Sustainable Urban Form

– an assessment of Swedish urban typologies

Hållbar Urban Form – en utvärdering av svenska stadstyper

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Swedish University of Agricultural Sciences, SLU
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Abstract

Achieving a sustainable urban form has been explored in multiple academic papers, with the primary objective of framing and evaluating the dimensions of sustainability. This thesis aims to understand the concept of sustainable urban form and evaluate how Swedish urban typologies score in this context. The complexity of sustainable urban form is evident due to its numerous interrelated dimensions. While this thesis does not delve deeply into policy, governance, or user behaviour aspects, it concludes by comparing the performance of Swedish urban typologies and constructing a framework for a sustainable urban form.

The scoping literature review reveals that the concept of sustainable urban form intersects with multiple planning ideals, such as the eco-city, urban compaction, and the compact city. This indicates the absence of a one-size-fits-all ideal. Synthesising the discourse on urban intensification highlights the challenges in achieving denser, more sustainable urban environments. It requires a nuanced understanding of the interplay between urban development, community engagement, and environmental stewardship. This discourse underscores the need for inclusive planning processes that recognise diverse interests and capacities, positioning urban intensification as a comprehensive approach to fostering sustainable, vibrant, and inclusive environments.

Aligning density with built form and the broader urban context remains crucial, challenging planners to reconcile quantitative measures with qualitative urban experiences. Assessments of Swedish urban typologies reveal no single typology scores highly across all dimensions. Patterns emerge, such as typologies farther from the city centre having more visible sky and lower Floor Space Index and Ground Space Index, indicating less compact urban fabrics. These typologies are prone to infill densification in contemporary planning, highlighting the challenge of densifying already compact forms without compromising quality of life aspects like daylight and greenery.

Developing an analytical framework to assess the contribution of different urban building typologies to sustainability is essential. This framework must consider reducing space and water demand, power and lighting use, and motorised transport while increasing self-sufficiency in lifestyle practices. The need for diverse types of compact development, accounting for local regulations and social preferences, is crucial. Compact development should enhance liveability rather than focus solely on densification, incorporating elements of human scale and quality of place.

Forewords

A shadow that is long overdue..

Tanks everyone that have supported me through this journey.

Christopher Klich, 2024

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1. Introduction

1.1. A continuous urban growth

We are living in the 'Century of the Cities'! In 2018, the UN announced that 55% of the global population resides in urban areas, and that by 2050, this number is projected to increase by 13% (UN, 2018). Although the largest increase is expected to occur in the developing world, the developed world will see both growth and decline in various areas. By the end of 2020 in Sweden, 88% of the population were living in urban areas (SCB, 2021). According to Sweden's Central Bureau of Statistics, new urban areas are forming closer to larger ones across the country (ibid.). Notably, a decline in population can be observed in urban areas in Sweden's northern regions. Overall, the population is increasing in the country, but this year (2023), the population increase has been the lowest in 17 years (0.4%) (SCB, 2023). From these statistics, we can argue that in the coming years, urban growth will continue, but will cluster around already densely populated urban areas. Urban growth can be defined as "*the movement of people from small, rural village communities […] to larger, more complex, and densely populated communities called towns and cities*" (Donald, p. 1). One of the most basic characteristics of human society is the desire to live in close proximity to one another, whether it be for greater exposure to job opportunities, an increased access to civic amenities, or for the sense of mutual belonging. In this sense, larger urban areas tend to be at the forefront of change in a society (ibid.). But what happens when people move to urban areas en masse?

A continuous movement of people resettling can eventually create a phenomenon known as *Urban Sprawl*. The Organisation for Economic Co-operation and Development (OECD) defines such phenomenon as:

"*…an urban development pattern characterised by low population density that can be manifested in multiple ways. That is, an urban area may be sprawled because the population density is, on average, low. Furthermore, urban areas characterised by high average density can be considered sprawled if density varies widely across their footprint, leaving a substantial portion of urban land exposed to very low density levels. Urban sprawl can also be manifested in development that is* *discontinuous, strongly scattered and decentralised, where a large number of unconnected fragments are separated by large parts of non-artificial surfaces* (OECD, 2018)."

This phenomenon leads to unsustainable land resource use as it rapidly changes land use and may destroy landscape values of future interest. Post-WWII, European countries experienced rapid urban decentralisation, characterised by a mix of suburban growth and smaller town expansion (Breheny, 2003). In the modern Swedish planning paradigm, especially during the 60s and 70s, the planning ideas tended to lean towards a 'rational' mind-set and followed so-called 'tabula rasa' principles ('starting from a blank canvas') (Dahl, 2020). The Million Programme is a prime example of such planning, where functions in newly developed neighbourhoods were to be separated, much in line with the 'ABC-city' planning type, which stood for *Arbete* (Work), *Bostad* (Housing), and *Centrum* (Centre), and whose functions were specifically segregated in the landscape from one another (Berg, Granvik, & Hedfors, 2012). The issues with these planning strategies and ideals were that they consumed a significant amount of land and utilised a scale that was later shown to be less than ideal for human needs, such as placing large and tall mass-produced buildings far apart. Indeed, this was just one of many factors and strategies contributing to the sprawling expansion of cities. Another well-known contributor was the 'Green wave', where middle-class families moved out of cities in large numbers to live in the 'ideal' suburb with their own house and garden. In today's society, the main factor is the influx of new inhabitants moving from rural areas into cities for work opportunities and access to better municipal services such as education and healthcare. This places significant pressure on current urban expansions as cities, especially in the south, are surrounded by valuable land such as farmland which leads to municipalities advocating for densification rather than an outward expansion. However, sometimes development of urban areas encroach on surrounding land as multiple interests are weighed against each other e.g. housing, industrial expansion. Thus, making urban sprawl a complex and multidimensional effect of both planning and societal change that cannot be simplified to merely the resettlement/movement of people (OECD, 2018). Nonetheless, it can be mitigated by managing land use sustainably and applying sustainable urban planning principles.

1.2. Growing a compact city

In terms of mitigating urban sprawl, the compact city has emerged as a concept, advocating for inward rather than outward growth, aiming for a more compact urban form (Larice & Macdonald, 2013; Jenks, Burton & Williams, 1996). The fundamental tenets of the compact city include urban containment, mixed land use, high density, public transportation, proximity and walkability, and social equity.

Contemporary planning in Sweden draws upon ideas from the compact city concept, these principles are evident in the planning principles of municipalities and their approaches to urban development, they are often gathered under the term '*Blandstaden*' (The Mixed City), which reflects similar principles, with the goal of integrating various functions within urban areas to create vibrant, and multifunctional cityscape (Bellander, 2005). This is also something that is recurrent in regulations and guidelines brought forth by the Swedish National Board of Housing whose one of many roles is to contribute to a more sustainable Swedish society (Boverket, 2016a).

A common scene of urban development within larger cities is the conversion of brownfield sites (industrial areas) into residential areas to promote urban containment and prevent the expansion of the city's perimeter (Boverket, 2016a). This is also a type of densification strategy to not consume valuable land. Moreover, it is not unusual for existing residential areas with sparse multi-dwelling units to undergo densification through infill development (constructing housing in-between existing buildings). In contemporary urban development, densification is pursued in diverse settings, from luxury villas and quaint cottages to apartment complexes in suburbs, defunct ports, and downtown green spaces (Berg, 2015). Cities are integrating high-rise buildings into neighbourhoods of traditional 1950s homes, as well as adding townhouses to outer suburbs and apartment blocks to residential villa areas. This strategy is not solely to fulfil local demand but often to capitalise on the allure these new structures hold in the real estate or commercial markets. According to Berg (2015), tailored densification can address the unique requirements of different urban areas. Single-family zones, for instance, might revive local commerce and communal spaces. Meanwhile, adding detached homes and townhouses in outer suburbs and apartment buildings in affluent areas could alleviate urban segregation. So in this sense, the compact city concept calls for densification in already existing cities, intensifying the urban land.

Urban intensification, as articulated by Williams, Burton & Jenks (2006), embodies a multifaceted approach towards achieving denser urban spaces, underscored by a broad spectrum of definitions and interpretations. This concept revolves around the strategic densification of urban areas to optimise the use of existing urban land, thereby reducing the expansion into rural territories. Such a process is pivotal for enhancing the compactness of urban environments, promoting the redevelopment of derelict, contaminated, or unused spaces, and advocating for higher densities of population and structures. The discourse on urban intensification extends to encompass both the physical transformation of urban areas, through redevelopment and construction at higher densities, and the intensification of urban activities, including the enhanced use of existing buildings and the fostering of vibrant community spaces.

In the compact city, liveability often gets challenged. For a city to be sustainable in its form, the argument often calls for functions and population be concentrated at higher densities (Neuman, 2005). Yet for a city to be liveable, functions and population should be dispersed at lower densities, as people want access to greenery, sense of safety, good schools, quiet streets, and so forth. This becomes paradoxical and also one of the more prominent arguments against compactness. Neuman (2005) stresses that we must be cautious in accepting claims that liveability is greater in one form of human settlement over another; as the same qualities exist in many cities and are not exclusive to low-density suburbs. In this sense, liveability is not only a matter of urban form, it is also a matter of personal preference.

1.3. An urban typology for sustainability

Lemoine-Rodríguez, Inostroza, & Zepp (2020) observed a trend towards more homogenized urban forms across cities regardless of their size or geographical location, influenced by both compact and dispersed expansion patterns. They pinpointed the homogenisation of urban form alongside rapid urban expansion as significant global sustainability challenges. Furthermore, they emphasized the importance of urban form analysis in the planning of urban expansion to alleviate the adverse effects of urban sprawl. By viewing urban form as a process, they advocate for an understanding of cities as dynamic entities that integrate social, ecological, and technological dimensions, underscoring the necessity of such analyses in fostering sustainable urban development strategies. Sustainable urban form plays a vital role in creating environmentally sustainable and liveable cities, the importance of compact and connected urban form as a means to promote sustainability. According to Glaeser (2008) dense urban environments can reduce energy consumption, limit sprawl, and facilitate social and economic interactions, leading to improved environmental outcomes. Further, the relationship between urban form and transportation is also seen as an important keystone of achieving a sustainable urban form. Newman & Kenworth (2015) argues that such a form should prioritise the development of transit-oriented communities, where mixed land uses and efficient public transportation networks reduce car dependency and promote sustainable mobility options.

So this sparks the questions – *What type of urban typologies promote a sustainable urban form? What type of qualities could we lose if we continue to densify and intensify the city? Should we continue to contain the city indefinitely to mitigate sprawl, or can we find a sustainable urban growth pattern? What types of strategies are municipalities implementing in their planning to achieve sustainable and denser urban structures?*

2. Aim and purpose

The purpose of this thesis is to contribute to our understanding of how the Swedish urban fabric and its typologies relate to the concept of sustainable urban form. The study aims to (1) identify urban building typologies in Swedish cities – both historic and contemporary, (2) explore the concept of sustainable urban form and decompose it into assessable components, and (3) to construct an analytical framework for evaluating identified typologies and their potential to support a sustainable urban form.

2.1. Research questions

-How do urban building typologies within the Swedish urban fabric contribute to and align with the principles of sustainable urban form?

-How can the concept of sustainable urban form be defined and broken down into measurable components suitable for evaluation?

-What analytical framework can be developed to assess the contribution of different urban building typologies to sustainability, and how effective is this framework in the context of Swedish cities?

2.2. Delimitations

This thesis focuses primarily on urban typologies at a meso-scale, abstaining from the micro and macro scales. It does not delve into the deeper morphological interweaving of these typologies through history. Similarly, it refrains from exploring social and psychological values, given their complexity and the nature of their assembly and agency. Although investigating how various typologies affect the daily lives of residents would have been an intriguing approach, this thesis does not undertake such analyses, as an ethnological perspective was not its aim. Furthermore, it avoids examining the visual representation of these typologies, such as identifying the most aesthetically appealing structures. While one might argue that the visual appeal of a structure plays a role within the urban fabric, this study neither explores building materials nor engages with the form of tenure, since these factors fall outside the scope of regulation within zoning plans.

3. Methodology

The methodology adopted for this study involved three key steps: (1) identifying urban typologies through literature and geospatial data analysis, (2) conducting a scoping literature review to develop an analytical framework based on urban planning metrics, and (3) evaluating the efficiency of these typologies using the established analytical framework.

3.1. Identifying urban typologies through literature and desktop research

The approach taken to identify typologies was to combine urban morphology principles and building footprint spatial data from the National Land Surveying Authority in Sweden. This approach was cross-referenced with the insights from the book '*Svenska stadstyper*' (translated as 'Swedish Urban Typology') by Rådberg & Friberg (1996). Spatial boundaries were established by categorising the urban fabric of Malmö and Lund into three types: *tall*, *low*, and *closed quarters*. 'Tall' refers to buildings of three storeys or more, 'Low' to buildings of two storeys or fewer, and 'Closed quarters' to buildings that are adjoined, forming extensive structures with internal courtyards.

To narrow down the number of urban typologies for evaluation in this thesis, only those consisting of three stories or more were included. This criterion does not imply that low-story housing is absent in urban areas or dense city structures; rather, it serves to delineate the study's scope.

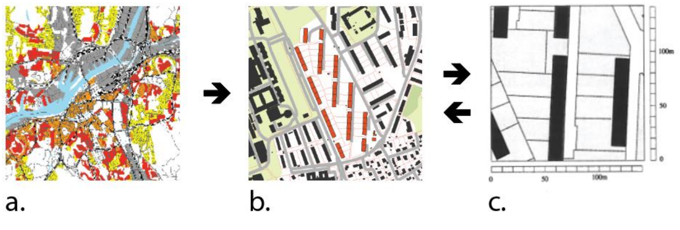

Figure 1, An illustration of the identification process of typologies where a. represents the categorisation of the urban fabric (red=tall, yellow=low, orange=closed quarters), b. displays the building footprint of the spatial analysis, and c. depicts the typology from the literature.

3.2. The creation of an analytical framework to evaluate typologies

The process that led to the analytical framework used to evaluate urban typologies involved two key steps: (1) deconstructing the research questions into key terms, supplemented by complementary terms from planning documents, and (2) conducting a scoping literature review using these identified key terms to pinpoint suitable literature for the framework.

3.2.1. Identifying keywords within contemporary planning

To identify keywords that can be used as search terms for the literature review, key terms were defined based on the research questions.

The following key terms were extracted from the questions:

- *Urban Typology* (Variations: Urban Archetypes, Urban Form, Urban Patterns)
- *Sustainable Urban Form* (Variations: Sustainable Urban Design)
- *Densification* (Variations: Urban Density, Urban Consolidation)

To widen the scope of searchable key terms, numerous planning documents were thoroughly analysed, focusing specifically on the comprehensive plans for new urban developments within the municipalities of Malmö, Gothenburg, and Stockholm. In addition, publications from the Swedish National Board of Housing, Building, and Planning were reviewed, given its role as the policymaking authority for planning in Sweden, which also issues recommendations and strategies on how urban developments should be approached. Further analysis encompassed planning documents issued by other municipalities, which assisted in enhancing the process of identifying key terms.

The following documents were analysed:

- *Hammarby Sjöstad Fördjupning av Översiktsplan*, Stockholm Stad.
- *Översiktsplan för Nyhamnen Fördjupning av Översiktsplan Malmö*, Malmö Stad.
- *Vision Älvstaden*, Göteborgs stad.
- *Hållbar täthet i stationsområden*, Ytterby kommun.
- *Blandstaden*, Gunilla Bellander, Boverket.
- *Rätt tätt en idéskrift om förtätning av städer och orter*, Boverket.
- *Täthet i Malmö: Ett planeringsunderlag*, Malmö stad.
- *Stadsbyggnadskvaliteter Göteborg*, Göteborgs stad.

The following key terms were extracted from the documents:

- *City Structure* (Variations: Urban Form, Urban Design, Urban Patterns)
- *Sustainable Development* (Variations: Sustainable City)
- *Urban metrics* (Variations: Urban measurements)
- *Densification* (Variations: Urban density, Urban consolidation)

3.2.2. Identifying key concept through a scoping literature review

A scoping review aims to map the key concepts, sources, and knowledge gaps within a broad research area. It provides an overview of the existing literature, without necessarily evaluating the quality of the studies or conducting an in-depth synthesis of the findings. For this particular study, the web search engine *Google Scholar* and two bibliographic databases of scientific publications, *ScienceDirect* and *SpringerLink*, were selected for the literature search. Google Scholar was chosen for its extensive coverage of academic literature across the web, while ScienceDirect and SpringerLink were chosen based on their relevance to the study's subject area and the licensing access available through the university.

To assess the relevance of the terminology and to refine the selection of terms to use, multiple test searches were conducted within the scientific databases. If a term was identified as common terminology that spans across multiple fields, it would yield results too divergent from the topic of this thesis. For instance, searching for the term 'densification' might produce results such as 'biomass densification in biological-based bio-refineries', which are unrelated to the intended area of study. Therefor terms with ‘Urban’ were prioritised in the selection process and used in the search operations.

The next step of the review involved understanding the extent to which the identified key terms appear within the academic literature. To ensure the search was focused on contemporary literature the range was limited to the years 2000 to 2023. The search results showed a gradual increase of publications in all three platforms (See figure 1-3). This could be explained by knowledge accumulating over time as well as the digital publications becoming more common. It is also notable that Google Scholar had ten times the amount of publications than the two databases, this is most certainly due to the engine showing publications from other databases. Another interesting finding were that the key terms Urban Form and Urban Morphology was tremendously more common within the literature than other search terms (See Appendix 1).

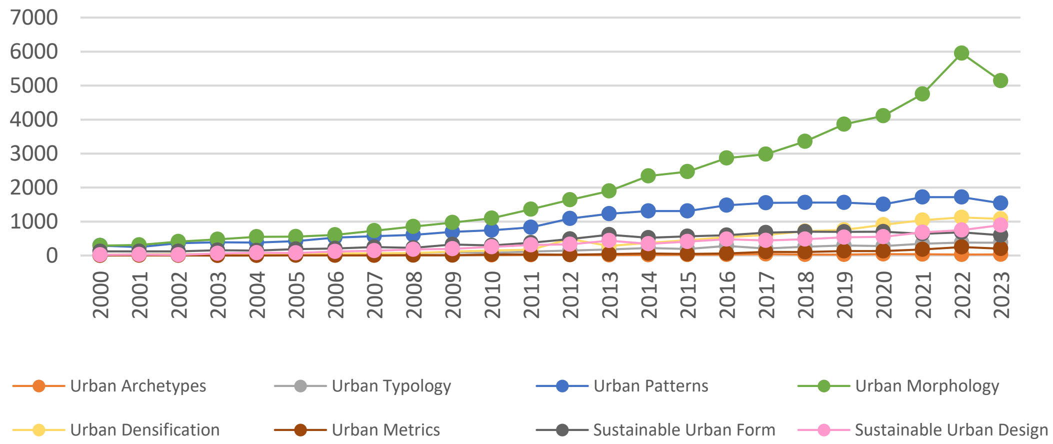

Figure 2. The volume of scientific publications for each key term from the years 2000 to 2023 in Google Scholar.

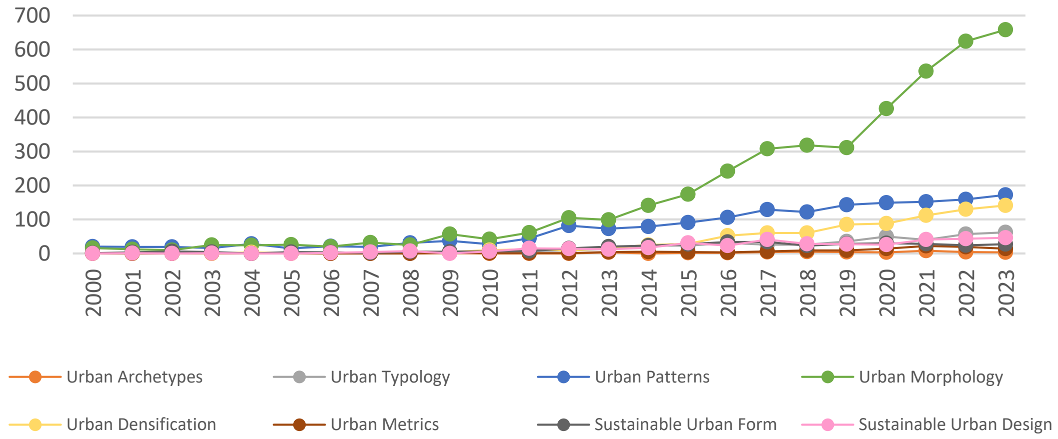

Figure 3. The volume of scientific publications for each key term from the years 2000 to 2023 in ScienceDirect.

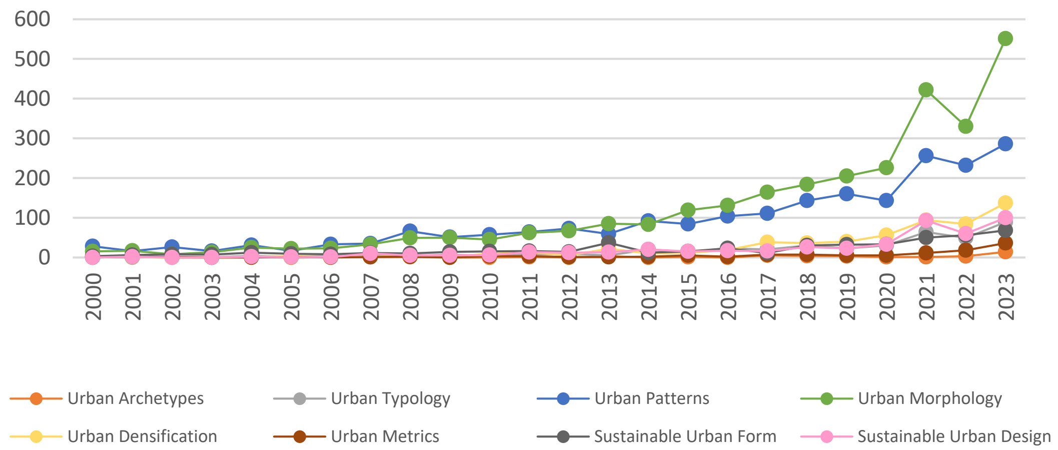

Figure 4. The volume of scientific publications for each key term from the years 2000 to 2023 in SpringerLink.

To refine the literature search, Boolean operators, specifically the 'AND' operator, were employed (See Table 1). Given that 'Sustainable Urban Form' serves as the overarching concept of this study, it was utilised as the primary clause in conjunction with other key terms within the two bibliographic databases. The term 'Urban Form' was excluded from the search, under the assumption that scientific literature addressing sustainable urban form would inherently encompass it within its terminology.

Search query	**ScienceDirect**	**SpringerLink**
Sustainable Urban Form AND Urban Typology	17	34
Sustainable Urban Form AND Urban Patterns	42	111
Sustainable Urban Form AND Urban Morphology	57	125
Sustainable Urban Form AND Urban Densification	18	43
Sustainable Urban Form AND Urban Metrics	3	3
Sustainable Urban Form AND Sustainable Urban Design	22	49

Table 1. The number of scientific publications between the years 2000 and 2023 for specific search queries within the two bibliographic databases.

In total, this resulted in 524 publications, the titles of which were visually assessed for their relevance in connection with the study topic. The publications deemed relevant were further evaluated based on their abstracts. This resulted in multiple themes that became the core structure for the evaluation framework. It should be noted that there were multiple overlaps between the query results, so the number 524 does not represent the amount of unique works.

3.3. Spatial analysis of the typologies

To be able to spatially evaluate the dimensions of sustainable urban form spatial analyses were derived from the literature (See figure 5), especially from Zhang, Ghosh, & Park’s (2023) results of their systematic review to develop a list of measures of urban morphology. Commonly, spatial approaches were presented in the literature, but in some cases a dimension’s metrics were presented as parts of a framework that was more conceptual rather than operational. For these scenarios a suitable method in GIS was chosen based on prior knowledge. It should be noted that some of the analytical approaches that were presented in the literature has been simplified for the scope of this thesis.

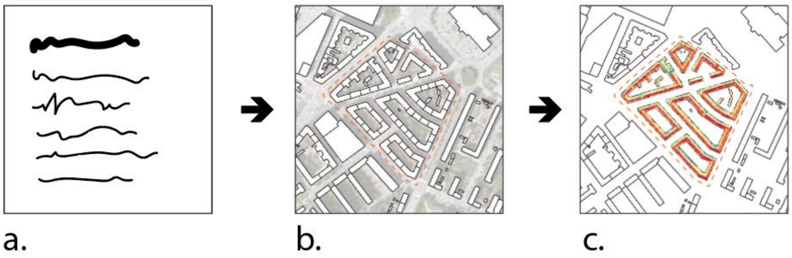

Figure 5. An illustration of the general spatial analytical process where a. represents the first step of finding suitable analyses to use from the literature, b. displays the next step of identyfing the spatial boundaries of the typology used for the chosen spatial analysis, and c. depicts the last step of conducting the analysis with GIS.

Spatial boundaries

In determining the perimeters of the typologies, the plot boundary served as the primary guideline; however, this was supplemented by guidelines from the works of Rådberg & Friberg (1996). These included the following:

- The perimeter is delineated by the grouping of the buildings.
- If the building group is surrounded by streets, the half of the street width is included.
- Building groups with adjacent parks, water bodies, are limited to half the distance of the average distance between buildings within the group. This means that for a building group with a distance of 20 meters in between the footprints a distance of 10 meters will be used around the building connected to the park.

Urban Performance Score

The literature review resulted in a Urban Performance Score which were divided into four ratios (1) *Density and Compactness Ratio*, (2) *Connectivity and Proximity to Public Transport Ratio*, (3) *Mixed Land-Use and Functional Diversity Ratio*, and (4) *Greening and Environmental Performance Ratio*. These ratios where futher sub-divided into metrics that were analysed in ArcGIS Pro.

Density & Compactness ratio

To analyse density and compactness, data were obtained from the National Land Survey Agency (Lantmäteriet) via SLU's Geo Extraction Tool, as well as from Malmö Municipality's own Geodata Portal (see Table 2). In order to calculate the

FSI, the number of floors needed to be known; these values were collected by visiting each typology on 25th November 2023.

Density & Compactness Ratio		
Metrics	**Data**	**Description**
- Floor Space Index (FSI) $FSI_x = \frac{F_x}{A_x}$	**Building Footprints** (Property map Built-up areas © Lantmäteriet, 2023.) **Amount of floors of buildings** (Field Visit 2023-11-25) **Plot area** (Property map Real property classification© Lantmäteriet, 2023; Ortofoto RGB 0.25/0.50 m © Lantmäteriet, 2023)	The Floor Space Index (FSI) was calculated by multiplying the area of the building footprints within the typology by the number of floors in each building, then dividing it by the total area of the plots. This yields a percentage value that indicates how intensively the plot is developed.
-Ground Space Index (GSI) (Ground coverage)		The Ground Space Index (GSI) was calculated by dividing the area of the building footprints by the total plot area. This yields a percentage value that indicates how much of the plot is built, also known as 'compactness'.
-Open Space Ratio (OSR) $OSR_x = \frac{1-GSI_x}{FSI_x}$		The Open Space Ratio (OSR) was calculated by subtracting the GSI from 1 (100%) and then dividing by the FSI. This yields a percentage value that indicates how much open space there is on the plot.
-Gross Floor Area (GFA)		The Gross Floor Area (GFA) was calculated by multiplying the building footprints by the number of floors. This yields a value in square metres (sqm) that indicates the total constructed area. This value is commonly used as a basis for calculations such as the number of parking spots required.
-People/100GFA	**Population Points** (bef_ar_2022_100x100_poi © Malmö stad, 2023)	The People/100GFA was calculated by selecting all population points within the typology and dividing this by the GFA, multiplied by one hundred. This yields a value representing the number of people per 100 GFA, which indicates population density. 100 GFA is the size of an average housing unit, where other functions such as stairwells and storage are accounted for within the value.
-People/km2		The People/km² was calculated by dividing the population of the typology by the area in square kilometres. This yields a value that helps compare the density of the typology with other typologies, and even cities.

Table 2. An overview of the data used for each metric for the Density & Compactness Ratio.

Connectivity & Proximity to Public Transport Ratio

To analyse connectivity, a Space Syntax analysis was performed on the road network obtained from Malmö Municipality (See table 3.). External connectivity was measured by the number of highly connected roads passing through the typology's perimeter, with a higher ratio indicating greater integration with the overall urban fabric (See Appendix 3). These connectivity values were compared between typologies, as no standard matrix for comparison exists. Additionally, the connectivity scores were categorised as Good, Decent, or Bad to simplify the metric for the reader. It is important to note that all types of roads were included in the analysis, based on the assumption that pedestrians and cyclists can traverse any road. As most typologies are located in denser urban areas, the margin of error was kept minimal.

Connectivity & Proximity to Public Transport Ratio		
Metrics	**Data**	**Description**
-External connectivity (Space Syntax)	**Roads** (Roads and Railroads © Malmö stad, 2024) **Plot area** (Property map Real property classification© Lantmäteriet, 2023; Ortofoto RGB 0.25/0.50 m © Lantmäteriet, 2023)	External connectivity was derived through a Space Syntax analysis of the entire city of Malmö. The road network was used to create points at every road intersection, which were then spatially joined to the corresponding roads. This resulted in a road network with information on the number of connections each road has.
-Amount of internal connections		The number of internal connections was determined by creating points at each road intersection and then selecting those within the perimeter of the typology.
-Proximity to transit-hub	**Transit-hubs** (Malmö Linjekarta © Skånetrafiken, 2024)	To determine the proximity to the nearest transit hub, a multiple ring buffer analysis with 50-metre increments was conducted from the typology's perimeter. The closest transit hub was then identified through a simple overlay. Note that the transit hubs were digitised based on Malmö's local transit map.

Table 3. An overview of the data used for each metric for the Connectivity & Proximity to Public Transport Ratio.

Mixed Land-Use and Functional Diversity Ratio

The initial plan was to measure all four metrics, but due to time constraints, only the number of Points of Interest (POIs) and the distance to the city centre were measured (See table 4.). The POIs were obtained from open-source data on OpenStreetMap. This data is publicly mapped and can sometimes be outdated, but since no other local data was available from authorities, it was used. Points of Interest can be quite subjective; therefore, the entire dataset was used to account for as many different interests as possible. For comparison within the neighbourhoods, POIs for both the typology and the neighbourhood were extracted.

Mixed Land-Use and Functional Diversity Ratio		
Metrics	**Data**	**Description**
-Amount of POI	**Points of Interest** (gis_osm_pois, Sweden © Open Street Map, 2024.) **Plot area** (Property map Real property classification© Lantmäteriet, 2023; Ortofoto RGB 0.25/0.50 m © Lantmäteriet, 2023)	The amount of Point of Interests (POIs) where extracted by overlaying the typologies with the data layer of the POIs. Examples of POIs in the data: *artwork, ATM, bakery, bank, bar, beauty shop, bench, bicycle shop, bookshop, butcher, café, car dealership, cinema, clinic, college, community centre, convenience store, dog park, fountain, hairdresser, kindergarten, museum, playground, police station, post box, restaurant, school, sports centre, supermarket, toilet* etc.
~~-% of commercial area of total land area~~	-	-
-Distance to city centre	**Central Station** (gis_osm_transport © Open Street Map, 2024.)	To determine the proximity to the city centre, a multiple ring buffer analysis with 50-metre increments was conducted from the city centre. Then the distances to each typology was identified through a simple overlay of the ring buffer layer.
~~-Diversity of Urban interfaces~~	-	-

Table 4. An overview of the data used for each metric for Mixed Land-Use and Functional Diversity Ratio.

Greening and Environmental Performance Ratio

A total of 6 out of 7 metrics were analysed to calculate the Greening and Environmental Performance Ratio (see Table 5). To extract vegetation, or in this case green spaces within the typologies, a Normalized Difference Vegetation Index (NDVI) was created using the formula (NIR - R) / (NIR + R), with bands from an infrared orthophoto. The wavelengths in the NDVI were then extracted with the aid of an RGB orthophoto (see Figure 6).

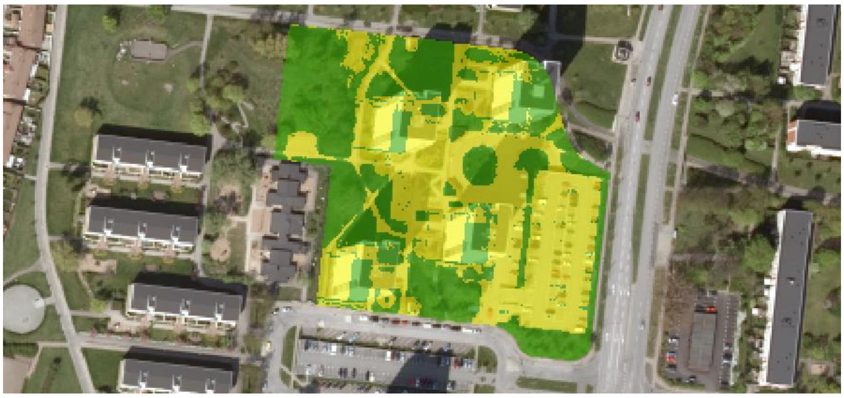

Figure 6. Image showing the classification of the NDVI with the help of the orthophoto (green=vegetation, yellow=hardscape).

Greening and Environmental Performance Ratio		
Metrics	**Data**	**Description**
-% of Green Space of Total Area	**NDVI** (Ortofoto IRF 0.25/0.50 m © Lantmäteriet, 2024) **Plot area** (Property map Real property classification© Lantmäteriet, 2023; Ortofoto RGB 0.25/0.50 m © Lantmäteriet, 2023)	To calculate the percentage of Green Space in relation to the total plot area, an NDVI (Normalized Difference Vegetation Index) data layer was created using the infrared bands of an orthophoto. Values representing vegetation were extracted from the NDVI, and the areas of the corresponding cells were summarised to determine the total area of vegetation. This total vegetation area was then divided by the total plot area.
-Green Space Density (m2/person)	**NDVI** (IRF 0.25/0.50 m © Lantmäteriet, 2024) **Population Points** (bef_ar_2022_100x100_poi © Malmö stad, 2023)	To calculate the green space density, the total amount of green space was divided by the number of people living within the typology's perimeter.
-% Canopy cover of Total area	**Canopy cover** (Tree Canopy cover © Malmö stad, 2022) **Plot area** (Property map Real property classification© Lantmäteriet, 2023; Ortofoto RGB 0.25/0.50 m © Lantmäteriet, 2023)	The canopy cover was imported as a pre-existing data layer and then divided by the total plot area.
-Proximity to parks (300m)	**Parks** (Parks and squares © Malmö Stad, 2024)	A 300-metre buffer was created around each typology and then overlaid with the park dataset from Malmö Municipality.
-% Solar Energy potential of total roof area	**Digital Surface Model** (Ytmodell 0.5 m, laz © Lantmäteriet, 2022) **Building Footprints** (Property map Built-up areas © Lantmäteriet, 2023.)	To calculate the percentage of Solar Energy potential, a Digital Surface Model (DSM) and building footprints were used. The footprints served as a mask to isolate the roofs from the DSM. The Area Solar Radiation tool in ArcGIS was then used to calculate the solar energy potential in kWh/m². Roof cells with a slope greater than 45 degrees, those sloping north, and cells with a radiation value below 800 kWh/m² were excluded from the analysis due to being not suitable.
-% of Visible Sky	**Digital Surface Model** (Ytmodell 0.5 m, laz © Lantmäteriet, 2022)	The percent of visible sky was calculated by placing a point in an open space of each typology and then running the Skyline toolset in ArcGIS. The origin point was always placed in a yard so the primary buildings of the typology affected the results and not the infrastructure e.g. parking lots.
~~-Wind Exposition Index~~	-	-

Table 5. An overview of the data used for each metric for the Greening and Environmental Performance Rati.

3.4. Method review and critique

The synthesis of the scoping literature review combines multiple dimensions to highlight the relationship between them. An important point to make is that this type of framing has excluded some dimensions that plays an important role of a sustainable urban form, such as socio-economic factors and employment density, eco-system services, water resource management, waste management, and others. Due to the complexity of trying to evaluate urban forms as sustainable these delimitations were made. Further, not all metrics were possible to be found, multiple were excluded due to time constraints. Analysing these metrics would yield a much richer data set, possibly adding more complexity to the results.

4. Framing urbanity and its form

This chapter frames the composition of the urban environment. What counts as urban as well breaks down the urban landscape into smaller building blocks.

4.1. What counts as 'urban'?

The consensus on what constitutes an urban environment is broadly established, yet the notion of 'urban' can still carry a degree of ambiguity and feel elusive. Perceptions of an urban environment vary globally, often influenced by local experiences and cultural interpretations. Typically, population density is a key determinant of urban status (UN, 2018; OECD, 2018, Eurostat, 2021). However, other prevalent factors shaping our perception of an urban environment include the scale and repetition of the built landscape. The sense of an urban landscape is amplified by tall buildings situated in close proximity, alongside a noticeable repetition of the fabric that fosters a seemingly endless built environment (Gehl, 2010). Moreover, the local context plays a crucial role in shaping one's perception of what counts as 'urban', as it provides a benchmark for individual interpretations.

By quantitative measures, urban areas in Sweden are defined as continuous built-up areas with at least 200 inhabitants (SCB, 2024). The distance between houses cannot exceed 150 metres, though the full extent of the area may include houses that are up to 500 metres apart once the initial criteria have been met (SCB, 2022). This implies that if you multiply these values, the minimum density for classification as an urban area would be 30 inhabitants per km^2. If one compares such a value to other type of classification standards the definition of 'urban areas' would vary. For example, by EU-metrics, areas with fewer than 50 inhabitants per km^2 are classified as low-density rural areas (Eurostat, 2021). So, it becomes a metric of locality, countries like Sweden with a small population size with a large land area will have their own local definition of 'urban'.

4.2. Urban morphology

The city and its urban fabric represent formations that have developed and evolved over many centuries into their present form. In older cities, remnants of the past are readily identifiable, not only as ruins but also as fully functional structures. These tend to embody an architectural language distinct from that of our contemporary buildings and infrastructure. A prime example of structures that have endured through time, albeit with less evolution, is often religious constructions in the landscape, such as churches, squares, trading routes etc. These serve as valuable reference points for aligning historical plans with our contemporary structures, thereby facilitating the tracing of structural heritage.

The term commonly used to describe the evolution of a city is 'Urban Morphology,' which is defined as "*..the study of human settlements, their structure and the process of their formation and transformation*" (Kropf, 2017, p. 9). Scheer (2010) identifies five essential layers that contribute to understanding a city's morphology, listed in ascending order: (1) *Site*, (2) *Superstructure*, (3) *Infill*, (4) *Buildings*, and (5) *Objects*. These layers are framed within a spatio-temporal hierarchy, ranging from natural land formations to finely crafted human interventions.

The first layer is 'Site,' encompassing land masses, water bodies, and vegetation (Scheer, 2010). These elements may exist naturally or can be human-made for development purposes. Following the Site layer is the 'Superstructure' layer, which includes administrative borders and pathways that predate urbanization but may evolve during the redevelopment of existing urban structures during significant interventions in the physical environment. Once Superstructures are defined, the 'Infill' layer comes into play, consisting of local-scale pathways and borders with higher detail. At this level, smaller plots begin to take shape and are defined. 'Buildings' constitute a distinct layer, which also encompasses human-made structures like large bridges defined by connecting pathways from the previous layers. These structures often endure longer than the buildings in a city. The final layer is 'Objects,' which includes planted vegetation such as shrubs, lawns, and trees, as well as monuments and other smaller artificial constructions, ranging from fences to underground structures.

Scheer (2010) not only describes the hierarchy of these layers as a chronological sequence of development but also as a spatio-temporal relationship that signifies the time it takes for each layer to change relative to the others, as well as its susceptibility to change. Additionally, this hierarchy dictates the impact each layer has on the layers beneath it. For example, if a river (part of the Site layer) serves as a vital transport link and exceeds its capacity, the solution might involve widening the river to accommodate the influx of traffic. Any intervention in the Site layer would trigger a cascading effect felt all the way down to the Objects layer, resulting in changes such as the widening encroaching upon planted vegetation. It's important to note that this assumption holds when all layers contain objects at the specific site in question. But how do these layers and their spatio-temporal aspects further contribute to our understanding of a city's morphology?

4.3. The Urban Fabric

By studying the Infill-layer of a city, one could distinguish patterns of various connective structures (Scheer, 2010). These patterns are called *Urban tissues*, similar to patterns in a regular piece of cloth these make up the urban fabric of a city (Kropf, 2017). Scheer (2010) describes these tissues as compounds of plots and buildings that have emerged and later defined by various infrastructure. The three most common and largest tissues are as follows: (1) *Static tissue*, (2) *Elastic tissue*, and (3) *Campus tissue*. These tissues are by all certainty the ones that can be found in every city.

Static tissue

This tissue is often planned around a specific type of building, in addition, the lot structures tend to be similar in size and are quite often arranged in a grid (Scheer, 2010). Static tissues are usually planned in one go that extends over approx. a 10-year period. It tends to be difficult to make major interventions in a static tissue as they usually consist of residential or mixed used areas, of either multi-storied housing or rows of terraced houses. Which in turn means that an intervention would affect multiple property owners, due to the smaller sizes lots tend to have within this tissue.

Elastic tissue

In contrast to the static tissue the elastic tissue can look quite unplanned. The plots are irregular and the building footprints usually don’t follow the formation of the neighbouring plots and tissues (Scheer, 2010). These elastic tissues often grow along major roads, so they are accessed more easily. Typical functions within this tissue are factories, offices. commercial construction. It is relatively easy to intervene in this tissue, as it usually has land and space to spare, and that it usually has one or more business that are dependent on the market. If a business goes bankrupt/moves, the space may be used by another business or fil another purpose. Elastic tissues usually have fewer but larger lots which makes interventions easier, due to fewer property owners that it may affect.

Campus tissue

The campus tissue can be thought of as an island, as there are usually better connections linking the area internally than externally. Several different buildings are usually also found on the same plot, typical examples of this are schools, hospitals and alike. They are also planned as one larger unit, perhaps even more planned than static tissues due to the internal road systems (Scheer, 2010). Campus tissues are usually easy to intervene in, as they tend to have fewer owners who own the plot.

4.4. Urban Form plays a role in Urban Design

Urban form is shaped by the natural environment and human responses to specific local conditions (Kropf, 2017). It is a transformation of nature to meet human needs and patterns of behaviour, fitting into societal expectations and urban ideals. As part of a complex adaptive system, urban form must evolve to successfully address current demands, guided by specific processes and agents.

Since the late 1980s, the urban form debate has highlighted planning's central role in sustainable development, with urban compaction becoming increasingly preferred over more expansive decentralised(poly-centric) strategies, now considered outdated due to environmental sustainability concerns (Breheny, 2003). Bertaud (2017) brings forth that both polycentric and monocentric cities draw people from across the city to jobs, albeit with different travel patterns. Polycentric cities feature sub-centres that attract journeys from the entire built-up area, resulting in a broad dispersion of journey origins and destinations, often appearing random. These journeys are generally longer than those in monocentric cities, due to the sub-centres not being self-sufficient. However, shorter journeys to potential destinations typically increase land value. Another observable effect of the poly-centric model is the increased consumption of non-urban land during urban growth (Pili, Grigoriadis, Carlucci, Clemente, & Salvati, 2017). An important note to make, is that no city is purely, mono-centric or poly-centric, centrist nor decentralised. Bertaud (2017) express that most mono-centric cities become poly-centric after the labour market growths to a specific size, likewise can be said for the opposite, when the labour market shrinks. He also highlights that the dichotomy of these models is just the age of the city when observed. So it is important to approach the city as a living organism and then see what type of morphological addition can be made to its urban system.

In addressing urban sprawl, Bueno-Suárez & Coq-Huelvat (2020) explore the adoption of greenbelts and urban containment policies as key strategies. They elucidate that greenbelts, designed to set physical boundaries to urban expansion by prohibiting construction in designated areas, aim to preserve the agricultural landscape and natural ecosystems surrounding urban centres. This concept, evolving since its inception in the 1950s, has seen varied applications across Europe and North America, from green corridors to peri-urban parks. Despite their potential in shaping social preferences and possibly inflating urban housing prices, greenbelts alone have struggled to curb the migration to suburban peripheries, a phenomenon notably observed in Greater London. However, in Germany, greenbelts, coupled with policies promoting compact urban morphologies, have demonstrated more success in containing urban sprawl, with about 60% of regions implementing such measures. This indicates the nuanced effectiveness of greenbelts and urban containment strategies in managing urban growth and highlights the importance of adapting these approaches to specific geographical and socio-economic contexts (Bueno-Suárez & Coq-Huelvat, 2020).

Jabareen (2006) discusses urban containment as a strategic approach aimed at curbing urban sprawl and directing growth towards existing urban centres. This model is characterized by the implementation of urban growth boundaries, incentives for densification, and the preservation of open spaces such as greenbelts. Urban containment policies are designed to promote efficient land use, protect natural and agricultural lands from development, and support sustainable urban expansion by encouraging higher density developments within defined urban areas.

Jenks, Williams & Burton (2006) advocate for a supportive policy framework that aligns with global sustainability objectives while allowing for the formulation and implementation of localized solutions. They present the pursuit of sustainable urban forms as a dynamic and ongoing process, requiring continuous research and collaborative efforts to address the complex challenges of urban sustainability. Through their work, they contribute to the broader dialogue on sustainable urban development, offering insights into how urban planning and policy can be leveraged to create more sustainable, livable urban environments.

5. Towards a Sustainable Urban Form

This chapter approaches the complexity of sustainable urban form by presenting views on sustainability in planning practice, then it presents planning models framed to promote sustainability, such as the compact city, and the eco-city. Later, the principles of densification are presented in relation to achieving a sustainable urban form.

5.1. Sustainability in Swedish planning practice

In Swedish planning practice, municipalities bear the responsibility for planning and managing the physical environment and resources within their boundaries (Boverket, 2023a). According to Swedish law, all municipalities must engage in continuous comprehensive planning and possess a comprehensive plan that guides future development. This plays a pivotal role in the efforts towards achieving a more sustainable society (Boverket, 2023b).

When looking at how planners develop these plans of various scales a trend emerges that speaks for a contemporary planning paradigm, with densification as a core denominator (Boverket, 2016; Malmö stad, 2018). This is further enhanced by planning guidelines and documents from the National Board of Housing, Building and Planning, which address densification as a core development strategy to achieve the Swedish environmental goal of *Good Built Environment* (Boverket, 2016).

In a study that investigated the integration of urban densification and ecosystem services in comprehensive plans for Malmö, Lund, and Helsingborg, several critical challenges were identified (Lisberg Jensen, Alkan Olsson, & Malmqvist 2023). The study revealed that despite the ambitious formulation of comprehensive plans concerning sustainability, there exists a notable struggle in addressing the scale of ecosystem services, clarifying long-term sustainability timeframes, and resolving priority conflicts between densification and the preservation of ecosystem services. Lisberg et al. (2023) explain that these findings underscore the complexities in achieving sustainable urban development, highlighting the recurrent issue of systemic contradictions where plans optimistically propose that urban growth, sustainability, and enhanced ecosystem services can be simultaneously achieved without adequately addressing potential trade-offs. On a strategic planning level this calls for a more explicit prioritisation process in urban planning to effectively balance densification with the holistic integration of not only ecosystem services, but other as well.

5.2. What makes an urban form sustainable?

Bibri and Krogstie (2019) highlight the enduring challenge and intellectual pursuit of crafting an ideal sustainable urban form, a goal that has galvanised collaboration among scholars, practitioners, and policymakers for over three decades. The quest for sustainable development has prompted diverse approaches, with various scholars proposing unique combinations of design and planning concepts to enhance sustainability. Despite the differences in these sustainable urban forms, the potential for integrating their unique attributes into a cohesive model is both promising and strategically beneficial, offering a path towards enhancing sustainability outcomes.

In Western nations, the compact city model is widely regarded as a blueprint for sustainable urban development, combining high-density living, mixed-use areas, and efficient transport systems to foster social and economic viability (Jenks, 2009; Jabareen, 2006; Bibri, Krogstie & Kärrholm, 2020). According to Jabareen (2006) the paradigm of sustainable urban form is delineated by these aspects. Such approach is celebrated for its potential to address environmental, social, and economic sustainability—the triple bottom line of sustainable development. By advocating for strategic urban planning that focuses on density, diversity, and accessibility, the model aims to minimize urban development's ecological footprint. Key features include high-density residential and commercial areas, the revitalisation of underutilised urban spaces, and the promotion of robust public transportation networks. Ultimately, the compact city seeks to diminish land consumption, boost energy efficiency, and reduce dependence on private vehicles, presenting a holistic framework for sustainable urban living.

The compact city is not the only sustainable urban form that literature tend to present, other concepts exists such as eco-city, transit-oriented development etc. (Abdullahi & Pradhan, 2017). For example, neotraditional development, inspired by New Urbanism, promotes a return to the integrated, pedestrian-friendly communities reminiscent of pre-modern urban design (Jabareen, 2006). This approach also emphasizes mixed-use developments, diversity in housing to cater to various demographics, and the creation of communal spaces designed to foster social interactions. On a similar note, the eco-city as an urban form is designed to achieve ecological balance through the integration of sustainable practices and green infrastructure into the urban environment (Jabareen, 2006). This model emphasizes the incorporation of natural elements within the cityscape, the implementation of sustainable water, waste, and energy management systems, and the active participation of local communities in environmental stewardship.

The distinction between compact city models, characterized by their defined planning and design tools, and the more fluid, undefined forms of eco-cities underscores the complexity and potential of synthesising these approaches into a unified model that could propel sustainable development forward (Bibri & Krogstie, 2019). Yet, the quest for a convincing model of sustainable urban form remains unfulfilled, with the components of such a form still not entirely delineated. Jabareen's (2006) suggests that urban forms that have attributes that contribute to sustainability, specifically the Compact City and Eco-City are more aligned with the multidimensional criteria of sustainability. This implies that no single urban form is universally the most sustainable in every context, but the Compact City model, in particular, shows significant promise for contributing to sustainability objectives.

On another note, Jenks et al. (2006) argue that the quest for sustainable urban development transcends the simplistic binary of compact versus dispersed urban forms. They highlight the imperative for sustainable development in response to the ecological challenges of global warming, energy consumption, and the exploitation of non-renewable resources, positioning cities as both contributors to and potential solvers of these challenges. Similarly, Bibri and Krogstie (2019) advocate that sustainable urban development requires not only a richer understanding of planning practices but also an appreciation of the nuanced processes of change necessary to realise sustainable urban forms. This demands the exploration of multiple pathways towards sustainability and a comprehensive grasp of the interplay between social and technical solutions in shaping sustainable urban environments.

5.3. The paradoxes associated with urban densification

Urban densification is a critical component of sustainable urban development, intricately balancing the benefits of compact living with the challenges it introduces. Berg et al. (2012) and Jenks et al. (2006) highlight densification's role in promoting sustainable urban forms, enhancing public infrastructure, and fostering economic growth through improved productivity and innovation. However, this process often pressures green spaces, leading to a reduction in residents' contact with nature, poorer air quality, and necessitating travel for recreational and cultural activities. Haaland & van den Bosch (2015) address the tension between densification and the preservation of urban greenery, emphasizing the need for strategic solutions to integrate green spaces within densely populated areas effectively.

The narrative around densification reveals its double-edged sword; while it can generate a vibrant, community-focused urban environment, it may also result in stress and perceptions of overcrowding (Berg et al., 2012; Williams, Burton & Jenks, 2006; Jabareen, 2006). Neuman (2005) and Bibri et al. (2020) delve into the paradoxes of the compact city model, arguing that high-density living can simultaneously offer suburban qualities and confront challenges such as noise pollution, social exclusion, and increased crime rates. They suggest that the negative aspects often associated with densification, like reduced living space for lower-income groups and restricted access to green spaces, may be more indicative of broader urban area characteristics rather than the urban form itself.

Berghauser Pont et al. (2021) contribute to the discourse with a systematic review that underscores the multifaceted impacts of densification, from enhancing public transport usage to fostering economic indicators like property values. Yet, they also note the environmental and social challenges, including biodiversity loss, the urban heat island effect, and mixed outcomes on community wellbeing and health.

Lozano (1990) advocates for a diversity of urban density options to cater to the varied preferences and needs of the population, emphasizing that optimal density should balance community interaction with personal privacy. This approach is illustrated through examples like London's Regent Street and the Mews, which demonstrate the feasibility of achieving desirable urban density without succumbing to the negatives of overcrowding.

The discourse on urban densification is complex, requiring a nuanced understanding of its benefits and drawbacks. In essence it’s important to prioritise both the economic and environmental sustainability of urban areas while ensuring social equity and access to green spaces. Similarly, Hernandez-Palacio (2014) underscores that the efficacy of densification and the compact city model as sustainable solutions in urban policy is nuanced. These strategies are contingent upon a broader set of factors beyond mere density, requiring integration with other urban sustainability measures like green mobility and access to services.

6. Analytical framework for evaluating urban typologies

This chapter presents the results of the scoping literature review by framing the most commonly occurring dimensions of sustainable urban form into four themes (See table 6), as well as presenting the spatial analytical approach to measure them. The dimensions are as followed (1) *Density and Compactness*, (2) *Connectivity and Proximity to Public Transport*, (3) *Mixed Land-Use and Functional Diversity*, and (4) *Greening and Environmental Performance*.

Density & Compactness	Connectivity & Proximity to Public Transport	Mixed Land-Use and Functional Diversity	Greening and Environmental Performance	
Density -Bramley & Power (2009) -Berg et al. (2012) -Berghauser Pont & Marcus (2014) -Bibri et al. (2020) -Bibri (2022) -Wang & Shaw (2018) -Wheeler (2000) **Compactness** -Bibri et al. (2020) -Bibri (2022) -Jabareen (2006) -Jenks (2000) -Zhu (2012) -Wang (2022) -Wheeler (2000)	**Connectivity** -Bibri et al. (2020) -Bibri (2022) -Jabareen (2006) -Næs & Vogel (2012) -Mahzouni (2018) -Salingaros (2014) -Ståhle (2005) -Scoppa et al. (2018) -Soufiane et al. (2015) **Proximity & travel time, & accessibility** -Creutzig (2014) -Ji et al. (2022) -Gurram et al. (2019) -Alawadi et al. (2022) -Bertolini et al. (2005) -Susilo et al. (2012) -Moyano et al. (2023)	**Mixed Land-Use** -Bibri et al. (2020) -Bibri (2022) -Jabareen (2006) -Salvate & Ricciardo Lamonica (2022) **Diversity** -Bibri et al. (2020) -Bibri (2022) -Jabareen (2006) -Dovey & Wood (2015) -Salingaros (2014) -Zhang et al. (2023)	**Green space & Ecosystem services** -Artmann (2016) -Artmann et al. (2019) -Bibri et al (2020) -Bibri (2022) -Blanco et al. (2022) -Delshammar (2014) -Ghosh (2023) -Haaland & van den Bosch, (2015) -Jabareen (2006) -Jansson (2014) -Puchol-Salort et al.(2021) -Strandell & Hall (2015) -Ståhle (2005) -Wellmann et al. (2020) **Micro-climate & resilience** -Budhiraja et al. (2020) -Cochran & Brunsell (2018) -Gaitani et al. (2014) -O'Regan & Nyhan (2023) -Pan (2021) -Trepci et al.(2021) -Xie et al. (2023)	**Urban Ventilation** -Cheshmehzangi & Butters (2016) -Deng & Wong (2020) -Juan et al. (2023) -Middel et al. (2014) -Silva & Monteiro (2016) **Daylight, Solar Energy potential & Energy efficiency** -Chokhachian et al. (2020) -Dawodu & Cheshmehzangi (2017) -Dekay (2010) -Jabareen (2006) -Li et al. (2022) -Mirzabeigi & Razkenari (2022) -Quan and Li (2021) -Vartholomaios (2017) -Xia & Li (2023)

Table 6. A synthesis of the literature review into four themes with notable dimensions in each theme. Notably plenty of literature overlap into other themes, here they've been categories by their most prominent dimension(s).

6.1. Density and Compactness

It is imperative to distinguish between density and compactness as two distinct dimensions within the context of urban planning. Bramley & Power (2009) and Bibri et al. (2020) underscore the vital role of density in cultivating sustainable urban environments, delineating it as a fundamental aspect in the conceptualisation of the 'compact city' model. Defined as **the ratio of dwellings or population to land area**, density encapsulates an array of urban characteristics and is indispensable for the vitality of urban landscapes (Berghauser Pont & Marcus, 2014). It mirrors the complex relationship between the quantity of habitable space or dwelling units within a specified area and the overarching quality and functionality of urban form.

Transitioning from a focus on room density to dwelling unit density has marked a significant evolution in urban studies, recognising the latter as a more representative measure of urban density. This evolution highlights the necessity of not merely quantifying density but understanding its ramifications on urban living and planning. According to Bramley & Power (2009), and supported by Berg, Granvik, & Hedfors (2012), a viable threshold of density is vital, indicating specific levels at which population density bolsters urban functions and interactions.

Furthermore, Jabareen (2006), Wheeler (2000) and Bibri et al. (2020) emphasise compactness as crucial to achieving sustainable urban environments, advocating for continuity and connectivity in urban areas. This strategy, promoting developments adjacent to existing structures to curb urban sprawl and optimise land use through intensification, aligns with key objectives such as rural conservation, life quality enhancement, energy consumption reduction, and greenhouse gas emission mitigation. Compactness can be defined as the **intensity of built structures of an area**.

Zhu (2012) delves into the compact configurations of urban typologies within high-density nations, distinguishing between the high-plot-ratio with low-site-coverage (HPR–LSC) and the low-plot-ratio with high-site-coverage (LPR–HSC) models. The research indicates a preference for the HPR–LSC model as a means to cultivate sustainable urban forms, while also recognising the significant role that the land rights framework plays in the selection of these models. Through a detailed case study in Vietnam, Zhu highlights the negative consequences associated with the LPR–HSC model, such as inefficient land use and excessive consumption of environmental resources. Wang & Shaw (2018) further contribute to the discourse by examining the ramifications of high-density development, which include issues such as overcrowding, a decline in environmental quality, the loss of public amenities, and a deterioration in service provision. These factors collectively undermine social cohesion and the sense of community. Additionally, the phenomenon of high-density-small-scale (HDSS) neighbourhood development, characterised by an increased **Floor Area Ratio** (FAR) on smaller sites, has precipitated social challenges within Chinese cities. This underscores an urgent need for a shift towards more socially sustainable practices in neighbourhood planning, emphasising the complex interplay between urban form, social wellbeing, and sustainability in high-density settings.

Berghauser Pont & Marcus (2014) proposes a multi-variable approach for measuring urban density, incorporating **Floor Space Index** (FSI), **Ground Space Index** (GSI), **Open Space Ratio** (OSR), and **building height** (L). This methodology captures urban space complexity through a combined analysis of these variables, illustrating that singular density metrics inadequately represent urban form's multifaceted nature.

6.2. Connectivity and Proximity to Public Transport

Bibri et al. (2020) underscore the critical role of sustainable transportation practices in shaping sustainable urban forms. These practices extend beyond merely enhancing public transport and encouraging non-motorized modes of transport, such as cycling and walking, to include a holistic integration of environmental, social, and economic factors into urban planning strategies. The adoption of such practices yields significant benefits, including improved transport efficiency, decreased emissions, and enhanced community well-being. Similarly, Næs & Vogel (2012) and Mahzouni (2018) call for a transformative approach towards sustainable urban development, highlighting the urgency of re-evaluating the expansion of mobility and building stock to mitigate environmental impacts. This shift necessitates a critical examination of the dominant economic and consumerist paradigms to cultivate a more sustainable urban landscape.

Ji, Li, Makvandi, & Zhou (2022) note that factors such as travel time, distance, household income, comfort preferences, car ownership, and perceived congestion levels significantly influence individuals' transport mode decisions. Mahzouni (2018) further illustrates this concept through the Vauban district, a notable example of successful transition towards a car-free environment. This transition has been facilitated by substantial investments in sustainable mobility, complemented by regulatory incentives that include restrictions on the construction of parking spaces within new residential developments, limitations on vehicular access to residential zones, and a legal mandate requiring residents to annually report their car ownership status. Remarkably, this approach has led to approximately 40% of

Vauban households forgoing car ownership, exemplifying a community-wide commitment to sustainable living. This reduction in car ownership not only demonstrates a significant shift in lifestyle but also results in a more efficient use of land, minimising the allocation of space to parking and thereby supporting more sustainable land use practices.

Creutzig (2014) suggests that fuel prices have a significant influence on urban structure, including the size of cities, their form, and the distribution of transport modes among residents, by facilitating reduced CO2 emissions through shorter commuting distances and the promotion of public transit. This effect is particularly pronounced at lower fuel prices, which decrease operational costs for public transport providers, thereby making public transportation a more viable option. Furthermore, Ji, Li, Makvandi, & Zhou (2022) reinforce the environmental benefits of opting for public transportation, identifying it as the mode of transport with the lowest per capita carbon emissions, significantly less than those emitted by private vehicles. This underscores the critical impact of selecting sustainable transportation options on reducing transport-related emissions, illustrating a direct correlation between fuel pricing, urban planning, and the environmental sustainability of transportation choices.

Bertolini, Le Clercq, & Kapoen (2005) discovered that focusing on consolidating around existing centres and developing public transport corridors with high cost-benefit ratios is most feasible. **Areas near urban centres enjoy better public transport accessibility**, yet it is significantly lower compared to car accessibility, potentially making less accessible areas less attractive and leading to longer commutes. Susilo, Williams, Lindsay & Dair (2012) found that car ownership reduces the frequency of public transport use, walking, and cycling, but good connectivity encourages more sustainable travel choices. Similarly, Scoppa, Bawazier, & Alwadi (2018) observed that **introducing small pathways through large superblocks improves walkability**, underscoring the importance of high connectivity in the urban fabric.

Salingaros (2014) articulates the importance of integrating diverse pathways and green spaces within urban design, highlighting that although such integration incurs costs, the societal expense of neglecting these elements is considerably greater. He further explains that **cities benefit from having redundant connections in their networks**, enhancing their resilience and functionality even when some connections are compromised, akin to the adaptive nature of the human brain. In the context of the COVID-19 pandemic, Alawadi, Khanal, Mouselly, & Aletaywi (2022) underscore the renewed appreciation for walkable neighbourhoods and readily accessible outdoor spaces, which have spurred a preference for suburban living.

Ståhle (2005) explores the concept of spatial integration within Space Syntax analysis, highlighting its significance in measuring a room's connectivity to others in a system. This method illuminates the spatial structure's role in influencing pedestrian flow, publicness, and navigability in urban environments. **Well-integrated spaces, as opposed to segregated ones, tend to enhance city movement**, improving visibility and ease of location by focusing on the relational aspects of spatial arrangements.

Building on this, Soufiane, Said, & Atef (2015) employ Space Syntax Analysis to examine the impact of urban layouts on movement and social interaction, emphasising the role of visual connectivity in urban behaviour. The analysis suggests that **fewer visual steps in a path can increase the likelihood of direct line of sight**, thereby facilitating easier navigation.

Lima, Brown, & Duarte (2022) compare different urban layouts, noting that regular orthogonal typologies may hinder the creation of walkable urban fabrics due to their focus on physical distance. In contrast, orthogonal grids, while performing better in topological metrics (e.g. Space Syntax), seem more suited to car-oriented cities, whereas non-orthogonal grids offer advantages for promoting walkability.

Furthermore, a study by Moyano, Solís, Díaz-Burgos, Rodrigo, & Coronado (2023) on the catchment areas of commuter rail stations in metropolitan Madrid emphasizes the need for policymakers to classify station catchment typologies. This classification aids in formulating sustainable mobility strategies, ranging from improving public spaces to encourage walking and cycling, to embarking on re-densification projects near stations, underscoring the interconnectedness of urban planning, mobility, and sustainable development strategies.

6.3. Mixed Land-Use and Functional Diversity

Salvate & Ricciardo Lamonica (2022) underscore the necessity of an in-depth local context analysis in urban strategies, which critically examine the evolving relationship between urban form and function. This scrutiny is essential for fostering sustainable metropolitan development that advocates for land conservation, equity, and spatial cohesion. Such strategies require quantifying the genuine costs and benefits of development projects to precisely evaluate the viability of transforming brownfield sites versus new greenfield developments.

Bibri et al. (2020) delve into sustainable urban planning through the lens of land-use, underlining its paramount role in distributing various urban functions and activities across the urban fabric. This includes a **diverse mix of residential, commercial, institutional, and cultural infrastructures**, essential for a vibrant urban life. They advocate for a land-use mix that signifies diversity and proximity of compatible uses, thereby enhancing the functionality and sustainability of urban environments. This approach aligns with Jabareen's (2006) advocacy for mixed land-use to achieve sustainable urban forms, by integrating residential, commercial, and industrial uses within close proximity to diminish travel needs and dependence on cars, thereby revitalising urban areas and enhancing public safety.

Referencing Jane Jacobs (1961), Jabareen (2006) highlights the importance of **activity diversity** in urban sustainability, integral to planning ideologies like new urbanism and smart growth. This diversity fosters vibrant urban areas that encourage walking and reduce automobile reliance for daily needs. Furthermore, Salingaros (2014) notes the importance of placing **contrasting urban nodes in proximity** to create vibrant urban webs, unlike dysfunctional cities that concentrate similar nodes together, failing to create a dynamic and interconnected urban fabric.

Dovey & Wood (2015) explore urban interfaces' dynamic role in linking private plots to public networks, crucial for the transition and interaction between public and private spaces. They emphasize the urban interface's importance in facilitating social exchanges and identity construction. Similarly, Zhang, Ghosh & Park (2023) discuss the **diversity of Points of Interest** (POIs) and its relation to mixed land use within sustainable urban forms. Dovey & Wood (2015) further categorise urban interfaces based on their materiality and legal boundaries, identifying variables that influence pedestrian access and the activity across the boundary, highlighting the interface's role in promoting or hindering pedestrian flow and its impact on urban vitality and safety. They identify five primary types of interfaces based on combinations of these variables, affecting access and visibility across the interface. Impermeable interfaces are viewed as inactive and potentially unsafe, often found in large-lot developments, commercial, and industrial properties with no pedestrian entry. Direct interfaces allow pedestrians to enter private space from the street without an interstitial zone, divided into "direct/opaque" for minimal exchange and "direct/transparent" for commercial visibility. Setback interfaces require crossing a semi-private space before entering private space, common in residential areas (pedestrian/setback) and areas where car parks serve as the interstitial zone (car/setback). The typology is designed for simplicity and utility in mapping and analysis, acknowledging that each variable represents a continuum and that interfaces can give access to multiple entities, leading to secondary interface systems within semi-public or quasi-public realms.

6.4. Greening and Environmental Performance

Green Space and Ecosystem Services

Puchol-Salort, O'Keeffe, van Reeuwijk, & Mijic (2021) propose the fusion of compact architectural designs with extensive Blue Green Infrastructure to augment Urban Ecosystem Services, advancing urban sustainability. This initiative aligns with the principles set forth by Bibri et al. (2020), Bibri (2022), and Jabareen (2006), who identify the incorporation of green spaces into urban landscapes as fundamental to cultivating sustainable urban forms. Artmann, Kohler, Meinel, Gan, & Ioja (2019) stress the necessity of close **proximity to green spaces,** advocating recreational areas to be within 300 to 500 meters of residential areas to improve the quality of life, particularly in densely populated regions. Blanco, Raskin, & Clergeau (2022) delve into the challenges of embedding ecological considerations within urban design frameworks, primarily due to prevailing anthropocentric viewpoints. Additionally, O'Regan & Nyhan (2023) and Strandell & Hall (2015) underline the significance of **equitable access to green spaces** in rendering future urban environments more sustainable, habitable, and healthful, especially in areas where the scarcity of greenery intensifies the utilisation of leisure homes (Strandell & Hall, 2015).

Ghosh (2023) critiques the sectoral approach in sustainable urban planning for failing to capture the urban environment's complexities, advocating for a comprehensive strategy that melds considerations of climate, energy, ecosystem services, waste management, and urban form. This broad perspective is deemed vital for effective water management and confronting urban expansion issues like the diminution of green areas, as noted by Wellmann, Schug, Haase, Pflugmacher, & van der Linden (2020), and Artmann (2016). Proposed remedies include the adoption of green roofs, rejuvenation of brownfield sites, and the creation of bioswales to foster a scenario of growth alongside greening. The **even distribution and connectivity of green spaces** are paramount in conserving biodiversity and ensuring recreational spaces are readily accessible to residents.

The Landscape Ecological Approach, as described by Haaland & van den Bosch (2015), focuses on integrating landscape ecological principles into the planning and establishment of green spaces, particularly in compact cities. This involves optimizing green space geometry for connectivity and employing network planning to work with core areas, buffer zones, and connecting corridors. The preservation or planning of 'green fingers' ensures **high connectivity of urban green space** from the city centre to the periphery, facilitating access to large, connected green areas and enhancing the ecological and recreational value of urban green spaces.

Jansson (2014) underscores the need for accessible parks to minimize commuting to recreation areas, with larger green spaces significantly impacting mental well-being by accommodating diverse activities. Moreover, Ståhle (2005) finds that parks well-integrated into the road network attract more visitors, highlighting the importance of strategic urban planning and design in fostering environmental sustainability through the thoughtful integration of green spaces within the urban fabric.

Micro-climate and Urban Ventilation

Budhiraja, Agrawal, and Pathak (2020) conducted a seminal study on the Urban Heat Island (UHI) effect, highlighting that mixed land-use areas endure significantly higher temperatures than garden cities, attributing this to minimal nocturnal heat dissipation and variations in canopy coverage. This discovery is paralleled by Cochran & Brunsell (2018) who noted increased urban density, geometric complexity, and temperatures across all vegetation cover classes in the São Paulo Metropolitan Region between 2004 to 2014, alongside a decline in overall greenness. These observations underscore the insufficiency of current urban forms in mitigating UHI effects, necessitating modifications in urban geometry, density, and greenness to balance rising temperatures against these factors.

Further research by Xie, Sun & Lin (2023) on Changchun's (City in China) resilience to climate disturbances over six decades revealed that areas near rivers with superior ecosystem conditions exhibited high storm-water absorption capacities, pointing to the importance of **large green spaces for flood resilience**, especially in newly developed or extensively open areas where urbanisation compromises adaptation capacity without adequate open spaces.

Pan (2021) addressed the challenges posed by large-scale urban structures, which, despite providing robust ventilation, suffer from significant UHI effects, highlighting the crucial role of **waterscapes, shading, and vegetation in enhancing thermal comfort**. Similarly, Trepci, Maghelal & Azar (2021) reported reductions in cooling demand by up to 26%, especially when surrounding buildings were tall and closely spaced to maximise shading, thus advocating for the strategic consideration of building height in urban design to facilitate passive cooling.

Silva & Monteiro (2016) explored the interplay between urban forms and outdoor pollutant concentrations, finding that an increased **Sky View Factor** and a greater **Ratio of Open Spaces** correlate with reduced outdoor pollutant levels, suggesting a need to balance urban density with environmental outcomes. Juan, Li, Lee, Wen & Yang (2023) further examined climate-responsive design within high-rise building arrays, revealing that higher urban densities facilitate high-speed airflows at pedestrian levels but also significantly reduce airflow through building openings due to fluid resistance.

Deng & Wong (2020) determined that solar access, along with the aspect ratio and orientation of urban canyons, are primary determinants of outdoor thermal comfort, with smaller, well-oriented canyons being cooler due to shading from surrounding buildings. However, Gaitani et al. (2014) found that **urban canyons with low albedo surface materials and low wind speeds increase air temperatures**, leading to thermal stress and discomfort, while Middel, Häb, Brazel, Martin & Guhathakurta (2014) noted that tall buildings' shading could mitigate urban heat during the day, highlighting the nuanced balance between compact development and UHI effects.

Daylight and Solar Energy Potential

Quan and Li (2021) highlight the variation in energy efficiency across urban typologies, with an emphasis on how single-family housing typically incurs higher energy consumption compared to multi-family housing. This discrepancy underscores the broader sustainability concerns, including housing affordability and socio-economic diversity within residential communities. Xia & Li (2023) articulate that morphological features capable of simultaneously improving indoor and outdoor lighting environments entail **spreading building masses towards the periphery of the site** and arranging slab buildings with significant masses as widely as possible. This spatial organisation becomes particularly effective in low-rise, high-density homes with a Floor Area Ratio (FAR) of 0.5, facilitating open spaces that enhance environmental conditions. Conversely, high-rise buildings, especially those in city centres with an FAR exceeding 3.0, encounter limitations in making adjustments, thereby necessitating the optimisation of light through the arrangement of smaller buildings at the site's edges or the segmentation of large buildings. Likewise, Dawodu & Cheshmehzangi (2017) identify a direct correlation between FAR, energy production, and consumption, also advocating for the strategic placement of taller buildings towards the edges of a plot to reduce shading and enhance solar radiation access.

Chokhachian, Perini, Giulini, & Auer (2020) and Mirzabeigi & Razkenari (2022) further expand on the theme of urban form's impact on energy efficiency and outdoor thermal comfort. They conclude that **mid-rise typologies with a north-south orientation**, alongside **wider urban canyons**, significantly contribute to nocturnal Urban Heat Island (UHI) mitigation, daylighting, and energy efficiency, albeit with varied satisfaction levels during warmer seasons due to increased density. Also, **higher Floor Area Ratios (FAR) result in narrower canyons**, thus constraining design possibilities (Chokhachian et al. 2020).

Vartholomaios (2017) delineates **low-energy urban forms as characterised by compactness and strategic orientation towards the south**. This architectural approach is particularly evident in perimeter urban blocks elongated along the east-west axis, developed at medium to high densities and incorporating open spaces with a minimum width-to-height (W/H) ratio. Such configurations are preferred for their superior energy efficiency, attributed to their compactness. Despite varying orientations, the overall block orientation significantly influences energy consumption, especially in elongated forms with enhanced W/H ratios. Yet, the energy consumption disparities between certain oriented slab configurations and low-energy blocks are minimal, indicating a lack of systematic preference for slab typologies in specific climates.

In contrast, Cheshmehzangi & Butters (2016) and Dekay (2010) argue that **high-rise buildings do not inherently guarantee thermal energy efficiency over low-density options**, given the significant space occupied by building services such as ventilation and lifts, which escalates costs. They suggest that favourable urban microclimates can also be achieved through low-rise configurations, highlighting the challenges posed by solar protection in high-rise buildings due to increased facade exposure.

The notion of the solar city is posited as an essential strategic response to environmental challenges. Byrne and Taminiau (2018) underscore that this paradigm promotes the decentralisation and modularisation of energy infrastructures, mainly via the incorporation of solar power technologies at a significant scale. This model, as Byrne and Taminiau (2018) explain, not only enhances resilience and energy security but also aligns with global commitments to counteract climate change, presenting an immediate and feasible solution for urban environments.

The effectiveness of solar energy utilisation within urban settings is significantly influenced by the interplay between urban density and solar radiation. Li, Wang, and Xia (2022) note that **urban density notably affects the incidence of solar radiation on both buildings and open spaces**, with a more pronounced reduction in open areas. The alteration of urban layouts, for instance, through the implementation of courtyard configurations, can substantially improve solar radiation exposure. Seasonal variations further delineate this relationship; during winter, **buildings experience a decrease in average radiation proportional to increased density**, whereas, in summer, specific layout types, including courtyards, U-shapes, and L-shapes, demonstrate enhanced solar radiation reception. Consequently, urban block configurations such as U-shape and courtyard designs are identified as having the highest potential for photovoltaic (PV) application, with the reduction of Floor Area Ratio (FAR) markedly boosting a block's PV utilization capabilities. These insights underscore the critical role of urban planning in optimizing solar radiation access.

Amado and Poggi (2012) provide empirical evidence supporting the solar city concept, revealing that a neighbourhood layout with buildings distributed across 37% of the total area could harness sufficient solar energy to meet the needs of 48% of its population sustainably. This finding underscores the viability of solar energy as a cornerstone for urban energy strategies, reiterating the critical need for integrated planning and design to realize the full potential of solar cities in mitigating environmental and social challenges.

6.5. Summary of the framework and proposed Urban Metrics

The outcomes of the literature review can be distilled into four ratios, some of which are composed of sub-metrics that form the primary ratio. These can be combined into an *Urban Performance Score* to facilitate a more straightforward comparison when assessing different urban typologies (See table 7).

Urban Performance Score			
Density & Compactness Ratio	**Connectivity & Proximity to Public Transport Ratio**	**Mixed Land-Use and Functional Diversity Ratio**	**Greening and Environmental Performance Ratio**
- Floor Space Index (FSI) $FSI_x = \frac{F_x}{A_x}$	-External connectivity (Space Syntax)	-Amount of POI	-% of Green Space of Total Area
-Ground Space Index (GSI) (Ground coverage)	-Amount of internal connections	-% of commercial area of total land area	-Green Space Density (m2/person)
-Open Space Ratio (OSR) $OSR_x = \frac{1-GSI_x}{FSI_x}$	-Proximity to transit-hub	-Distance to city centre	-% Canopy cover of Total area
-Gross Floor Area (GFA)		-Diversity of Urban interfaces	-Proximity to parks
-People/GFA			-% Solar Energy potential of Total area
-People/km2			-% of Visible Sky
			-Wind Exposition Index

Table 7. Overview of the Urban Metrics that contribute to the Urban Performance Score.

In a similar study that this thesis is conducting, Pakzad and Salari (2018) attempt to define a formula for correlating various indices based on their positive contribution to sustainability. However, they conclude that there is no specific formula for correlating different indices. Instead, they propose a linear formula for calculating the overall sustainability of an urban block. This formula includes both positive and negative values (for indices that detrimentally affect sustainability), their coefficients, and possibly constant values. Therefore, I argue that aggregating the indices found in this study's analytical framework serves merely to indicate the direction towards sustainability in urban form. It is crucial to examine the individual indices and implement urban densification strategies that are locally adaptable.

Density and Compactness Ratio:

The calculation of density will follow Berghauser Pont & Marcus (2014) proposed approach of **Floor Space Index** (FSI), **Ground Space Index** (GSI), **Open Space Ratio** (OSR), and **building height** (L), but also include Bibri et al. (2020) view on density as '**the ratio of dwellings or population to land area**'.

The formulas to calculate these metrics are as follows:

$$GFA = F \times N$$

$$FSI = \frac{GFA}{A}$$

$$GSI = \frac{F}{A}$$

$$OSR = \frac{1 - GSI}{FSI}$$

$$L = \frac{FSI}{GSI}$$

$$D_1 = \frac{P}{GFA}$$

$$D_2 = \frac{P}{\frac{A}{10^6}}$$

GFA = Gross Floor Area (m^2)
F=Sum of building footprints (m^2)
N = Amount of floors
FSI=Floor Space Index (%)
GSI= Ground Space Index (%)
A = Area of the plot (m^2)
OSR=Open Space Ratio (%)

D_1=Population density (m^2)
D_2=Population density (km^2)
P=Amount of people

As compactness is understood as the '**intensity of built structures of an area'**, it synonymous with the Ground Space Index (GSI).

Connectivity and Proximity to Public Transport Ratio:

To evaluate the connectivity, the methodology will use Space Syntax similar to how Ståhle (2005) utilises it. **External connectivity** will be measured by the typology's amount of connections in the whole network, and evaluated by urban morphology categorisation from Scheer (2010), as well as Salingaros (2014) views on amount of connections.

Internal connectivity will be measured by the amount of crossings in the urban tissue divided by the area, borrowing parts of the approach Zhang et al. (2023) identified in their systemic review of spatial measures of urban morphology. Further, this type of measuring internal connectivity is reinforced by Ståhle (2005) and Salingaros (2014) arguments that an increased amount yields higher walkability resilience.

As highlighted by Moyano et al. (2023) and others, the significance of **proximity to transit hubs** is paramount. Accordingly, the methodology adopted will involve conducting a Buffer Analysis, adhering to the principle of 'as the crow flies'. It is asserted that a reduced distance is indicative of enhanced accessibility and use of public transport.

Mixed Land-use and Functional Diversity Ratio:

The methodology employed to assess mixed land-use is simplified in response to the observation that urban tissues often occupy smaller land areas compared to the extents delineated for urban forms within the literature. Therefore, only the amount of commercial area to total land area will be measured, also inspired by Zhang et al (2023).

To assess functional diversity the density of Point of Interest to total land area will be measured, as well as distance to city centre, similarly to what Zhang et al. (2023) proposes in their study. To increase the complexity, the variety of Urban Interfaces as identified by Dovey and Wood (2015) will mapped and divided by the five types. Here a higher value indicates greater variety.

Greening and Environmental Performance Index:

To evaluate greening and environmental performance, a framework comprising seven metrics is proposed, four of which are adapted from Zhang et al. (2023). These metrics include (1) the percentage of green space relative to the total area, (2) green space density normalized by the resident population, (3) canopy coverage of the total area, and (4) proximity to parks. The assessment of proximity employs a buffer analysis, adopting the 300-meter benchmark as suggested by Artmann et al. (2019), a standard corroborated by Swedish regulations (Boverket, 2023c).

The solar potential within the area is determined through a spatial analysis considering Solar Irradiance, Aspect, and Slope on rooftops. To approximate urban ventilation, a method informed by the studies of Mirzabeigi & Razkenari (2022) and Chokhachian et al. (2020), the analysis is streamlined to the calculation of the Wind Exposure Index and the Sky View Factor.

To summarise, the employment of these urban metrics and spatial analytical techniques assist in the understanding of the Urban Performance Index for the assessment of typologies. The index supports urban planning and development strategies aimed at achieving more balanced and sustainable urban form and land-use patterns.

7. Swedish Urban Typologies

This chapter describes and assesses dense urban typologies that can be found within the Swedish urban fabric. These typologies where found in 14 different neighbourhoods in Malmö, Sweden (See figure 7).

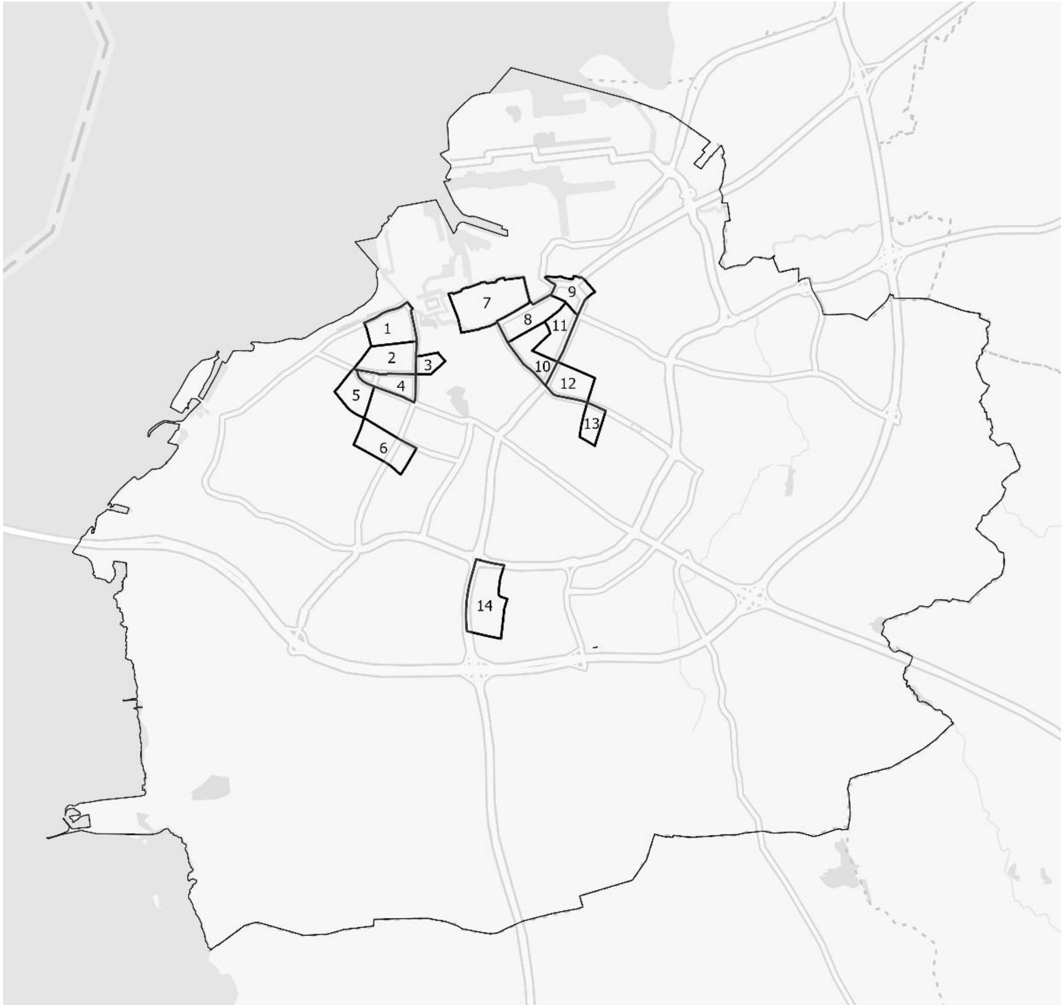

Figure 7. An overview of the selected neighbourhoods where each urban typology can be found. 1=Ribersborg, 2=Rönneholm, 3=Fågelbacken, 4=Dammfri, 5=Mellanheden, 6=Bellevuegården, 7=Gamla staden, 8=Rörsjöstaden, 9=Östervärn, 10=Västra Sorgenfri, 11=Värnhem, 12=Sorgenfri, 13=Törnrosen, 14=Almvik. Data source: Delområden, Malmö © Malmö stad, 2024.

7.1. Old and new urban typologies

Rådberg and Friberg (1996) identifies 26 different typologies, from these around 20 are then categorised into 8 main classes (See figure 8). The ones excluded from the categorisation are solely industrial types or business districts in various combinations.

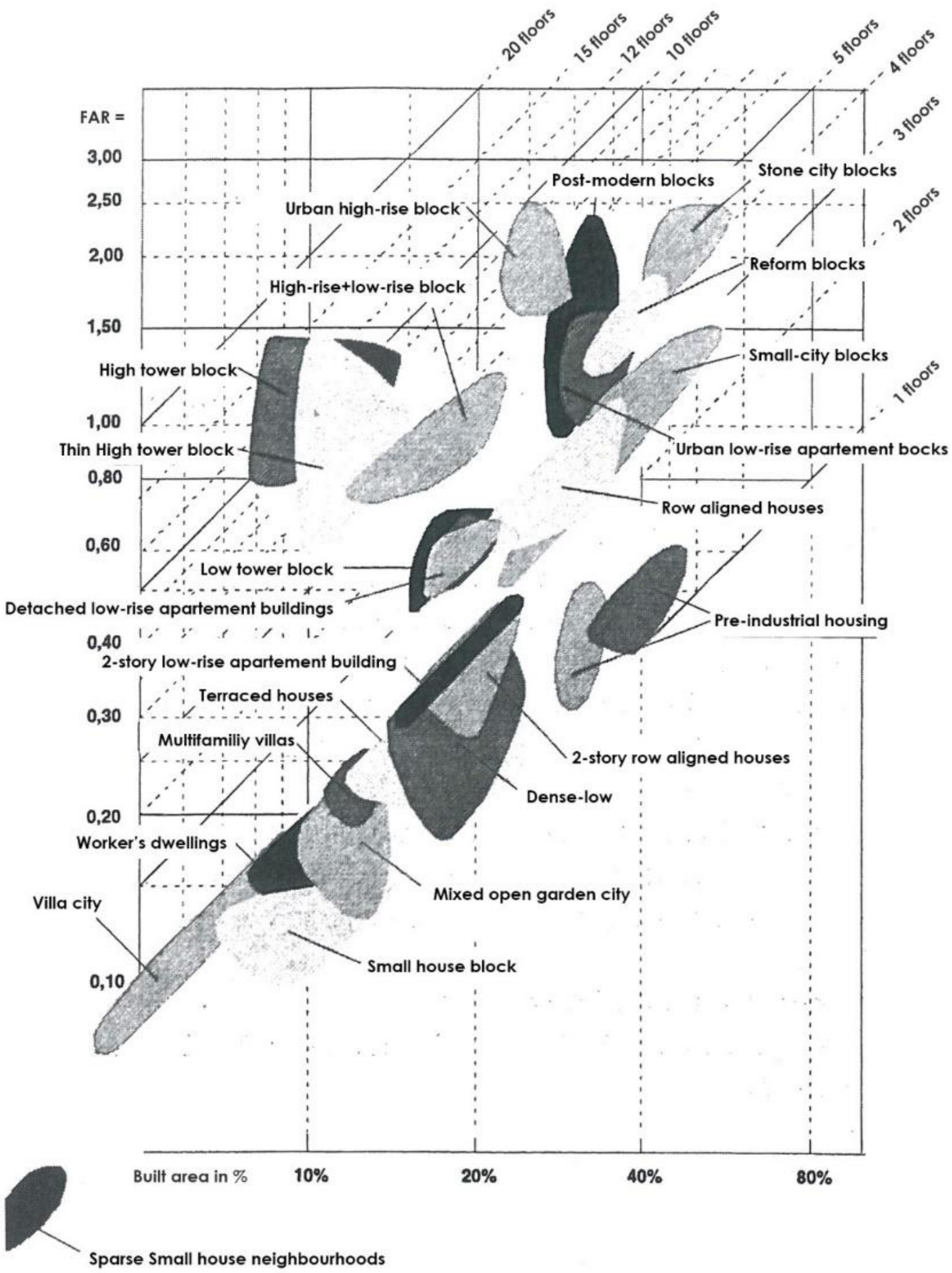

Figure 8. Density diagram showing the 23 urban typologies identified by Rådberg and Friberg. X-axis shows the percentage of built area on the plot. Y-Axis shows the Floor Area Ratio (alt. FSI), which is the ratio of a building's total floor area to the size of the plot upon which is built. Source: Rådberg & Friberg (1996), translated by Christopher Klich.

7.1.1. Urban Blocks

7.1.1.1. Stone City

The advent of rental housing quarters, characterized by continental-style stone constructions of four to five stories, marked a significant urban development in major cities starting from the mid-19th century (Rådberg & Friberg, 1996). The emergence of the "stone city" as a distinctive urban form was largely influenced by the enactment of the 1874 Building Act. This legislation stipulated the permissible building height in correlation to the street width, mandating that new urban streets be established with a minimum width of 18 meters (See figure 9). It allowed the building height up to the ridge to extend no more than the street width plus an additional 1.5 meters, with a limitation of five residential stories. The act further specified that lots could be developed to cover two-thirds of their area, with corner lots permitted up to three-quarters coverage.

Moreover, the construction of courtyard houses and annexes was subject to specific requisites, including a mandated minimum separation of 12 meters from opposite structures and a requisite minimum courtyard area of 180 square meters (Rådberg & Friberg, 1996). These regulations were applicable solely within designated new urban zones. Conversely, in older urban districts, local building codes prevailed, permitting more intensive lot usage. Consequently, development in these older areas was characteristically denser, with higher lot utilization rates and diminished open courtyard spaces.

Figure 9.Photo of the street of stone city blocks in Rörsjöstaden. Source: Google maps, 2024.

Stone city blocks in Rörsjöstaden

In the south-western part of Rörsjöstaden, you will find multiple blocks that feature characteristics of courtyard houses (See figure 10). The area was planned in 1886 and part of the master plan for the whole of Rörsjöstaden (Malmö stad, 1984). The urban tissue that can be identified through looking at the road network is the one of static type.

Figure 10. Overview of the Stone city blocks in Rörsjöstaden. Source: Property map © Lantmäteriet, 2024.

Urban Performance Score			
Density & Compactness Ratio	**Connectivity & Proximity to Public Transport Ratio**	**Mixed Land-Use and Functional Diversity Ratio**	**Greening and Environmental Performance Ratio**
- Floor Space Index (FSI) 1.779468	-External connectivity (Space Syntax) Good	-Amount of POI 20 (80)	-% of Green Space of Total Area 13.4%
-Ground Space Index (GSI) (Ground coverage) 0.448665	-Amount of internal connections 15	~~-% of commercial area of total land area~~	-Green Space Density (m2/person) 5.9
-Open Space Ratio (OSR) 0.309831	-Proximity to transit-hub 800	-Distance to city centre 800	-% Canopy cover of Total area 6%
-Gross Floor Area (GFA) 148557.9		~~-Diversity of Urban interfaces~~	-Proximity to parks (300m) Yes
-People/100GFA 1.287713			-% Solar Energy potential of total roof area 24.7%
-People/km2 22914.443461			-% of Visible Sky 28.4%
			~~-Wind Exposition Index~~

Figure 11.The urban performance score of the stone city in Rörsjöstaden.

Notable in the Stone city block typology is the high value of GSI, that is almost 50% of the plot (Se figure 11).

7.1.1.2. Reformed Blocks

At the dawn of the 20th century, a notable shift in urban development philosophy emerged as a critique of the previously prevalent, densely constructed stone cities and the overcrowded rental barracks characteristic of the era (Rådberg & Friberg, 1996). This period witnessed a growing consensus towards diminishing urban development intensity, which found legislative support in the enactment of the 1907 City Planning Act. This act introduced mechanisms for the implementation of specific construction regulations for distinct blocks and plots within the urban plan, marking a pivotal change in urban regulation.

This legislative framework facilitated the establishment of guidelines that allowed for reductions in building heights and lot coverage beneath the thresholds set by the 1874 Building Act (Rådberg & Friberg, 1996). Moreover, it introduced the concept of an inner building line, which effectively reduced the construction of courtyard houses and annexes. The adoption of these regulations gave rise to what could be termed as ‘reform blocks’, which became a prevalent feature in the urban landscape post-1910, particularly in the inner areas of major cities.

Characteristically, these reform blocks are defined by their closed configurations devoid of courtyard houses, wherein the interior part of the block is dedicated to open space (Rådberg & Friberg, 1996). This space is sometimes organised as a large, communal courtyard accessible to all residents of the block, though it is more commonly partitioned according to property boundaries. Leading to buildings being erected by various developers and that exhibits diverse architectural styles (See figure 12).

Figure 12.Photo of the reformed block type standing at the plot boundary. Source: Google maps, 2024.

Reformed blocks in Östervärn

'In the southern part of Östervärn, multiple reformed blocks can be found. The houses stand at the perimeter of the plot boundaries (See figure, 13), creating spacious courtyards. However, due to the multiple plots, this also results in fragmented yards. These buildings were planned back in the beginning of the 20th century (Malmö stad, 1939). Similar to the previous typology the urban tissue here is static but not as grid-like with the diagonal road going through the neighbourhood.

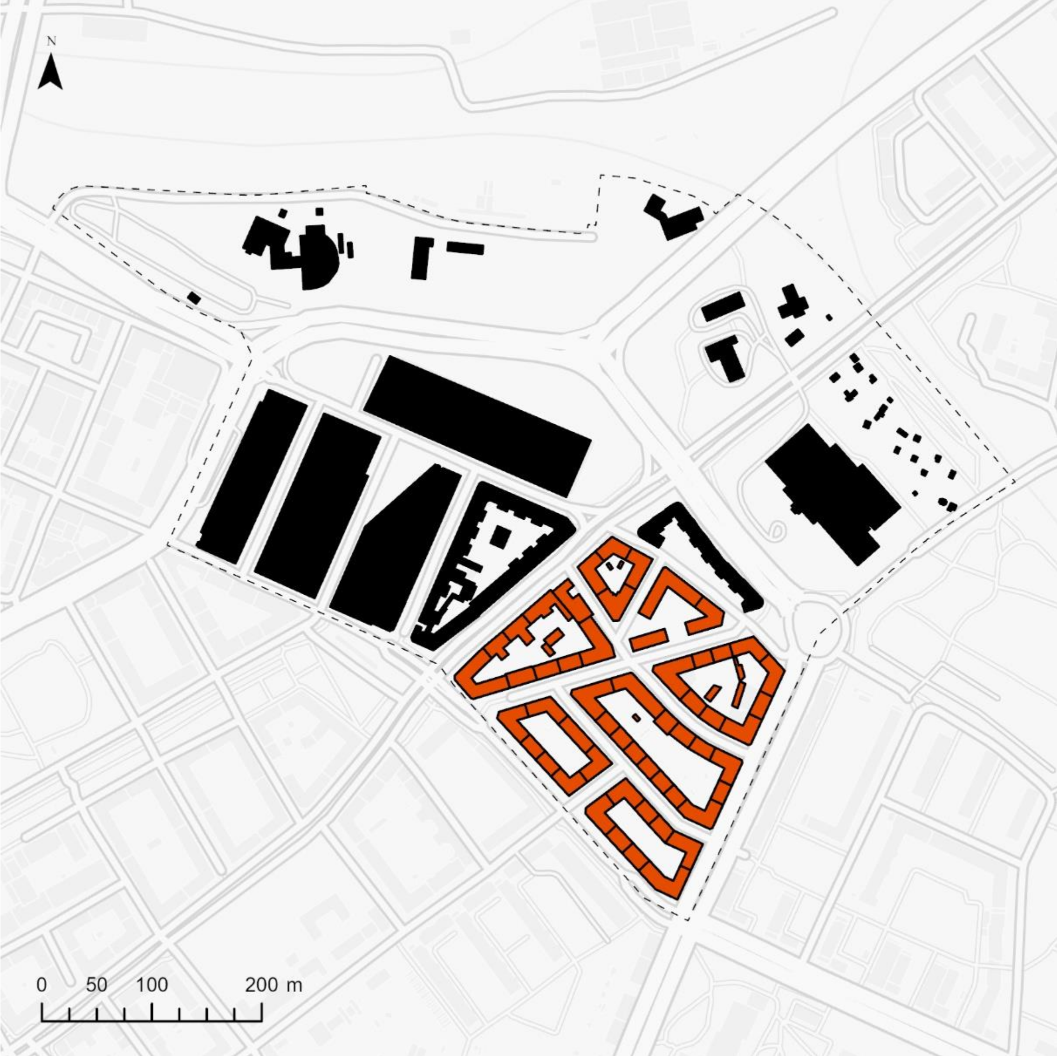

Figure 13. Overview of the the reformed blocks in Östervärn. Source: Property map © Lantmäteriet, 2024.

Urban Performance Score			
Density & Compactness Ratio	**Connectivity & Proximity to Public Transport Ratio**	**Mixed Land-Use and Functional Diversity Ratio**	**Greening and Environmental Performance Ratio**
- Floor Space Index (FSI) 1.614075	-External connectivity (Space Syntax) Good	-Amount of POI 18 (57)	-% of Green Space of Total Area 26.4%
-Ground Space Index (GSI) (Ground coverage) 0.398376	-Amount of internal connections 30	~~-% of commercial area of total land area~~	-Green Space Density (m2/person) 6.6
-Open Space Ratio (OSR) 0.372736	-Proximity to transit-hub 400	-Distance to city centre 2000	-% Canopy cover of Total area 8.5%
-Gross Floor Area (GFA) 98283.9		~~-Diversity of Urban interfaces~~	-Proximity to parks (300m) Yes
-People/100GFA 2.476499			-% Solar Energy potential of total roof area 26%
-People/km2 39972.564011			-% of Visible Sky 43%
			~~-Wind Exposition Index~~

Figure 14. The urban performance score of the reformed blocks typology.

Similar to the previous typology, the reformed blocks also score high on the GSI (see Figure 14). A notable difference, however, is the density of people, which rises to 2.47 per 100 GFA (approximately the size of an apartment).

7.1.1.3. Urban Lamella Houses

In the 1930s, following the success of functionalism as a dominant architectural and urban planning paradigm, a significant revision of older city plans was undertaken (Rådberg & Friberg, 1996). This period saw the traditional model of enclosed blocks being supplanted by configurations of parallel-aligned slab buildings. Despite this transformative approach to building alignment, the pre-existing block structure and street network were preserved. Consequently, urban landscapes came to be characterized by densely arranged slab buildings, integrated within the extant framework of streets and blocks.

The reconfiguration of urban areas into slab block neighbourhoods witnessed a notable level of development intensity. This process was generally predicated on the assumption of maintaining the existing degree of urban development (Rådberg & Friberg, 1996). The architectural form prevalent in these neighbourhoods is often described as 'thick buildings' (See figure 15). These structures are distinguished by their considerable depth (reaching up to 16 meters) and are comprised of numerous small apartments, typically designed with a single aspect. Such buildings were not exclusive to major urban centres but were also evident in smaller municipalities.

However, the era of urban slab block neighbourhoods was relatively brief, spanning approximately a decade (Rådberg & Friberg, 1996). A contributing factor to the decline of this urban form was the post-1945 planning of new peripheral land areas, which led to a departure from the traditional street network and block structure. Concurrent with these changes was the phasing out of 'thick buildings' as a prevalent architectural type. The demise of thick buildings, characterized by their small, single-sided apartments and diminutive secondary lit kitchens, coincided with the introduction of new regulations governing state housing loans.

Figure 15. Photo of the earliest urban lamella houses in Malmö spanning more than 13 meters in width. Source: Google maps, 2024.

Lamella houses in Östra Sorgenfri

In the north-western parts of Östra Sorgenfri, you will find two formations of lamella houses (see Figure 16). As these were planned and built simultaneously with those in 'western' Sorgenfri, both were included in the analyses. They were planned during the 1930s and built during the 1940s when the administrative area was known as ‘Mellersta Förstaden’ (Malmö stad, 2024). This type of urban lamella houses tends to be located in a static tissue, just like these.

Figure 16. Overview of the urban lamella houses in Östra Sorgenfri. Source: Property map © Lantmäteriet, 2024.

Urban Performance Score			
Density & Compactness Ratio	**Connectivity & Proximity to Public Transport Ratio**	**Mixed Land-Use and Functional Diversity Ratio**	**Greening and Environmental Performance Ratio**
- Floor Space Index (FSI) 0.843662	-External connectivity (Space Syntax) Good	-Amount of POI 3 (33)	-% of Green Space of Total Area 40.4%
-Ground Space Index (GSI) (Ground coverage) 0.220443	-Amount of internal connections 11	~~-% of commercial area of total land area~~	-Green Space Density (m2/person) 20.7
-Open Space Ratio (OSR) 0.924015	-Proximity to transit-hub 1200	-Distance to city centre 1600	-% Canopy cover of Total area 18%
-Gross Floor Area (GFA) 30409.6		~~-Diversity of Urban interfaces~~	-Proximity to parks (300m) Yes
-People/100GFA 2.321635			-% Solar Energy potential of total roof area 31.6%
-People/km2 19586.764257			-% of Visible Sky 53.5%
			~~-Wind Exposition Index~~

Figure 17. The urban performance score of the Lamella house typology.

A notable parameter is due to the non-closed of courtyard form we see a jump in the OSR due to less ground coverage of building footprints (See figure 17).

7.1.1.4. Urban High-Rise buildings

Detached high-rise buildings emerged as a core feature in the evolution of urban planning concepts around the year 1930 (Rådberg & Friberg, 1996). The practical application of these innovative ideas became feasible in 1931, subsequent to the repeal of the 1874 Building Act, along with its stipulation for a maximum of five stories.

The new architectural approach led to the creation of neighbourhoods with high-rise buildings., comprising six to ten-story point and slab buildings. These developments were predominantly situated on the peripheries of major urban centres, integrating into the traditional grid layout to form what might aptly be described as 'urban high-rise neighbourhoods' (Rådberg & Friberg, 1996). This new typology represented a departure from the closed block structures characteristic of the 1920s, featuring instead detached high-rise building (See figure 18). Moreover, these urban high-rise neighbourhoods markedly diverged from their subsequent suburban counterparts, which are noted for their lower land utilization rates, increased spacing between buildings, and more expansive street networks.

Figure 18.Photo of the urban high-rise buildings in Ribersborg. Source: Google Maps, 2024.

Urban High-Rise buildings in Ribersborg

In the northen part of Ribersborg lies what is commonly known as Ribershus. These were erected in the late 1930s (Malmö stad, 1936) and are similar to the urban lamella houses in shape, the only difference is the height. They lay in an urban tissue that is static but have some hints of being a campus tissue, at least in the western parts were the road network doesn't connect to the west (See figure 19).

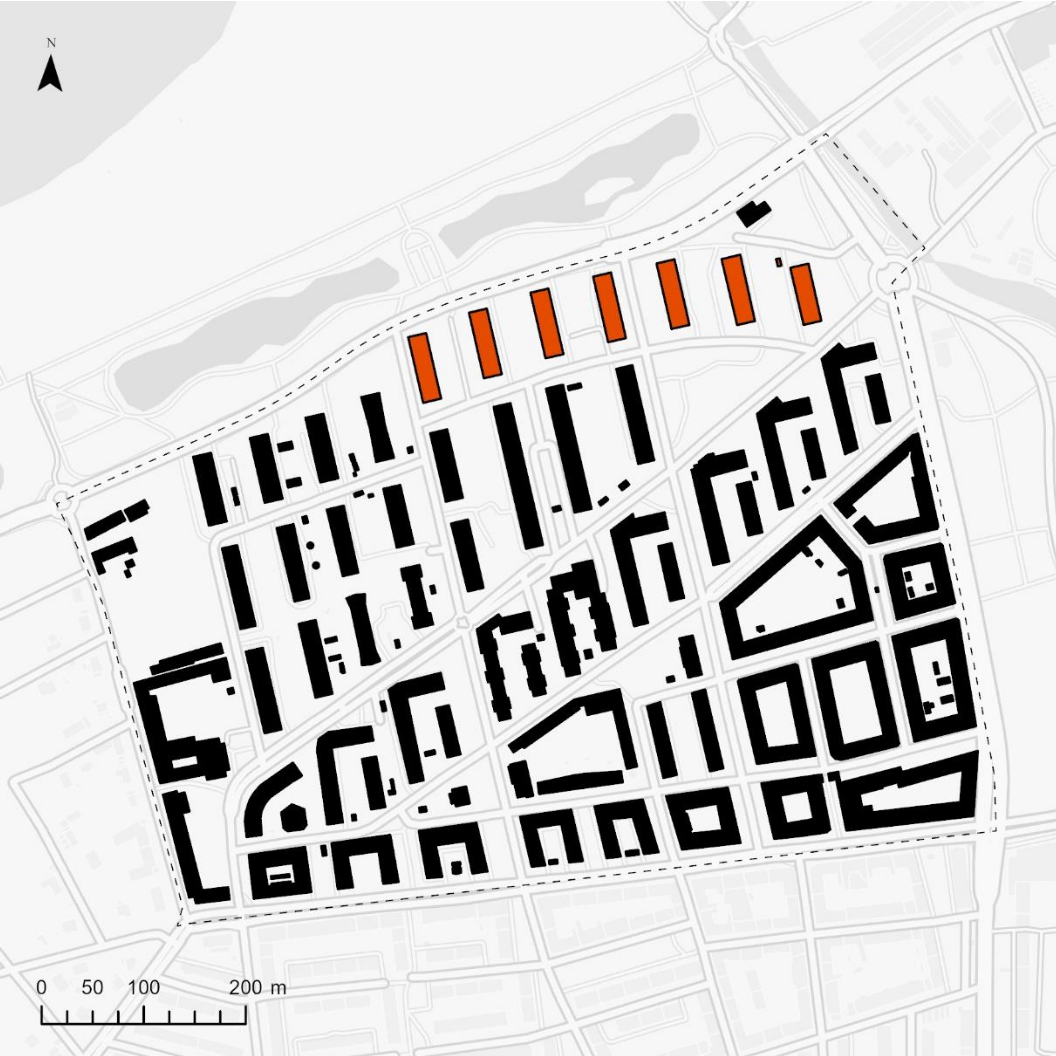

Figure 19. Overview of the urban high-rise buildings in Ribersborg. Source: Property map © Lantmäteriet, 2024.

Urban Performance Score			
Density & Compactness Ratio	**Connectivity & Proximity to Public Transport Ratio**	**Mixed Land-Use and Functional Diversity Ratio**	**Greening and Environmental Performance Ratio**
- Floor Space Index (FSI) 1.701928	-External connectivity (Space Syntax) Good	-Amount of POI 3 (54)	-% of Green Space of Total Area 62.4%
-Ground Space Index (GSI) (Ground coverage) 0.189645	-Amount of internal connections 22	~~-% of commercial area of total land area~~	-Green Space Density (m2/person) 24
-Open Space Ratio (OSR) 0.47614	-Proximity to transit-hub 1600	-Distance to city centre 1600	-% Canopy cover of Total area 11%
-Gross Floor Area (GFA) 73557.9		~~-Diversity of Urban interfaces~~	-Proximity to parks (300m) Yes
-People/GFA 1.525329			-% Solar Energy potential of total roof area 15%
-People/km2 25959.99955			-% of Visible Sky 52%
			~~-Wind Exposition Index~~

Figure 20. The urban performance score of the Urban High-Rise typology.

A notable factor in the performance score is that the Urban High-rise has a slightly lower OSR due to a higher FSI that is the result of building heights (See figure 20).

7.1.1.5. Postmodern Blocks

From 1930 to 1975, there was a general cessation in the creation of new city plans incorporating traditional closed blocks, as noted by Rådberg & Friberg (1996). However, circa 1975, a paradigm shift occurred in urban planning, with a renewed interest in the closed block forms reminiscent of the late 1920s, particularly the large courtyard blocks. Although these newer designs bore a striking resemblance to their historical counterparts in terms of block layout, closer inspection reveals several fundamental distinctions.

The reform blocks of the 1920s were characterised by a uniformity in height, according to Rådberg & Friberg (1996). Conversely, the heights within the so-called postmodern reform blocks vary, with some reaching up to eight stories. Additionally, whereas the 1920s reform blocks maintained a clear demarcation between the public spaces of the streets and the semi-private courtyards, this boundary is notably less defined in the postmodern era. Here, public spaces, manifesting as streets or squares, frequently penetrate into the blocks, with secondary streets often traversing the plots.

Post-1975, 'postmodern' city plans not only revisited closed blocks but also explored alternative block-like urban structures composed of interconnected, angular building volumes (Rådberg & Friberg, 1996). These configurations are collectively referred to as ‘postmodern hybrid areas’. Characteristically, these areas consist of interconnected Y- or T-shaped building volumes, frequently in high-rise forms. Unlike traditional blocks, these hybrid areas blur the conventional distinctions between streets and courtyards, and between public and private spaces.

Figure 21. Photo of the Postmodern Block kv. Papegojan (Parrot) in Fågelbacken. Source: Google Maps, 2024

Postmodern blocks in Fågelbacken

In the north-eastern part of the Fågelbacken administrative area, you can find a postmodern block that was built in the 1990s (Malmö stad, 1992) (See figure 22). Here, you can observe the characteristic variety of building heights (See figure 21).

Figure 22. Overview of the postmodern block in Fågelbacken. Source: Property map © Lantmäteriet, 2024.

Urban Performance Score			
Density & Compactness Ratio	**Connectivity & Proximity to Public Transport Ratio**	**Mixed Land-Use and Functional Diversity Ratio**	**Greening and Environmental Performance Ratio**
- Floor Space Index (FSI) 1.873634	-External connectivity (Space Syntax) Good	-Amount of POI 1 (31)	-% of Green Space of Total Area 41%
-Ground Space Index (GSI) (Ground coverage) 0.314347	-Amount of internal connections 5	~~-% of commercial area of total land area~~	-Green Space Density (m2/person) 16.1
-Open Space Ratio (OSR) 0.365948	-Proximity to transit-hub 1200	-Distance to city centre 1200	-% Canopy cover of Total area 4%
-Gross Floor Area (GFA) 25433		~~-Diversity of Urban interfaces~~	-Proximity to parks (300m) Yes
-People/GFA 1.360437			-% Solar Energy potential of total roof area 19.6%
-People/km2 25489.618811			-% of Visible Sky 49%
			~~-Wind Exposition Index~~

Figure 23. The urban performance score of the postmodern block typology.

What really stands out in this block, but not necessarily representable for the whole typology is that there is on 4% canopy cover, though compensated for with 41% of total green space percentage (See figure 23).

7.1.2. Small Town Blocks

7.1.2.1. Small Town Blocks

In smaller and medium-sized cities, the architectural landscape of rental housing neighbourhoods was marked by a diverse and heterogeneous development pattern. Buildings of varying heights were often juxtaposed, creating a distinctive and varied urban skyline. The preservation of traditional architectural styles, evocative of wooden cities, was evident in the maintenance of gaps between buildings at plot boundaries and the incorporation of open spaces (Rådberg & Friberg, 1996). This approach allowed remnants of pre-industrial structures to remain within the inner parts of these blocks for extended periods.

Rental housing in these cities was characteristically less dense, and the buildings rarely matched the taller heights seen in larger urban centres (Rådberg & Friberg, 1996). Following the 1874 Building Act, construction typically did not exceed two or three stories, rarely reaching the legislation's maximum allowable height. Despite these height restrictions, the utilisation of lot space was often maximised through the frequent construction of courtyard houses.

The prevalence of lower building heights can be attributed to several factors. The development pressure in these smaller cities was not as intense, reducing the need for taller, continental-style apartment buildings (Rådberg & Friberg, 1996). Moreover, many of these construction projects were located in older urban areas with relatively narrow streets, where building regulations further limited the possible height of new structures (See figure 24).

Figure 24. Photo of the Small Town block in Gamla staden. Source: Google Maps, 2024

Small Town blocks in Gamla staden

In the western part of Gamla Staden, you'll find a peculiar type of building formation where one-storey buildings are attached to five-storey ones (See figure 25). These types of blocks can also be seen as part of the Stone City. What makes this area interesting is the juxtaposition of preserved buildings from the 1800s with those from a newer time period.

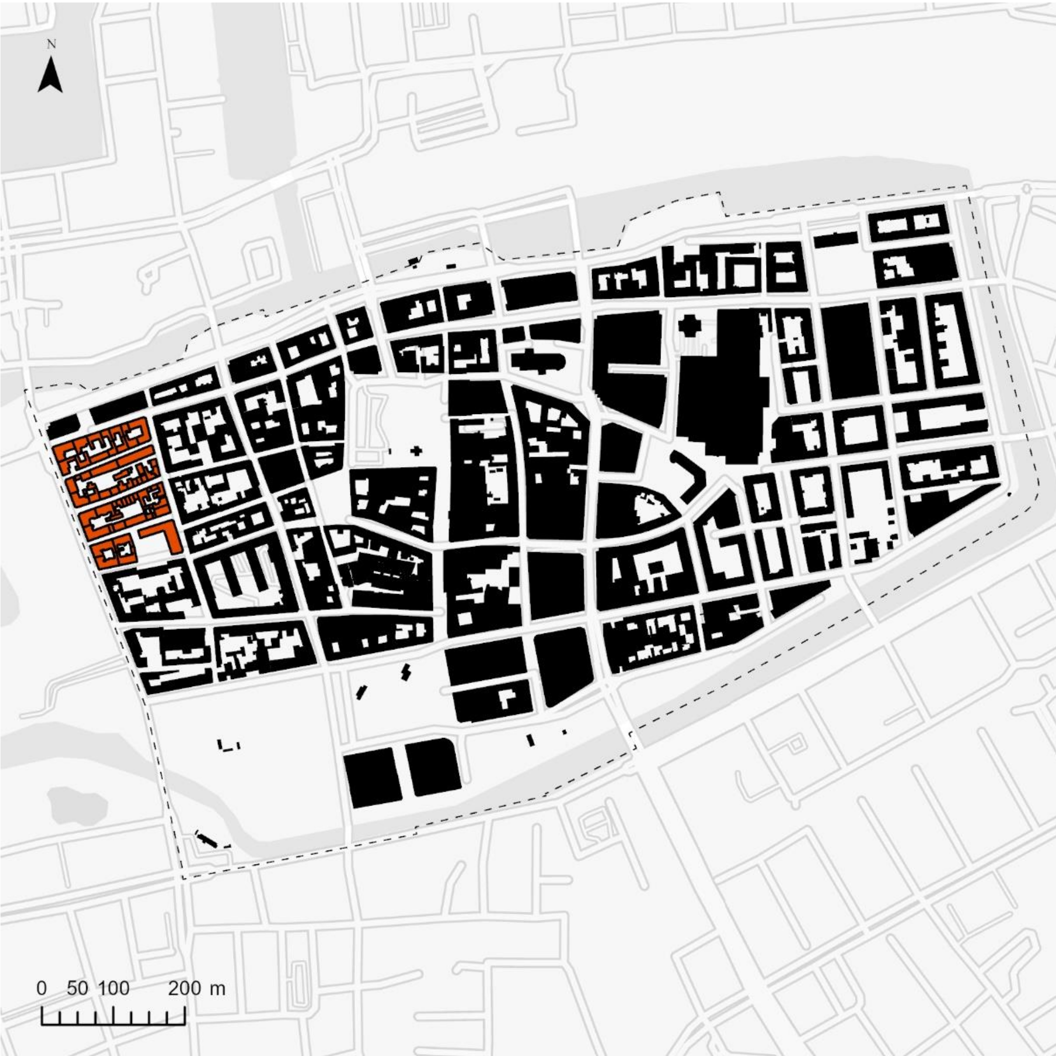

Figure 25. Overview of the small town block in Gamla staden (a.k.a. Gamla Väster). Source: Property map © Lantmäteriet, 2024.

Urban Performance Score			
Density & Compactness Ratio	**Connectivity & Proximity to Public Transport Ratio**	**Mixed Land-Use and Functional Diversity Ratio**	**Greening and Environmental Performance Ratio**
- Floor Space Index (FSI) 1.441473	-External connectivity (Space Syntax) Good	-Amount of POI 3 (395)	-% of Green Space of Total Area 14%
-Ground Space Index (GSI) (Ground coverage) 0.48853	-Amount of internal connections 13	~~-% of commercial area of total land area~~	-Green Space Density (m2/person) 6.12
-Open Space Ratio (OSR) 0.354825	-Proximity to transit-hub 800	-Distance to city centre 800	-% Canopy cover of Total area 5%
-Gross Floor Area (GFA) 40193.4		~~-Diversity of Urban interfaces~~	-Proximity to parks (300m) Yes
-People/100GFA 1.622157			-% Solar Energy potential of total roof area 17%
-People/km2 23382.959076			-% of Visible Sky 41.8%
			~~-Wind Exposition Index~~

Figure 26. The urban performance score of the small town block typology.

What notably stands out in this typology is the number of points of interest (POIs) compared to the whole administrative area of Gamla Staden (See figure 26). This may be due to the smaller, older houses, but also because this is the city centre and the central boulevard is further east of the typology. There is an immense lack of greenery, with only 6.12 sqm per person.

7.1.2.2. Townhouses

During the 1910s and 1920s, developments comprising closed blocks of three-story buildings emerged in the suburbs of major cities and in medium-sized cities (Rådberg & Friberg, 1996). These areas typically featured blocks with enclosed open courtyards, which were often divided into separate properties, although occasionally, block-sized units with a shared courtyard were also developed.

The 1919 Building Act proposal introduced the concept of a 'row of houses' defined as low-rise blocks, limited to two or three stories, constructed contiguously at the property boundary (Rådberg & Friberg, 1996). Note that these were not what we commonly think of ‘Rowhouse’ but rather ‘Townhouses’ Under this proposal, courtyard houses or ‘wings’ were not permissible, and the buildings' depth could not exceed 15 meters.

This concept encompassed two variations: a denser version with three-story buildings in a predominantly closed construction, and a less dense version, often comprising connected single-family homes (Rådberg & Friberg, 1996). In the denser variant, building on up to half of the lot area was allowed, whereas the less dense variant restricted building coverage to a maximum of one-third of the lot area.

Figure 27. Photo of the Townhouse block in Västra Sorgenfri (area of Sankt Knut). Source: Google Maps, 2024

Town houses in Sankt Knut, Västra Sorgenfri

In the western parts of Västra Sorgenfri, you will find townhouses that are four storeys high and relatively dense, with a row of houses within the courtyard (see Figure 27-28). These are not single-family houses but multi-dwelling units. According to a master plan proposal from 1927, all the blocks to the north, south, and east were part of the same vision, but with a variety in typology (Malmö stad, 1927). These blocks lay in a clear static tissue that follows a grid-type orientation in the north.

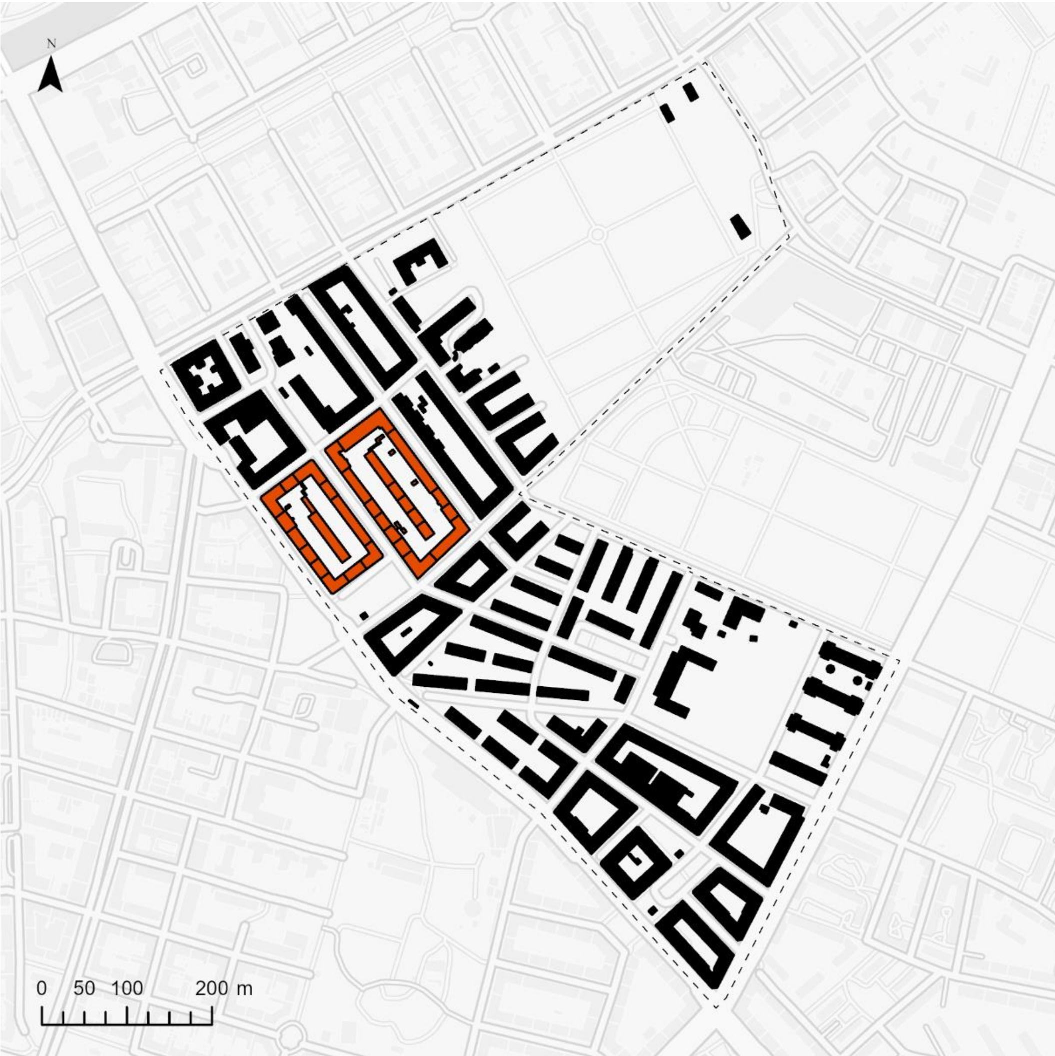

Figure 28. Overview of the small town block in Gamla staden (old city). Source: Property map © Lantmäteriet, 2024.

Urban Performance Score			
Density & Compactness Ratio	**Connectivity & Proximity to Public Transport Ratio**	**Mixed Land-Use and Functional Diversity Ratio**	**Greening and Environmental Performance Ratio**
- Floor Space Index (FSI) 1.594746	-External connectivity (Space Syntax) Good	-Amount of POI 6 (49)	-% of Green Space of Total Area 26.6%
-Ground Space Index (GSI) (Ground coverage) 0.40131	-Amount of internal connections 6	~~-% of commercial area of total land area~~	-Green Space Density (m2/person) 7
-Open Space Ratio (OSR) 0.375414	-Proximity to transit-hub 1200	-Distance to city centre 1200	-% Canopy cover of Total area 9%
-Gross Floor Area (GFA) 54689.6		~~-Diversity of Urban interfaces~~	-Proximity to parks (300m) Yes
-People/100GFA 2.450192			-% Solar Energy potential of total roof area 23.8%
-People/km2 39074.32511			-% of Visible Sky 40.5%
			~~-Wind Exposition Index~~

Figure 29. The urban performance score of the Townhouse block typology.

What stands out in the urban performance score for the townhouse type is the lack of green space density due to the denser population in these blocks (See figure 29). This is most likely affected by the central row of houses in the courtyard, which increases the number of people that can live within the block.

7.1.3. Medium-Density Open Development

7.1.3.1. Detached Lamella Houses

The detached lamella house, typically three stories high and often with 2-4 stairwells, was the dominant building type in Swedish residential construction from the 1930s (Rådberg & Friberg, 1996). At times, this building type accounted for over 50% of the new additions of apartment buildings. A specific subtype of the lamella house is the ‘smalhus’ (thin house) which has a building depth of 8-10 meters and was limited to three storeys. They were primarily built between 1935 and 1945. However, as a typology, thin house areas do not differ significantly from other early detached lamella house areas.

Lamella houses of three to four stories were often integrated into the traditional block structure during the 1930s and 1940s (Rådberg & Friberg, 1996). But after 1945, they were increasingly built in the form of large developments outside the old city centres. In these consolidated developments, the traditional block structure was abandoned: the building volumes were grouped, the street layout was more adapted to the terrain than the buildings, often with cul-de-sacs to create conditions for a connected network of pedestrian and cycling paths. During this period, short detached lamella houses became less common, and there was a transition to a city type with lamella house in block structures that enclosed courtyards.

Figure 30. Photo of the Detached Lamella Houses in Rönneholm. What significant in this images is how the configuration the buildings enclose a courtyard. Source: Google Maps, 2024

Detached lamella Houses in Rönneholm

These detached lamella houses were part of a master plan for Västra Förstaden (western city suburb) in 1934 (Malmö stad, 1934). They are mainly four storeys tall, but have sides that tend to be five storeys here and there. Characteristic of these blocks is their orientation and the presence of non-drive-through roads on the horizontal axis, likely designed to protect the cycling and pedestrian path running from north to south through the neighbourhood (See figure 30-31). This was already planned in the old master plan.

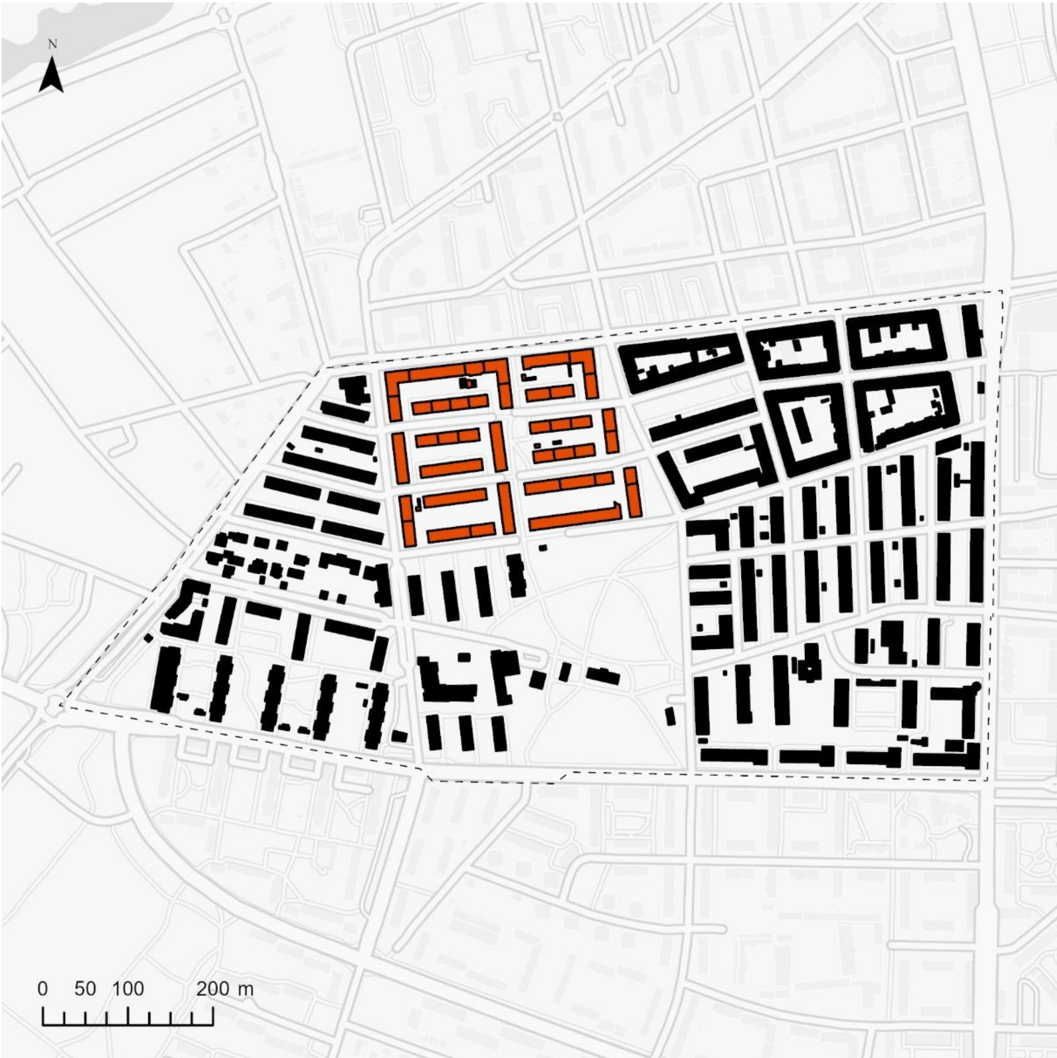

Figure 31. Overview of the Detached Lamella typology. Source: Property map © Lantmäteriet, 2024.

Urban Performance Score			
Density & Compactness Ratio	**Connectivity & Proximity to Public Transport Ratio**	**Mixed Land-Use and Functional Diversity Ratio**	**Greening and Environmental Performance Ratio**
- Floor Space Index (FSI) 1.28295	-External connectivity (Space Syntax) Decent	-Amount of POI 14 (60)	-% of Green Space of Total Area 41.5%
-Ground Space Index (GSI) (Ground coverage) 0.304081	-Amount of internal connections 23	~~-% of commercial area of total land area~~	-Green Space Density (m2/person) 18.3
-Open Space Ratio (OSR) 0.542436	-Proximity to transit-hub 2000	-Distance to city centre 2000	-% Canopy cover of Total area 10.5%
-Gross Floor Area (GFA) 86847.6		~~-Diversity of Urban interfaces~~	-Proximity to parks (300m) Yes
-People/GFA 1.773221			-% Solar Energy potential of total roof area 26%
-People/km2 22749.54205			-% of Visible Sky 53.2%
			~~-Wind Exposition Index~~

Figure 32. The urban performance score of the Detached lamella house typology.

What is notable in this example is the percentage of green space as well as the amount of visible sky from the courtyards (See figure 32). This is most likely due to the urban form not enclosing the courtyards, even though the ground coverage being 30%.

7.1.3.2. Terraced Lamella Courtyards

Post-1945, Sweden witnessed the emergence of a new urban housing typology known as lamella house areas, which were characterized by more enclosed constructions and distinct courtyards (Rådberg & Friberg, 1996). This architectural style typically features blocks that form courtyards and are partially enclosed, surrounded by interconnected three-story lamella houses adopting L- or U-shaped configurations. Additionally, these buildings sometimes form long, meandering shapes. Predominantly constructed during the 1950s, this typology proliferated across Sweden, epitomizing a unique urban style that could be termed 'angle house courtyards' or 'semi-open courtyards'. A notable variation within this typology includes the 'stjärnhus' (star houses), which are interconnected in long, continuous loops (See figure 33 & 34).

While lamella house areas with semi-open courtyards lean towards a more traditional block layout, significant distinctions remain (Rådberg & Friberg, 1996). Unlike traditional closed blocks where residential buildings typically have one facade facing the street and the other overlooking a private courtyard, lamella house areas blur the lines between public and private spaces. In these developments, it is not uncommon for buildings to have both facades facing courtyards, and for some courtyards to face towards the street, thus integrating public space more seamlessly into the urban fabric. This arrangement marks a departure from the conventional separation of street and courtyard, reflecting a more fluid and integrated approach to urban residential design.

Figure 33. Photo of the Terraced Lamella house in Mellanheden. This specific house is what's called 'star houses'. Source: Google Maps, 2024

Terraced lamella houses in Mellanheden

This specific type of lamella house was planned and built in Malmö at the end of the 1940s (Malmö stad, 1949). Its hexagonal form resembles a chemical bond symbol. The urban fabric presents a hybrid structure, with some sides appearing static while others feel more elastic, particularly to the east, where there is open nature and schools.

Figure 34. Overview of a variation of the Terraced Lamella typology. Source: Property map © Lantmäteriet, 2024.

Urban Performance Score			
Density & Compactness Ratio	**Connectivity & Proximity to Public Transport Ratio**	**Mixed Land-Use and Functional Diversity Ratio**	**Greening and Environmental Performance Ratio**
- Floor Space Index (FSI) 0.653257	-External connectivity (Space Syntax) Good	-Amount of POI 24 (83)	-% of Green Space of Total Area 62.4%
-Ground Space Index (GSI) (Ground coverage) 0.220704	-Amount of internal connections 14	-% of commercial area of total land area	-Green Space Density (m2/person) 44.6
-Open Space Ratio (OSR) 1.192939	-Proximity to transit-hub 2000+	-Distance to city centre 2800	-% Canopy cover of Total area 12%
-Gross Floor Area (GFA) 32129		-Diversity of Urban interfaces	-Proximity to parks (300m) Yes
-People/100GFA 2.141368			-% Solar Energy potential of total roof area 27%
-People/km2 13988.6357			-% of Visible Sky 65.7%
			~~-Wind Exposition Index~~

Figure 35. The urban performance score of the Detached lamella house typology.

What is interesting in the performance of this typology is the high Open Space Ratio, most likely affected by the low Floor Space Index (See figure 35). Which can indicate in raw numbers that this typology may handle some densification. Similarly, the amount of visible sky is also quite high.

7.1.3.3. Low-Rise Apartment Buildings

The elevator-less low-rise apartment building, typically spanning three to four stories, represents an evolution from the multi-family villa or lamella house formats (Rådberg & Friberg, 1996). This architectural form increases the number of units—from two to three or four—arranged around a central stairwell, thereby enhancing the utilization of space. During the 1930s and 1940s, such low-rise apartment buildings were predominantly constructed within the traditional street and block patterns found in medium-sized and smaller cities.

In the post-war era, these buildings became a common feature in larger suburban developments, often situated alongside lamella houses, particularly in hilly terrains where the construction of lamella houses was impractical due to their larger footprints (Rådberg & Friberg, 1996). Throughout the 1960s and 1970s, there were instances of densely arranged groups of these low-rise apartment buildings, three to four stories tall, designed without elevators. This trend reflects a continued preference for low-rise housing solutions in suburban environments, adapting architectural practices to suit the geographical and urban context of the developments.

Figure 36. A photo of a group of low-rise apartment buildings in Dammfri, Malmö. Such buildings are quite rare in the city, with only a few from the same period found in Limhamn. They are characterised by their modest height and are surrounded by greenery and well-maintained pathways. Source: Google Maps, 2024

Low-Rise Apartment buildings in Dammfri

In the central part of Dammfri administrative area you'll find 9 of these low rise buildings (See figure 36-37.). They were part of a masterplan in the 1950s where there was supposed to be two more to the west (Malmö stad, 1950), so they could have somewhat symmetry in the block. Quite commonly this type of typology is often found in campus tissues, which this one isn't due to being surrounded with other typologies, compacting the urban form.

Figure 37. Overview of a Low-Rise building typology. Source: Property map © Lantmäteriet, 2024.

Urban Performance Score			
Density & Compactness Ratio	**Connectivity & Proximity to Public Transport Ratio**	**Mixed Land-Use and Functional Diversity Ratio**	**Greening and Environmental Performance Ratio**
- Floor Space Index (FSI) 0.740186	-External connectivity (Space Syntax) Bad	-Amount of POI 0 (31)	-% of Green Space of Total Area 55%
-Ground Space Index (GSI) 0.24981	-Amount of internal connections 3	~~-% of commercial area of total land area~~	-Green Space Density (m2/person) 16.8
-Open Space Ratio (OSR) 1.01351	-Proximity to transit-hub 1600	-Distance to city centre 2000	-% Canopy cover of Total area 12%
-Gross Floor Area (GFA) 7837.64		~~-Diversity of Urban interfaces~~	-Proximity to parks (300m) Yes
-People/100GFA 4.44011			-% Solar Energy potential of total roof area 29.5%
-People/km2 32865.105419			-% of Visible Sky 52%
			~~-Wind Exposition Index~~

Figure 38. The urban performance score of the Low-Rise Apartment building typology.

The Open Space Ratio is quite high due to the low GSI and mediocre FSI, as well as a low GFA (See figure 38). Interestingly, there are quite a few people per 100 GFA in this specific typology. Furthermore, the connectivity is not on par with other typologies, mostly due to the free-floating low towers in the landscape.

7.1.4. High-Density Open Development

7.1.4.1. High-Rise Tower Blocks

By the late 1940s, a shift in urban development saw apartment buildings being more liberally distributed across the landscape, adhering to the modernist principle of 'buildings in a park' (Rådberg & Friberg, 1996). This transition laid the groundwork for what would become the golden age of apartment buildings in the 1950s. From 1955 to 1965, a substantial number of these building areas were constructed not only in major Swedish cities but also in smaller towns, marking a significant expansion in the prevalence of apartment living.

However, the introduction of prefabricated elements in the early 1960s initially proved disadvantageous for traditional apartment buildings, prompting a shift towards the construction of high-rise slab buildings (Rådberg & Friberg, 1996). Despite this, the 1980s witnessed a resurgence in the popularity of tall apartment buildings, typically ranging from 6 to 10 stories (See figure 39). These newer buildings often adopted a larger, more extended T-shaped plan. In certain cases, these T-shaped apartment buildings were interconnected to form what could be described as ‘postmodern hybrid areas’.

In these homogeneous areas where apartment buildings dominated, the structures typically ranged from six to as many as sixteen stories. This architectural trend reflects both a continuation and an evolution of apartment building design, adapting to changes in construction technologies and urban planning paradigms over the decades.

Figure 39. Image of High-Rise Tower Blocks in Högaholm, Almvik. One of the few really tall ones in Malmö   Source: Google Maps, 2024

High-Rise Tower Blocks in Almvik

These tower blocks are often grouped similarly to the previous low-rise typology. In 1969, a master plan was developed for the area, and construction began in the early 1970s (Tykesson & Ingemark, 2002a). These specific tower blocks are 17 storeys tall and lays in a campus type of urban tissue. This becomes clear due to the low connective score but also due to the layout of how you access the neighbourhood. It is purely from the east (See figure 40).

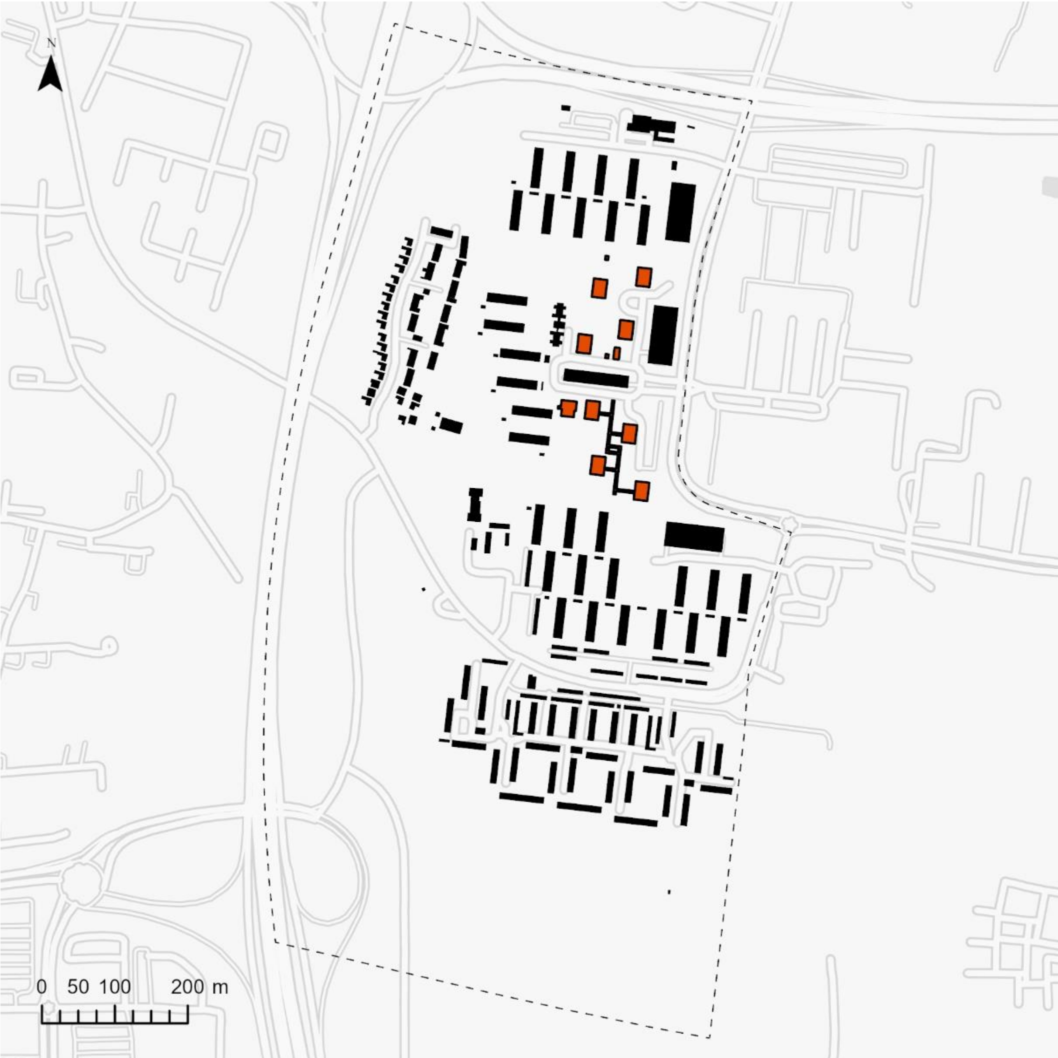

Figure 40. Overview of a High-Rise tower typology. Source: Property map © Lantmäteriet, 2024.

Urban Performance Score			
Density & Compactness Ratio	**Connectivity & Proximity to Public Transport Ratio**	**Mixed Land-Use and Functional Diversity Ratio**	**Greening and Environmental Performance Ratio**
- Floor Space Index (FSI) 1.396656	-External connectivity (Space Syntax) Bad	-Amount of POI 0 (61)	-% of Green Space of Total Area 50%
-Ground Space Index (GSI) 0.110193	-Amount of internal connections 0	~~-% of commercial area of total land area~~	-Green Space Density (m2/person) 19.8
-Open Space Ratio (OSR) 0.637098	-Proximity to transit-hub 2000	-Distance to city centre 4800	-% Canopy cover of Total area 24%
-Gross Floor Area (GFA) 65108.6		~~-Diversity of Urban interfaces~~	-Proximity to parks (300m) Yes
-People/100GFA 1.800069			-% Solar Energy potential of total roof area 32%
-People/km2 25140.782107			-% of Visible Sky 56%
			~~-Wind Exposition Index~~

Figure 41. The urban performance score of the High-Rise tower block typology.

This type of typology results in a low GSI, making it not a compact form but a dense one in terms of population within a neighbourhood (See figure 41). It also scores highly in greening and environmental performance, with high values in most parameters.

7.1.4.2. Slab Buildings

The concept of 'slab buildings' typically denotes elevator-equipped buildings, usually between 6 to 10 stories high, that belong to the lamella house type and have a minimum length of 50 meters (Rådberg & Friberg, 1996). These structures may feature straight or curved plan shapes and generally include 3 - 4 separate stairwells, although variants exist, such as corridor houses where stairwells are attached externally, creating lofts.

Slab buildings first emerged in the 1930s within traditional city blocks of major cities, forming a distinctive urban type (Rådberg & Friberg, 1996). However, it was during the substantial suburban expansions of the 1950s and 1960s that tall slab buildings became more prevalent. These developments often required considerable separation between buildings, leading to a lower ratio of built-up land. In certain instances, slab buildings were integrated with tower blocks within the same development area, reflecting a diversified approach to urban residential construction.

Figure 42. Image of High-Rise Tower Blocks in Högaholm, Almvik. One of the few really tall ones in Malmö. Source: Google Maps, 2024.

Slab buildings in Bellevuegården

Bellevuegården lies in the south-western part of Malmö and features a varied typology. The slab buildings, constructed as part of the 1970s Million Programme strategy, are situated in the eastern part of the area. This is commonly referred to as Bellevuegården (Tykesson & Ingemark, 2002b) (see Figure 42-43). This neighbourhood was one of the last to be developed in Malmö as part of the Million Programme.

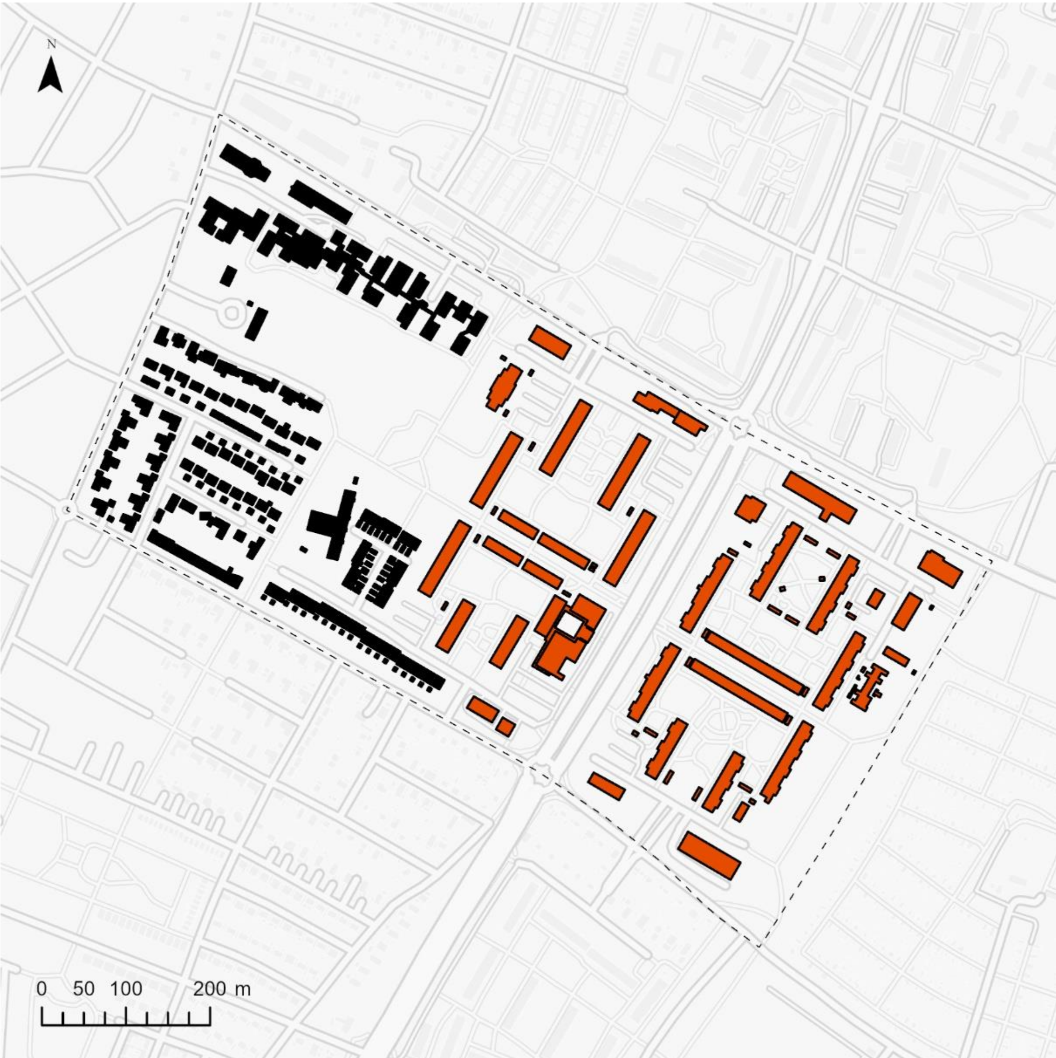

Figure 43. Overview of the Slab building typology in Bellevuegården. Source: Property map © Lantmäteriet, 2024.

Urban Performance Score			
Density & Compactness Ratio	**Connectivity & Proximity to Public Transport Ratio**	**Mixed Land-Use and Functional Diversity Ratio**	**Greening and Environmental Performance Ratio**
- Floor Space Index (FSI) 0.660436	-External connectivity (Space Syntax) Good	-Amount of POI 22 (52)	-% of Green Space of Total Area 52%
-Ground Space Index (GSI) (Ground coverage) 0.179533	-Amount of internal connections 127	~~-% of commercial area of total land area~~	-Green Space Density (m2/person) 33
-Open Space Ratio (OSR) 1.24231	-Proximity to transit-hub 2000	-Distance to city centre 2800	-% Canopy cover of Total area 13%
-Gross Floor Area (GFA) 166594		~~-Diversity of Urban interfaces~~	-Proximity to parks (300m) Yes
-People/100GFA 2.399846			-% Solar Energy potential of total roof area 36%
-People/km2 15849.45678			-% of Visible Sky 72.8%
			~~-Wind Exposition Index~~

Figure 44.Urban performance score for the Slab building typology in Bellevuegården.

Similar to the previous one the Slab buildings also score higher on greening and environmental performance. Bellevuegården specifically had a really high percentage of visible sky (See figure 44).

7.1.4.3. High-Rise and Low-Rise Buildings

During the large-scale urban developments of the 1950s and 1960s, and in areas built with prefabricated elements from 1965 to 1975, there emerged blocks that combined high-rise buildings (either lamella houses or tower blocks) with low lamella houses (Rådberg & Friberg, 1996). This architectural strategy was clearly aimed at optimizing the advantages of both building types.

By incorporating low three- or four-story buildings, planners were able to create semi-open, protected courtyards, enhancing the living environment (Rådberg & Friberg, 1996). The addition of occasional high-rise buildings within these blocks not only maximized land use but also aimed to offer a more varied and visually engaging skyline. This approach often had an aesthetic dimension as well, intending to provide residential areas with a dramatic and visually interesting skyline that could be appreciated from afar. The resulting mixed-use areas reflect a deliberate effort to extract the 'best' qualities from both high-rise and low-rise structures, contributing to both functional and aesthetic enhancements in urban development.

Figure 45. Image of the High-Rise and Low-Rise mix of a typology. Source: Google Maps, 2024.

High-Rise and Low-Rise in Törnrosen

The administrative area is almost as large as the typology in this specific part of Malmö (See figure 45-46). A concept the planners had with this neighbourhood was that the number of floors would increase the further in you were (Tykesson & Ingemark, 2002). Quite opposite to todays style were the tallest buildings are placed in the outskirts of the block to protect from e.g. sound.

Figure 46. Overview of the High-Rise and Low-Rise mix of a typology. Source: Google Maps, 2024.

Urban Performance Score			
Density & Compactness Ratio	**Connectivity & Proximity to Public Transport Ratio**	**Mixed Land-Use and Functional Diversity Ratio**	**Greening and Environmental Performance Ratio**
- Floor Space Index (FSI) 0.835442	-External connectivity (Space Syntax) Decent	-Amount of POI 22 (32)	-% of Green Space of Total Area 49%
-Ground Space Index (GSI) (Ground coverage) 0.175872	-Amount of internal connections 15	~~-% of commercial area of total land area~~	-Green Space Density (m2/person) 20.5
-Open Space Ratio (OSR) 0.986457	-Proximity to transit-hub 1600	-Distance to city centre 2800	-% Canopy cover of Total area 28%
-Gross Floor Area (GFA) 109299.7		~~-Diversity of Urban interfaces~~	-Proximity to parks (300m) Yes
-People/100GFA 2.87375			-% Solar Energy potential of total roof area 27%
-People/km2 24008.520731			-% of Visible Sky 64.35%
			~~-Wind Exposition Index~~

Figure 47. Urban performance score for the High-Rise and Low-Rise typology in Törnrosen.

Similar to other typologies with tall buildings but large plots, this type of typology scores well in greening and decent in connectivity (See figure 47).

7.1.4.4. New modernistic buildings

In the 21st century, urban planning paradigms began to deviate from the traditional closed block form, embracing a more open configuration (See figure 48-49) (Björk, Nordling, & Reppen, 2018). The integration of urban spaces with water and natural environments was deemed as crucial as the configuration of urban streetscapes. Typically, residential buildings in these plans range from five to eight stories, positioned in close proximity to one another. Strategic placement of occasional taller structures is employed to achieve distinct architectural impacts in specific locations. By the mid-1990s, urban living had gained popularity among diverse demographics, including families with children. This period marked a phase of urban intensification, characterized by the construction of new residential structures showcasing neo-modernist architectural styles. Additionally, the design of small courtyards and nearby areas was executed with fine attention to detail.

Figure 48. Image of the new modernistic typology in Värnhem (Norra Sorgenfri). Source: Google Maps, 2024.

New modernistic typology in Värnhem

In the sourthern part of Värnhem administrative area lays a quite new development that mirrors today’s way to build and plan neighbourhood. Here there exists ideals about compact as well as dense city. Though what usually gets forgotten is access to greenspace.

Figure 49. Overview of the new modernistic typology. Source: Google Maps, 2024.

Urban Performance Score			
Density & Compactness Ratio	**Connectivity & Proximity to Public Transport Ratio**	**Mixed Land-Use and Functional Diversity Ratio**	**Greening and Environmental Performance Ratio**
- Floor Space Index (FSI) 1.424844	-External connectivity (Space Syntax) Good	-Amount of POI 3 (17)	-% of Green Space of Total Area 31%
-Ground Space Index (GSI) (Ground coverage) 0.357344	-Amount of internal connections 35	~~-% of commercial area of total land area~~	-Green Space Density (m2/person) 25.2
-Open Space Ratio (OSR) 0.451036	-Proximity to transit-hub 800	-Distance to city centre 1600	-% Canopy cover of Total area 2%
-Gross Floor Area (GFA) 99090		~~-Diversity of Urban interfaces~~	-Proximity to parks (300m) Yes
-People/100GFA 0.86487			-% Solar Energy potential of total roof area 27.6%
-People/km2 12323.057113			~~-% of Visible Sky~~
			~~-Wind Exposition Index~~

Figure 50. Urban performance score for the new modernistic typology in Värnhem.

Due to limited digital surface models the Sky View Factor could not be calculated. On the other hand, it’s interesting to see that there is a high Green Space Density (See figure 50). Though the canopy cover is quite alarming, this is most likely due to the trees are still young and don’t have expansive canopies.

7.2. Assessment overview

The parameters for each typology have been compiled into a single table to provide an overview of how each typology compares to the others (see Table 8). A mean value for each metric has been calculated at the bottom of the table, serving as a reference for what is considered ‘normal.’ Values scoring above this threshold are considered better and are marked in green, except for the parameter People/GFA as this would promote overcrowding affecting people’s quality of life in a negative manner. The more values scoring above average a typology has, the higher its Urban Performance Score.

Typology	Administrative area	Floor Space Index (FSI)	Ground Space Index (GSI) (Ground coverage)	Open Space Ratio (OSR)	Gross Floor Area (GFA)	People/GFA	People/km2	External connectivity (Space Syntax)	Amount of internal connections	Proximity to transit-hub	Amount of POI	Distance to city centre	-% of Green Space of Total Area	Green Space Density (m2/person)	-% Canopy cover of Total area	Proximity to parks (300m)	% Solar Energy potential of total roof area	% of Visible Sky
Stone City block	Rörsjöstaden	1.77	0.44	0.30	148557.9	1.28	22914.44	Good	15	800	20 (80)	800	13.4%	5.9	6%	Yes	24.7%	28.4%
Reformed Blocks	Östervärn	1.61	0.39	0.37	98283.9	2.47	39972.56	Good	30	400	18 (57)	2000	26.4%	6.6	8.5%	Yes	26%	43%
Urban Lamella Houses	Östra Sorgenfri	0.84	0.22	0.92	30409.6	2.32	19586.76	Good	11	1200	3 (33)	1600	40.4%	20.7	18%	Yes	31.6%	53.5%
Urban High-Rise buildings	Ribersborg	1.70	0.18	0.47	73557.9	1.52	25959.99	Good	22	1600	3 (54)	1600	62.4%	24	11%	Yes	15%	52%
Postmodern Blocks	Fågelbacken	1.87	0.31	0.36	25433	1.36	25489.61	Good	5	1200	1 (31)	1200	41%	16.1	4%	Yes	19.6%	49%
Small Town Blocks	Gamla staden	1.44	0.48	0.35	40193.4	1.62	23382.95	Good	13	800	3 (395)	800	14%	6.12	5%	Yes	17%	41.8%
Townhouses	Västra Sorgenfri	1.59	0.40	0.37	54689.6	2.45	39074.32	Good	6	1200	6 (49)	1200	26.6%	7	9%	Yes	23.8%	40.5%
Detached Lamella Houses	Rönneholm	1.28	0.30	0.54	86847.6	1.77	22749.54	Decent	23	2000	14 (60)	2000	41.5%	18.3	10.5%	Yes	26%	53.2%
Terraced Lamella Courtyards	Mellanheden	0.65	0.22	1.19	32129	2.14	13988.63	Good	14	2000+	24 (83)	2800	62.4%	44.6	12%	Yes	27%	65.7%
Low-Rise Apartment buildings	Dammfri	0.74	0.24	1.01	7837.64	4.44	32865.10	Bad	3	1600	0 (31)	2000	55%	16.8	12%	Yes	29.5%	52%
High-Rise Towerblocks	Almvik	1.39	0.11	0.63	65108.6	1.80	25140.78	Bad	0	2000	0 (61)	4800	50%	19.8	24%	Yes	32%	56%
Slab buildings	Bellevuegården	0.66	0.17	1.24	166594	2.39	15849.45	Good	127	2000	22 (52)	2800	52%	33	13%	Yes	36%	72.8%
High-Rise and Low-Rise Buildings	Törnrosen	0.83	0.17	0.98	109299.7	2.87	24008.52	Decent	15	1600	22 (32)	2800	49%	20.5	28%	Yes	27%	64.35%
New modernistic buildings	Värnhem (Norra Sorgenfri)	1.42	0.35	0.45	99090	0.86	12323.05	Good	35	800	3 (17)	1600	31%	25.2	2%	Yes	27.6%	-
Mean		1.27	0.28	0.66	74145.13	2.09	24521.84	Good	22.7	1323.077	10	2000	40.36%	18.90143	12%	Yes	25.91%	51.71%

Table 8. The table shows all the assessed parameters compiled, with green highlighting values that score higher than the mean value at the bottom of each column.

Some interesting results that can be derived from the table reveal that typologies situated farther from the city centre generally display higher values for greening metrics, including canopy coverage and green space. This pattern is consistent across various typologies, including *Detached Lamella Houses* in Rönneholm, *Terraced Lamella Courtyards* in Mellanheden, and *Slab Buildin*gs in Bellevuegården. A similar trend can be observed for solar energy potential, where typologies with lower density and compactness scores, typically located farther from the city centre, demonstrate greater potential for solar energy. This is supported by existing research that highlights the adverse effects of shading from adjacent buildings on solar potential. Also, these typologies often demonstrate higher resilience to environmental challenges, such as flash floods and urban heat islands, in comparison to typologies with lower Open Space Ratios, which are less sustainable in managing these threats.

The relationship between density and land use, as indicated by metrics such as Floor Space Index (FSI) and Ground Space Index (GSI), further illustrates this trend. Neighbourhoods like Rörsjöstaden (FSI 1.77) and Fågelbacken (FSI 1.87) are characterised by denser development, while areas such as Mellanheden (FSI 0.65) reflect less dense environments with more open space. GSI values provide additional insight, showing that neighbourhoods with lower GSI, such as Bellevuegården, cover less ground with buildings, thereby offering more open areas. Mellanheden, for example, has the highest Open Space Ratio (1.19), which indicates a significant amount of open space that likely enhances residents' wellbeing. Neighbourhoods like Bellevuegården (52% green space) and Almvik (50%) also benefit from substantial green space, contributing to better environmental quality and liveability.

The results from the assessment also show that typologies located further from the city centre often trade off proximity to transit hubs and external connectivity. This implies that residents in these areas may be more reliant on less sustainable modes of transport, as they must travel longer distances to reach key *Points of Interest* (POIs). Although these typologies tend to have numerous POIs within their boundaries, this is largely a function of their larger plot areas, which can naturally accommodate more amenities. The number of POIs within a neighbourhood is indicated in parentheses, highlighting that typologies closer to the city centre tend to have a higher concentration of POIs at the neighbourhood level. This, in turn, enhances the sustainability of these central neighbourhoods from a transportation perspective, as residents can access a greater number of amenities within shorter distances.

Neighbourhoods with stronger connectivity, such as Östervärn and Norra Sorgenfri, score higher in terms of internal and external connections, indicating greater accessibility both within the neighbourhood and to surrounding areas. Proximity to transit hubs also plays a crucial role in enhancing mobility. Typologies closer to transit hubs (800-1600m), such as Rörsjöstaden and Gamla Staden, enjoy greater accessibility to public transport, making commuting more convenient. Additionally, population density and the availability of amenities are important considerations. Higher-density urban typologies, such as Östervärn (39,972 people/km^2), tend to foster more vibrant, though potentially more crowded, environments. Meanwhile, areas like Bellevuegården (24 POIs) and Mellanheden (22 POIs) offer a range of amenities, contributing to a higher quality of life for residents.

Environmental sustainability is also closely tied to canopy cover and solar energy potential. Higher canopy cover, as seen in Bellevuegården (13%) and Törnrosen (28%), provides benefits such as shading, which helps mitigate the urban heat island effect. Additionally, areas like Mellanheden (65.7% solar energy potential) and Almvik (56%) are well-suited for sustainable energy generation. A clear trend emerges regarding the relationship between distance from the city centre and environmental factors such as visible sky and canopy coverage. Typologies further from the city centre, such as Almvik (4800m, 56% visible sky) and Mellanheden (2800m, 72.8%), tend to have more visible sky, likely due to lower building heights and reduced density. Similarly, these areas demonstrate higher canopy coverage and green space, with Almvik featuring 24% canopy cover and 50% green space, compared to more central areas like Rörsjöstaden, which has just 6% canopy cover and 13.4% green space.

In summary, typologies located further from the city centre generally exhibit greater visible sky, higher canopy coverage, more green space, and enhanced solar energy potential. On the other hand, central typologies tend to feature higher population densities, superior connectivity, and fewer open spaces, reflecting the trade-off between urban density and environmental quality. Bellevuegården with its Slab building typology stands out as a high performer across multiple environmental and connectivity metrics, while Mellanheden and its Terraced Lamella courtyards excels in open space, green space, solar potential, and visible sky. Östervärn and the Reformed block typology scores well in population density, connectivity, and liveability, making all three typologies strong all-round performers based on the diverse range of metrics in the table. This suggests that trade-offs are inevitable, as certain metrics, such as Open Space Ratio (OSR) and Ground Space Index (GSI), are often inversely related and do not complement each other. In essence, no single typology emerges as the optimal solution across all sustainability metrics. Therefore, achieving a sustainable urban form requires a combination of different typologies, each contributing its strengths to create a more balanced and resilient urban environment.

8. Concluding discussion

A way to achieve a sustainable urban form has been approached in multiple academic paper. The point of departure has been to frame the dimensions of sustainable form and find ways to both understand it and evaluate it. Just as in this thesis, the aim has been to understand the concept of sustainable form and to where Swedish Urban Typologies score on such concepts. Notably, the complexity of such concept seems to be wicked in its essence with its multitude of dimensions that interlope with each other. A key point to make is that this thesis has not dwelled deep in the policy and governance type of aspects that is a dimension as well of the assemblage of a sustainable urban form, similarly user's behavioural patterns and attitudes to reaching such concept plays a role. Though, what can be concluded in this study is how the Urban Typologies in Sweden preform in relation to each other and how a framework towards a Sustainable Urban Form can be constructed.

How can the concept of sustainable urban form be defined and broken down into measurable components suitable for evaluation?

From the scoping literature review, it is clear that the concept of sustainable urban form intersects with multiple planning ideals, such as the eco-city, urban compaction, and the compact city. This indicates that there is no one-size-fits-all ideal.

In synthesising the discourse on urban intensification, it becomes evident that the journey towards denser, more sustainable urban environments is fraught with challenges. It requires a nuanced understanding of the interplay between urban development, community engagement, and environmental stewardship. The dialogue around urban intensification, which includes both the redevelopment of physical spaces and the enhancement of urban life, underscores the critical need for inclusive planning processes that recognise the diverse interests and capacities of urban communities. Urban intensification thus emerges not merely as a strategy for urban development but as a comprehensive approach to fostering sustainable, vibrant, and inclusive urban environments.

Similarly, the ongoing discourse highlights the necessity of aligning density with built form and the broader urban context. This challenges planners and critics to reconcile quantitative measures with qualitative urban experiences. Such dialogue remains crucial in navigating the pursuit of sustainable, compact urban forms that resonate with contemporary societal and environmental imperatives.

How do urban building typologies within the Swedish urban fabric contribute to and align with the principles of sustainable urban form?

What we can see from the assessment (See chapter 7.)(alt. table 4) there is no typology that fits all, or rather scores highly. Though there exist some patterns in the final result e.g. if the typology is further away from the city centre it tends to have more visible sky, this is also reflected in the Floor Space Index and Ground Space Index as those tend to become lower, which in terms mean less compact of an urban fabric. A further interesting aspect, is that these type of typologies are prone to infill densification in the contemporary planning. But in sense, it’s logical it’s hard to make an already compact form more compact. In that sense, the aim should be on densifying rather than compacting. But yet again that may fall entail other quality of life sacrifices e.g. less daylight, greenery etc. So can one really say that a typology in that sense can contribute to a sustainable form? Perhaps, but it all depends on the policy makers view on sustainability.

What analytical framework can be developed to assess the contribution of different urban building typologies to sustainability, and how effective is this framework in the context of Swedish cities?

There can be little doubt that making our cities more sustainable in the future requires a holistic approach to reducing demand for space and water eating, power and lighting and use of motorised transport, and increasing self-sufficiency in lifestyle practices. I argue that there's a need for diverse types of compact development that account for local regulations and social preferences, aligning with suggestions from various urban planning experts. Compact development should evolve towards enhancing liveability rather than focusing solely on urban densification, incorporating elements of human scale and Quality of Place/life.

8.1. Method reflection and further explorations

Multiple papers have conducted systematic reviews attempting to frame sustainable urban form in various ways. An interesting reflection is that similar literature recurs and could lead to confirmation bias connected to the aims of these studies, including this one. Categorising the dimensions of the scoping literature review into ecological, economic, social, and cultural sustainability might have made the study more aligned with common planning strategies and terminology, potentially reaching a wider audience.

There are also various approaches to achieving the different parameters. For instance, this study did not consider the block surface ratio (facades + roof + open space/plot area) when calculating solar potential, meaning no vertical potential was calculated. Due to the study's limitations, urban interfaces and wind exposition indices were not explored further. The space syntax analysis did not examine green space integration as Ståhle (2005) did in his dissertation, resulting in a negligible assessment of green space connectivity and access.

Further studies may try to utilise some of these typologies in a parametric modelling approach. Additionally, the environmental theme could be explored with more specialised tools like Envi-met. However, the search for a sustainable urban form would still continue.

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10. Appendix 1

Google Scholar search result data.

Search term	Total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Urban Archetypes	484	11	7	5	3	12	21	11	5	10	10	14	19	19	16	19	24	30	46	28	31	42	37	30	34
Urban Typology	3901	23	39	37	36	50	49	57	55	73	100	76	119	148	178	224	193	285	210	260	296	281	350	384	378
Urban Form	166610	1800	1890	2270	2380	2550	2900	3070	3680	3950	4480	5070	5700	6990	7590	8210	7840	9360	9780	10600	11500	11600	12700	13900	16800
Urban Patterns	23671	295	253	363	390	383	426	529	572	607	696	746	831	1090	1230	1310	1310	1480	1550	1560	1560	1510	1720	1720	1540
Urban Morphology	49599	293	310	409	478	552	559	608	732	855	973	1100	1360	1640	1900	2340	2470	2870	2980	3360	3860	4110	4750	5950	5140
Urban Densification	9197	19	29	41	29	43	42	56	66	74	117	148	177	484	282	372	453	543	602	718	756	906	1040	1120	1080
Urban Metrics	1476	1	10	5	3	2	5	6	8	9	10	28	33	26	42	61	48	64	111	105	131	135	178	250	205
Sustainable Urban Form	10049	123	123	125	155	147	191	209	251	229	325	299	376	486	613	524	566	599	675	702	699	703	644	686	599
Sustainable Urban Design	7845	19	29	19	63	80	76	120	144	178	198	256	311	331	441	345	412	482	443	481	536	550	684	752	895
Sustainable Urban Form																									
Sustainable urban form AND Urban typology	91	0	0	2	0	1	0	1	1	1	3	2	3	7	6	4	3	12	8	4	7	5	3	6	12
Sustainable urban form AND Urban patterns	885	8	6	10	7	14	8	15	18	20	26	30	32	38	48	49	50	72	60	78	60	47	63	71	55
Sustainable urban form AND Urban morphology	1376	7	7	7	14	14	17	11	12	19	27	31	58	61	64	72	47	87	98	105	115	131	95	151	126
Sustainable urban form AND Urban densification	524	1	5	4	1	5	6	6	4	4	16	8	15	27	23	23	24	35	37	38	37	53	48	41	63
Sustainable urban form AND Urban metrics	38	1	0	0	0	0	1	0	0	1	0	0	0	1	0	3	1	5	4	3	5	3	2	2	6
Sustainable Urban Design																									
Sustainable urban design AND Urban typology	85	0	0	1	1	1	0	0	2	0	1	0	4	11	4	6	3	7	7	5	5	4	5	7	11
Sustainable urban design AND Urban patterns	447	1	3	2	6	5	5	11	11	11	11	16	16	22	34	20	21	37	26	28	23	28	40	35	35
Sustainable urban design AND Urban morphology	1014	0	1	1	4	2	5	7	5	14	15	14	32	42	45	28	50	62	66	61	62	88	119	145	146
Sustainable urban design AND Urban densification	192	0	1	0	1	0	2	1	1	3	4	3	5	12	6	7	5	13	11	16	15	16	23	21	26
Sustainable urban design AND Urban metrics	19	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	3	0	2	3	3	5
Sustainable Urban Form AND Sustainable Urban Design	624	2	4	5	5	7	13	14	15	15	25	14	29	29	35	37	34	44	50	56	46	40	37	40	28

ScienceDirect search result data.

Search term	Total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Urban Archetypes	40	1	0	0	0	0	0	0	0	0	1	0	0	0	3	0	2	2	4	5	4	3	8	4	3
Urban Typology	427	1	1	1	2	1	1	3	2	0	6	6	7	9	14	23	23	31	26	26	35	50	40	57	62
Urban Form	9418	61	91	81	69	99	104	102	109	149	178	167	236	302	335	372	511	573	657	669	800	884	946	957	966
Urban Patterns	1753	20	19	19	16	28	15	21	19	31	37	27	44	82	73	79	91	106	129	122	143	149	152	159	172
Urban Morphology	4292	16	12	10	25	24	26	20	32	25	57	42	61	105	99	141	174	242	308	318	311	426	536	624	658
Urban Densification	846	0	0	1	0	3	1	3	1	5	4	10	12	9	16	25	28	52	60	60	85	88	112	130	141
Urban Metrics	116	0	0	0	1	0	1	0	0	0	2	1	1	1	4	5	4	3	6	9	9	14	22	19	14
Sustainable Urban Form	359	1	3	6	4	0	4	3	2	5	5	6	7	15	20	23	27	34	34	23	28	30	28	24	27
Sustainable Urban Design	385	0	1	0	1	0	0	2	4	7	0	6	15	14	12	17	31	23	41	28	27	26	41	43	46
Sustainable Urban Form																									
Sustainable urban form AND Urban typology	17	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	3	3	0	1	1	1	2	2
Sustainable urban form AND Urban patterns	42	0	0	0	0	0	0	0	0	0	0	0	0	3	1	4	4	4	4	3	3	6	4	3	3
Sustainable urban form AND Urban morphology	57	0	0	0	0	0	1	0	0	0	1	0	1	1	1	1	1	6	8	5	5	7	8	4	7
Sustainable urban form AND Urban densification	18	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	1	2	0	0	1	5	0	3	0
Sustainable urban form AND Urban metrics	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0
Sustainable Urban Design																									
Sustainable urban design AND Urban typology	9	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	3	0	1	0	1	2	0
Sustainable urban design AND Urban patterns	26	0	0	0	0	0	0	0	0	1	0	0	1	2	1	3	2	1	5	4	1	3	0	0	2
Sustainable urban design AND Urban morphology	79	0	1	0	0	0	0	0	0	0	0	1	5	3	0	0	4	3	9	6	3	6	13	11	14
Sustainable urban design AND Urban densification	10	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	3	1	1	2	0
Sustainable urban design AND Urban metrics	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Sustainable Urban Form AND Sustainable Urban Design	22	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	3	1	5	3	0	1	2	3	1

SpringerLink search result data.

Search term	Total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Urban Archetypes	42	1	1	0	0	1	0	1	1	1	0	0	1	0	3	0	1	0	5	4	3	1	1	3	14
Urban Typology	416	1	0	2	1	4	1	4	5	4	7	4	7	9	5	20	14	23	20	30	23	30	64	49	89
Urban Form	9027	79	68	90	87	100	105	102	169	165	169	179	259	263	330	343	366	473	503	576	647	710	974	1126	1144
Urban Patterns	2183	28	16	26	16	31	17	33	35	66	51	57	64	73	59	92	84	104	111	143	160	143	256	232	286
Urban Morphology	2929	15	17	8	13	25	22	23	33	49	50	45	62	67	85	83	119	131	164	184	205	226	422	330	551
Urban Densification	590	1	1	0	1	1	3	1	2	3	3	9	13	5	22	10	11	19	38	36	40	56	94	84	137
Urban Metrics	114	0	2	1	0	0	2	0	1	2	0	3	3	1	1	2	5	2	7	7	5	5	11	18	36
Sustainable Urban Form	500	3	6	8	7	12	9	8	11	10	14	15	16	14	37	12	15	23	11	30	32	33	50	56	68
Sustainable Urban Design	473	0	2	0	0	2	1	1	10	5	5	6	13	12	13	20	15	17	16	26	23	33	93	60	100
Sustainable Urban Form																									
Sustainable urban form AND Urban typology	34	0	0	0	0	0	0	0	0	0	1	0	11	0	0	0	0	1	0	1	0	1	5	7	7
Sustainable urban form AND Urban patterns	111	0	1	2	0	2	1	0	1	3	1	1	5	4	1	3	2	5	4	4	5	6	21	22	17
Sustainable urban form AND Urban morphology	125	0	1	1	1	2	1	1	3	0	3	1	1	2	1	3	1	4	2	5	7	9	21	26	29
Sustainable urban form AND Urban densification	43	0	0	0	0	1	0	0	0	0	0	0	1	1	1	0	1	1	0	0	0	6	8	12	11
Sustainable urban form AND Urban metrics	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1
Sustainable Urban Design																									
Sustainable urban design AND Urban typology	12	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	2	3	5
Sustainable urban design AND Urban patterns	58	0	0	0	0	2	0	0	2	1	0	0	3	1	0	1	2	1	1	3	1	7	9	11	13
Sustainable urban design AND Urban morphology	85	0	0	0	0	2	0	0	0	0	1	0	1	2	1	1	5	1	3	3	3	3	13	21	25
Sustainable urban design AND Urban densification	17	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	2	2	4	7
Sustainable urban design AND Urban metrics	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	3
Sustainable Urban Form AND Sustainable Urban Design	49	0	1	0	0	1	0	0	0	1	2	1	0	1	0	1	0	2	1	7	6	5	4	7	9

11. Appendix 2

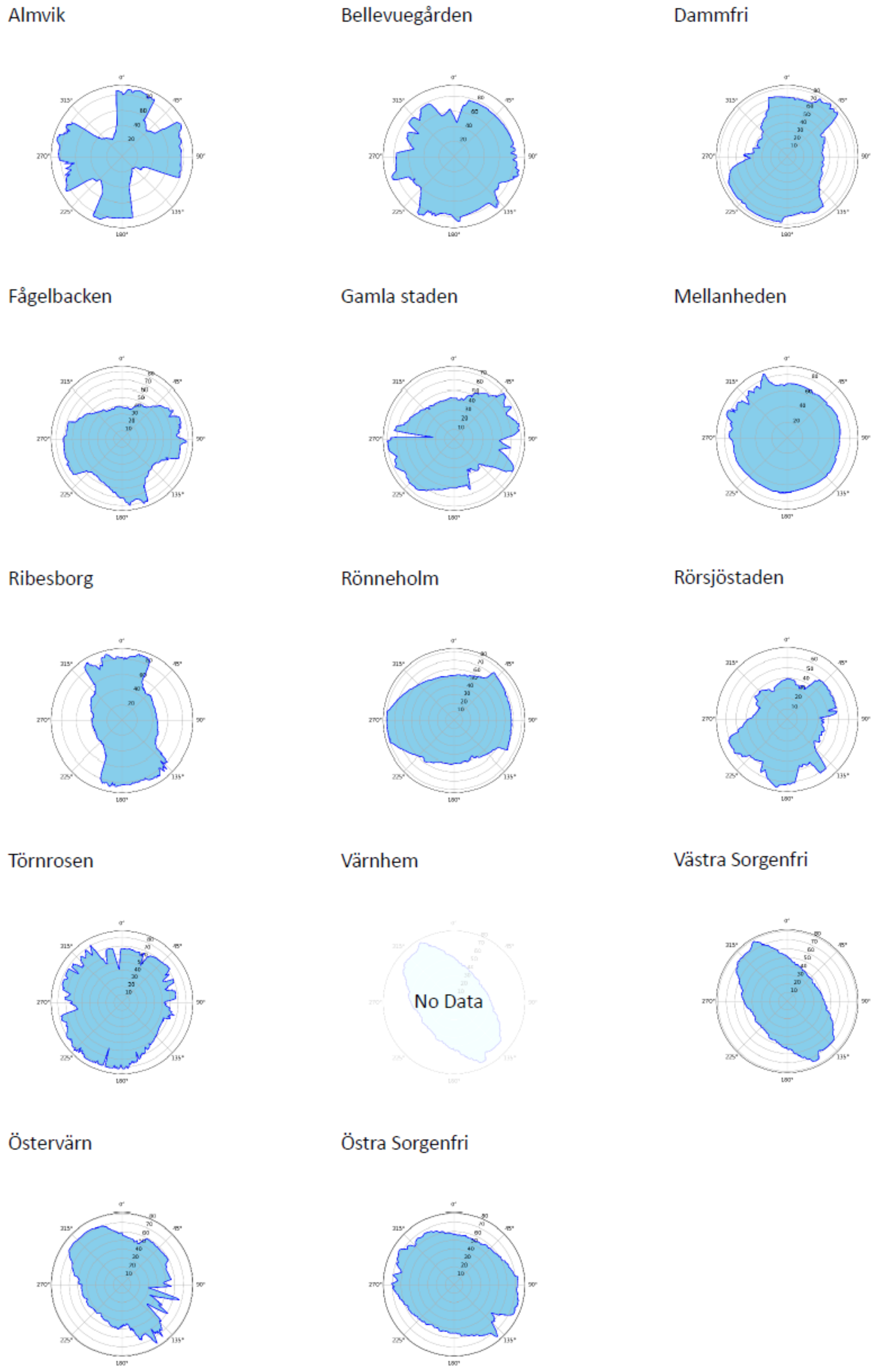
List of all the keywords found in the articles from the literature review. There were 111 keywords in total, and 59 of them were unique.

- Urban form (4)
- Urban planning (4)
- Compact city (3)
- Green infrastructure (3)
- Sustainable urban development (3)
- Sustainability (3)
- Urban morphology (3)
- Infrastructure (2)
- Urbanization (2)
- Urban Development (2)
- Resilience (2)
- Governance (2)
- Ecosystem services (2)
- 3D visualization (2)
- Indicators (2)
- Cities (2)
- Public transit (2)
- Quality of life (2)
- Urban sprawl (2)
- Compactness (2)
- Sustainable urbanism (2)
- Infill development (2)
- Public participation (2)
- Sustainable urban design (2)
- Suburbs (2)
- Accessibility (2)
- Suburban design (2)
- ZEB (2)
- Microclimate (2)
- Planning policy (1)
- Land assembly (1)
- Development controls (1)
- Zoning (1)
- Local Geographically Weighted Regression (1)
- Post-pandemic cities (1)
- Complex adaptive system (1)
- Green space change (1)
- Ecological urban design (1)
- New urbanism (1)
- Space syntax (1)
- Traditional urban design (1)
- Urban ecology (1)
- Shanghai neighborhoods (1)
- Building energy performance (1)
- FAR (1)
- Sustainable urban form (1)
- Fractional vegetation cover (1)
- Landscape metrics (1)
- 2-D wavelet multiresolution analysis (1)
- Urban metabolism (1)
- Bibliometric analysis (1)
- Recycling (1)
- Procedural modeling (1)
- Urban green space typology (1)
- Generic pattern design (1)

- Urban Underground Space (1)
- Future Cities (1)
- Resource Management (1)
- Solar analysis and parametric urban design (1)
- Photovoltaic systems (1)
- Urban sustainability framework (1)
- Systems approach (1)
- Blue green urban design (1)
- Urban ecosystem services (1)
- Urban natural capital (1)
- Thermal comfort (1)
- Urban microclimate (1)
- ENVI-met (1)
- Mean radiant temperature (1)
- Climate change (1)
- Court-yarded cluster (1)
- Sustainable housing (1)
- Energy crisis (1)
- Solar radiation (1)
- BIPV (1)
- Compressed earth blocks (1)
- Green economy (1)
- Architecture character (1)
- Urban identity (1)
- Arid city (1)
- Urban pollution (1)
- PM10 (1)
- Urban air pollution (1)
- Modal choice (1)
- Urban Morphology (1)
- Landscape (1)
- Measures (1)
- Spatial Analysis (1)
- Quantitative Methods (1)

12. Appendix 3

Space syntax of all typologies by neighbourhood.



SkyViewFactor of all typologies by neighbourhood.