban form and function. By treating urban space not only as a static arrangement of built structures but as dynamic of systems, planners and designers can begin to imagine cities that are not only livable for humans but also hospitable to a diversity of life forms. This thesis lays the groundwork for such an approach for a suburban context, offering both a conceptual foundation and methodological entry points for designing multifunctional suburban networks that aspire toward co-existence and long-term social-ecological resilience.

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Figure 6

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Figure 9

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Figure 10

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Figure 13

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Figure 26

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Figure 33 Land cover types [Data set]. (Source: Naturvårdsverket)

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Appendix 1 HNAT-analysis output Lesser spotted woodpecker - Late spring







Appendix

Appendix 2 HNAT-analysis output Lesser spotted woodpecker - Winter

Cost-Distance Raster



Dispersal Raster



Functionality raster



Source raster





Cost-Distance Raster



Dispersal Raster



Functionality raster



Appendix 3 HNAT-analysis output Amphibians



Friction Raser



Quality raster





V

Cost-Distance Raster





Functionality raster



Appendix 4 HNAT-analysis output Small scabious mining bee

Source raster







Appendix 5 Parameter table for the HNAT-tool





_	_									_	_											_	
0 1	0 1	0 1	0 1	0 1	0 1	0 1	0 2	0 1	0 1	0 1	0 1	0 1	0 1	0 1	0 10	0	0 1	0 1	0 1	0 1	0 1	0 1	0
100 3	7 5	7 7	6 7	7 7	1 5	5 7	100 5	100 6	10 8	10 10	10 10	10 10	1 7	10 10	2 1	1 2	1 9	1 5	1 6	1 3	1 0	1 2	1 7
0 0	0 0	0 0	0 0	0 0	5 0	0	0 0	0 0	0 0	0 0	0 0	0 0	4 0	0 0	5 0	10 1	10 0	3 0	3 0	3 0	10 0	10 1	0 6
1	1	1	0 1	1	0 10	1	1	0 1	0 1	0 1	0 1	0 1	0 20	1 1	0 5	1	0 1	0 1	0 1	1 1	0 1	0 1	1
2	8	8	8	6	1	3	3	3	6	6	6	10	0	10	0	1	6	6	10	10	1	1	7
1	1	1	1	1	10	1	1	1	1	1	1	1	20	1	5	1	1	1	1	1	1	1	1
2 0	8 0	8 0	8 0	0 6	1 0	3 0	3 0	3 0	0 6	0 6	0 6	10 0	0 0	10 1	0 0	1 0	0 6	0 6	10 0	10 1	1 0	1 0	7 0
1	1	1	1	1	10	1	1	1	1	1	1	1	20	1	5	1	1	1	1	1	1	1	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
G	8	8	2	8	1	2	10	5	5	5	5	10	0	10	0	-	10	10	10	10	1	1	
1. 1.1.3. Barrblandskog/Mixed coniferous 113	1. 1.1.4. Lövblandad barrskog/Mixed fore 114	1. 1.1.5. Triviallövskog/Deciduous forest 115	 1.1.1.6. Ädellövskog/Deciduous hardwoo 116 	1. 1.1.7. Triviallövskog med ädellövinslag/ 117	 1.1.1.8. Temporärt ej skog (inkl hyggen)/7118 	2. 1.2.1. Tallskog/Pine forest 121	2. 1.2.2. Granskog/Spruce forest 122	2. 1.2.3. Barrblandskog/Mixed coniferous 123	2. 1.2.4. Lövblandad barrskog/Mixed fore 124	 1.2.5. Triviallövskog/Deciduous forest 125 	2. 1.2.6. Ädellövskog/Deciduous hardwoo 126	2. 1.2.7. Triviallövskog med ädellövinslag/127	 1.2.8. Temporärt ej skog (inkl hyggen)/ 128 	 129. Triviallövskog med rikligt av björk/a129 	8200. Järnväg/Railway	306. Öppen sandig mark i sydläge/Open 306	440 Bäck <6m/Stream <6m 440	700. Skyddsvärda träd/Valuable trees 700	701. Skyddsvärda träd med håligheter († 701	702. Skyddsvärda triviallövträd (björk, a 702	703 Artrika vägkanter/Flower rich road 703	704 Ängsvädd och åkervädd/Succisa pra 704	800. Kyrkogårdar/Graveyards 800
NMD - Swedish land cover raster map (Naturvårdsv 1.)	NMD - Swedish land cover raster map (Naturvårdsv 1.)	NMD - Swedish land cover raster map (Naturvårds) 1.1	NMD - Swedish land cover raster map (Naturvårdsv1.3	NMD - Swedish land cover raster map (Naturvårdsv 1.3	NMD - Swedish land cover raster map (Naturvårdsv1.3	NMD - Swedish land cover raster map (Naturvårdsv 1.)	NMD - Swedish land cover raster map (Naturvårds) 1.1	NMD - Swedish land cover raster map (Naturvårdsv1.)	NMD - Swedish land cover raster map (Naturvårdsv 1.2	NMD - Swedish land cover raster map (Naturvårdsv1.)	NMD - Swedish land cover raster map (Naturvårdsv 1.1	NMD - Swedish land cover raster map (Naturvårdsv 1.1	NMD - Swedish land cover raster map (Naturvårds) 1.2	Skogsstyrelsen 1.2	Terrängkartan 5.	SGU & Lantmäteriet	Lantmäteriet	Artportalen & Länsstyrelsen Västra Götaland	Artportalen & Länsstyrelsen Västra Götaland	Artportalen & Länsstyrelsen Västra Götaland	Trafikverket	Artportalen	NMD - Swedish land cover raster map (Naturvårdsv5.

Appendix 6

Empirical testing of Lesser spotted woodpecker -Earl spring model



Lesser spotted woodpecker (Early Spring) Habitat functionality

Similar to the late spring, as quality biotopes and friction values are the same. The difference is in the dispersal range, meaning it utilizes the same biotope, but reaches more as it can move bigger distances. When empirical observations are compared, it can be seen a pattern that they start to cluster more around the vicinity of the moste important patches.

Dispersal probability

Follows the same accuracy of the winter model in the vectorizeed 50% and 75% dispersal probability range, with a lesser pecision in the 25% probability polygon of dispersal probability. A reason for this is that this is the season where the specie starts to have more habitat specificy, and therefore requires more precision in the data of source layers.

Habitat functionality map - Lesser spotted woodpecker, Early spring





Dispersal probability map - Lesser spotted woodpecker, Early spring

Legend Top_layers

Case-study area

Östra Göteborg

Ecological_analysis

HNAT_analysis

Observations_species

Woodpecker_ES_17_24

Early_spring_deciduous

Counted_Vectorized_Dispersal

Dispersal probablity, 75%

Dispersal probability, 50%

Dispersal probability, 25%

This model shows habitat connectivity for one species in a single season in terms of cost-weighted dispersal probabilities. The Dispersal Probability Raster was calculated based on the Cost-Distance Raster in combination with the average dispersal distance specified in the parameter file (see Appendix). In this map, the Dispersal Probability Raster has been vectorized using three threshold values: ≥25%, ≥50%, and ≥75%. The number of observations within the vectorized polygons was counted to assess the model's performance in predicting the species' dispersal pattern.

C. C.		1 1 1 1 1 1 1
SUM_25	TOT_OBS_ES	PERCENT_25
168	220	0.764
	1. martin and a	

SUM_50 TOT_OBS_ES PERCENT_50 134 220 0.609

SUM_75 TOT_OBS_ES PERCENT_75 220 0.455 100

SUM_X: Amount of observations counted withing the specific dispersal probability PERCENT_X: Percent of observations counted within the dispersal probability TOT_OBS: Total amount of observations

Scale: 1:150 000

Charlotta Blom ACEX65 - Chalmers University of Technology

Data sources: Artportalen, Göteborgs stad (Miljöförvaltningen), SMoG Chalmers, Länsstyrelsen Göteborg, Naturvårdsverket, Skogsstyrelsen, Lantmäteriet, ESRI



Appendix 7

Creation of data sets 'Dead/decaying wood' and 'sun-exposed sand'

1. Valuable trees with softer wood

Litterature studies: Miljöförvaltningen (2023) & Wiktander m.fl. (2001)

- Birch (Betula spp.)
- Alder (Alnus spp.) ٠
- Goat Willow (Salix caprea) ٠
- Aspen (Populus tremula)

Data sources: Artportalen (Skyddsvärda träd) & Skyddsvärda träd Länsstyrelsen Västra Götaland

The data (Länsstyrelsen Västra Götaland) includes: Trees with a diameter greater than 1 meter at chest height (Giant trees >1m), trees with a diameter greater than 40 cm and with a developed cavity (large cavity trees), pollarded trees, trees with the presence of a red-listed species and/or notable indicator species, future giant trees, i.e., trees with a circumference of 300–313 cm. Includes trees inventoried up to March 2023.

Selection by expression in OGIS

"TRADSLAG" = 'ALAR' OR "TRADSLAG" = 'Asp' OR "TRADSLAG" = 'ASP / POPPLAR' OR "TRADSLAG" = 'BJÖRK' OR "TRADSLAG" = 'Björkväxter' OR "TRADSLAG" = 'Glasbjörk' OR "TRADSLAG" = 'Klibbal' OR "TRADSLAG" = 'Sälg' OR "TRADSLAG" = 'Sälg (ssp. caprea)' OR "TRADSLAG" = 'VIDEN' OR "TRADSLAG" = 'Vårtbjörk'

2. Trees infected by fungus

Litterature studies: Artportalen, Park- och naturförvaltningen (2021),

Fungus growing on dead/dying/older birch or alder trees are indicators of valuable trees and suitable reproduction habitats for the Lesser spotted woodpecker. Observations of these fungus species are also observations of the trees that they grow on and are therefore added to the data of valuable deciduous trees for the lesser spotted woodpecker.

Data source: Artportalen (20170601-20241001)

- **Björkticka** (*Piptoporus betulinus*), a fungus that attacks birch trees, causing them to rot and become soft and weak.
- Sprängticka (Inonotus obliquus) Deciduous and mixed forests. Living and dead trunks of birch and alder. Rarely on other deciduous trees.

3. Data from Miljöförvaltningen

Data source: Miljöförvaltningen biotopkartering av mindre hackspett.

Selection by expression in OGIS

Lämplghet = Mycket Lämplig (Very suitable)

Codes in this category of the data: AA, BA, AB and AC

Creation of new column 'vardeobjek' (valuable elements) in the attribute table through the field calculator in QGIS

Based on the report from Miljörförvaltningen on suitable biotopes for the lesser spotted woodpecker (2023), different codes (AA, AB, etc) indicate different habitat quality based on possibility to forage (first letter) and reproduction (second letter). Depending on the second letter of the code, the area ('area_hekta') was multiplied with different numerical values in a new column 'vardeobjek' ("valuable elements") in the attribute table.

CASE WHEN "bokstavsko" = 'AA' OR 'BA' THEN "area hekta" *21 END

CASE WHEN "bokstavsko" = 'AB' THEN "area hekta" *12 END

CASE WHEN "bokstavsko" = 'AC' THEN "area hekta" *3 END

The values (21, 12 and 3) are based on how many "value elements" (decayed trunks, tall stumps, or dead trees) exist within an occupied territory of the lesser spotted woodpecker. A study on this topic was conducted under the direction of the Swedish Transport Administration on the Onsala Peninsula. This survey concluded that in occupied territories, there were between 3 and 21 "value elements" per hectare (Elg 2019, Bengtsson et al. 2020). The value 12 is the mean value of 3 and 21 and is therefore given to areas with the letter code Β.

Based on this column, random points were iterated in the polygons through QGIS:

Vector > Research tools > Random points in polygons

If area_hekta was given an area less than 1 hectare in the attribute table, this was manually rounded up to 1.

The different data layers were now merged, rasterized and clipped into the BiotopeMap for the Lesser spotted woodpecker.

Creation of sun exposed sand

- 1. Aspect of Lantmäteriets hojdata1m
- Selection of south facing pixles by RasterCalculator Aspect1 247.5 >= 112.5
- 3. Export result to change resolution to 10x10 georeferenced unit to match scale of the biotope map
- 4. Import layer with sandy soil by Amanda
- 5. Vectorized the layer of Aspect facing south.
- 6. Cut Amandas soil layer by mask layer
- 7. = sunexposed sandlayer.

Appendix 8 Strategic street design interventions

Based on the spatial analysis and the result presented in the previous maps, a strategic design was developed. Following are design interventions to increase the centrality value and integration of the street, both on local and city scales. The ambition was to connect the attractors (local centers, addresses, tram stops) to the movement. In general, where roads are red, they have been straightened up. Other more morphological (but also configurational) interventions are stated below:

1. Tramstop Kviberg becomes a "square" designed for passed-through movement. The entrance to Kviberg Park is more articulated. This intervention means lowered speed on arriving trams.

2. Tramstop Nymånegatan becomes a "square" designed for passthrough movement. Same principle as Kviberg.

3. Streets are straightened out, Månadparken gets cognitively clear paths, and plot sizes of Månadsgatan are shrunk to fit two additional rows of houses along Almanacksvägen where the entrances can constitute the road without setbacks. The pedestrian underpass between Månadsparken and Helge Härnemans väg is leveled with Almanacksvägen.

4. Pedestrian paths towards Kortedala Torg are straightened up to strengthen connections to Almanacksvägen.

5. Kortedala torgs tram station is redeveloped to be square and becomes located in the intersection of the MS and NMS network, while still adjacent to the services of Kortedala torg. The Roundabout becomes a three-way intersection. Pathways under the bridge were removed, and paths connected to Kortedala torg.

6. The height difference between pedestrian paths and tram traffic is leveled out where it is possible. Utilize the parking lot adjacent to City torget to redirect flow from Förstamajgatan to go through the square.

7. Level out the pedestrian underpass and create an entrance to the nature area of Kviberg Park. 8. Remove the roundabout

9. Remove the roundabout

10. Remove the pedestrian underpass linking Västra bergsjön and Norra Kortedala.

 Establish today's "unofficial" street (pedestrian-made path through the woods)

12. Straighten up and make a cognitively clear pedestrian path through Gärdsåstorg/ Galaxen. Connect to streets of residential slab buildings on each side. In Galaxen the terrain is steep, meaning some parts would need stairs as a consequence of them being straightened up.

13. Remove differentiation of MS and NMS flows.

14. A small street segment is added between Barefjällsgatan in Utby to the pedestrian/ bicycle road Sjustjärnan to connect Bergsjövallen (football courses) to Kviberg Park. This new connection is a compensation for the development of Kvibergs bäckväg, which uses some of the football courses in the North part of Kviberg Park for mixed-use development. The new connection links the sports facility functions of Kviberg Park to surrounding neighborhoods and enables a mixed-use area in the North part of Kviberg Park, which today is monofunctional with extensive sequences of football courses that are far away from public transport. This is in alignment with Kviberg Park's development vision (Göteborgs stad, 2015) to create mixeduse and connect to adjacent neighborhoods.

15. New bridge at the same location as the existing one, but picking up the angle of Kamgatan. Decrease centrality of Gärdsåsvägen.

16. Potentially an additional pedestrian bridge over Kvibergsbäcken, to strengthen the connection to Bergsjön, creating a circular movement going from the middle of Bergsjön, through Kviberg park, towards Kortedala torg.

17. New public transport stop in the new square in the intersection between Kvibergs bäckväg and Krutstråket.

Appendix 9 Habitat functionality before and after strategic land use interventions



Figure 75. Habitat functionality, Woodpecker (Before)



Figure 76. Habitat functionality, Amphibians (Before)



Figure 77. Habitat functionality, Small scabious mining bee (Before)

xvi



Figure 78. Habitat functionality, Woodpecker



Figure 79. Habitat functionality, Amphibians (After)



Figure 80. Habitat functionality, Small scabious mining bee (After)

Appendix 10 **AI Appendix**

AI Appendix

AI has been used as a tool to rephrase and structure sentences in English. The answers from AI have been critically examined, bearing in mind that the answers can be biased or lack important information to be able to understand what I am trying to say. No new information or sources were taken from AI.

Al has been used to sort the sources in alphabetical order. All sources was gone through after this process.

Al has been used to help cite to sources in accordance with APA. This was done by giving the information needed for the citing or sending a link to published material.

AI has been used to calculate dispersal distances for the lesser spotted woodpecker in different seasons, as this information about dispersal range was needed for the HNAT tool and could not be found in meters in any source I found. The prompts were based on the source:

Wiktander, U., Olsson, O., & Nilsson, S. (2001). Seasonal variation in home-range size, and habitat area requirement of the lesser spotted woodpecker (Dendrocopos minor) in southern Sweden. Biological Conservation, 100(3), 387-395. https://doi.org/10.1016/S0006-3207(01)00045-3

In the source, the seasonal variation in dispersal is given in hectares.

Lesser Spotted Woodpecker Dispersal Distance Calculations

User Prompt:

I read that the lesser spotted woodpecker uses a mean area of 742 hectares in winter, but how could this be translated to dispersal distances in meters?

Al Answer:

- Converted 742 hectares to square meters:

742 ha = 7,420,000 m²

- Calculated radius of a circular home range:
- $r = \sqrt{(7,420,000 / \pi)} \approx 1,537$ meters
- Estimated dispersal distance in winter: ~1,537 meters

User Prompt:

I read that the mean home-range size is 43 hectares during nesting and 103 hectares during early spring. Using the same way of calculating dispersal distances, what is the nesting and early spring home-range size in meters?

Al Answer:

- Nesting Season (43 ha):
- r = √(430,000 / π) ≈ 369 meters
- Early Spring (103 ha):
- r = $\sqrt{(1,030,000 / \pi)} \approx 572$ meters

User Prompt:

Sorry, I meant that the mean home-range size is 103 hectares during late spring. For early spring the mean home-range size is 355. Can you calculate the dispersal distance in meters and summarize it for the different seasons again?

Al Answer:

- Early Spring (355 ha):
- r = $\sqrt{(3,550,000 / \pi)} \approx 1,062$ meters
- Late Spring (103 ha):
- $r = \sqrt{(1,030,000 / \pi)} \approx 572$ meters

Summary of Dispersal Distances by Season:

Season	Home-Range Size	Estimated Dispersal Distance
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	· · · · · · · · · · · · · · · · · · ·
	· · · · · · · · · · · · · · · · · · ·

43 ha	~369 meters	
103 ha	~572 meters	I
355 ha	~1,062 meters	Ι
742 ha	~1,537 meters	I
	43 ha 103 ha 355 ha 742 ha	43 ha ~369 meters 103 ha ~572 meters 355 ha ~1,062 meters 742 ha ~1,537 meters

These values approximate how far the lesser spotted woodpecker may travel from the center of its home range in each season, assuming a circular range.

OpenAI. (2023). ChatGPT (Mar 14 version) [Large language model]. https://chat.openai.com/



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