Pedal Power and Footsteps: Developing a Sustainable Neighborhood by Empowering Active Mobility in Niederrad

Master Thesis

Master of Science Urban Agglomerations

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Abstract

Niederrad neighborhood is located between the city center and Frankfurt airport on the southern bank of the Main River in Frankfurt am Main. Despite its location and growing population, Niederrad faces challenges related to pedestrian and cycling experiences. The majority of mono-functional areas contribute to a lack of friendliness and vitality. Moreover, the absence of a well-connected, continuous, and secure network for pedestrians and cyclists is a drawback in the neighborhood's overall accessibility. This thesis focuses on a specific section of the neighborhood within Ped-Shed circles with radii measuring 400 meters and 800 meters. It employs a combination of desktop and on-site research using an analytical framework. In addition, it acknowledges the features of land use and active mobility, including walking and cycling, within the theoretical basis. The assessment identifies neighborhood characteristics through a SWOT analysis, offering a comprehensive insight into the existing urban fabric and potential areas for enhancement. This research focuses on integrating pedestrian-friendly infrastructure, enhancing bicycle networks, and implementing community engagement measures. The study addresses sustainable urban development by providing insights into strategies for empowering active mobility through neighborhood transformation. These strategies include prioritizing pedestrians and cyclists, engaging communities through vibrant public spaces, and integrating green infrastructure. Finally, the recommended actions aim to create vibrant, pedestrian-friendly, and environmentally sustainable urban spaces, with timelines ranging from immediate to short-term for effective implementation and monitoring.

Keywords: Active mobility, Sustainable urban development, Land use, Neighborhood transformation

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1

Introduction

1. Introduction

1.1. Background problem and significance

Urban areas have changed over the years. Under the increasing industrial development, the cities have transformed from pedestrian-friendly to car-oriented places. This issue has become a worldwide threat concerning obesity, air pollution, and health problems. However, due to the growing awareness of global warming and the need to conserve the environment in recent years, efforts have been made to make the cities more sustainable (Doheim, et al., 2020).

The built environment, transport infrastructure, and urban design influence sustainability and sense of place and community in cities. As Newman mentioned, positive change in mobility infrastructure will adapt the automobile city fabric to the human scale. This new environment is not only livable but also sustainable (Newman, 2015).

Building a sustainable neighborhood involves empowering active mobility. Active travel provides a sustainable and easy way to engage in physical activity, especially walking and cycling. Increasing walkability not only increases individual territory on a human scale but also leads to better social, economic, cultural, and environmental sectors on a global scale (Yildirim, et al., 2023).

In recent years, researchers have been exploring the connection between active travel and public health. The built environment plays a significant role in determining whether people engage in active transportation for daily travel. Factors such as the presence of walking and cycling infrastructure, access to public transit, street connectivity, housing density, and mixed land use all influence active transport (Pucher, et al., 2010). So, increasing walking and cycling on a neighborhood scale is a big step toward having sustainable neighborhoods.

Many European cities are increasingly focused on encouraging people to walk and cycle in urban areas, aligning with the 17 UN Sustainable Development Goals (Bianchi, et al., 2023). So, prioritizing active mobility as a sustainable mode of transportation is a key factor. As cities worldwide struggle with redefining their urban fabric, localized challenges in transport infrastructure and urban design are the main points for creating sustainable neighborhoods.

This thesis will investigate the specifics of the Niederrad neighborhood in the City of Frankfurt, employing it as a case study to assess and recommend how active mobility might be achieved to promote sustainability within this neighborhood.

Niederrad, situated on the southern bank of the Main River in Frankfurt am Main, is a neighborhood with new and old areas characterized by a mix of main roads, narrow local streets, and alleys. According to statistics from Stadt Frankfurt 2023, approximately 30% of Niederrad's total settlement area is designated as residential space. On the other hand, Niederrad has an ascending population. One reason is the Frankfurt-Niederrad business district redevelopment. This redevelopment project was completed in 2022, which turned a

mono-functional office quarter of the past into an integrated and mixed-use city district for 3,000 new residents (Peterek & Bürklin, 2014).

Niederrad is located between the city center and the Frankfurt airport. With recent construction activities, particularly in transforming the office spaces into a mixed-use district, Niederrad presents potential for development. These factors raise a need to prioritize sustainable active mobility modes to facilitate pedestrian-friendly pathways and cycling infrastructure. This strategy aims not only to accommodate the growing number of residents but also to create a lively environment and eco-friendly commuting options among the ongoing transformations and future developments.

Despite Niederrad's appealing location and ascending population (Stadt Frankfurt am Main, 2023), Niederrad faces several challenges that need to be addressed to empower a sustainable neighborhood. One of the problems in Niederrad is the narrow width of sidewalks in certain parts of the neighborhood. The limited space for pedestrians on the narrow local streets and alleys makes it challenging to walk comfortably and safely. This situation poses a problem for residents who rely on walking for short distances. Connectivity is also a concern in Niederrad. The neighborhood lacks a well-connected network of streets, pathways, and public transportation options. Furthermore, Niederrad lacks continuous cycling paths, which reduces the desire for cycling as an active and sustainable mode of transportation. The absence of dedicated lanes for cyclists makes it less safe and efficient for residents to choose cycling as a means of getting around the neighborhood. Additionally, the allocation of bike-sharing stations in Niederrad is not optimized. The current distribution of these stations may not meet the demand for residents who wish to use shared bicycles.

Whilst the above reflects a general overview of some of the problems facing Niederrad, a much more thorough and detailed appraisal of the area is needed to understand its problems and how they might be addressed. This thesis aims to achieve this.

1.2. Scope and objectives

1.2.1. Scope

This research focuses on only a part of Niederrad to have a detailed analysis. A Ped-Shed circle with a radius of 800 meters from a center point in the middle of the neighborhood is defined as having a standard walking distance through a pedestrian catchment. A Ped-Shed refers to a walkable catchment, which is an accessible area within a five-minute walking distance from a neighborhood or town center or a ten-minute walk from major transportation stops based on Congress for the New Urbanism (2012).

The main concern of the study is to understand the current built environment and opportunity areas to create a safe, continuous, and connected pedestrian and bicycle infrastructure with appropriate land uses with greater livability and sense of place.

1.2.2. Objectives

The goal of this research firstly is to conduct a systematic and scientific assessment of Niederrad's urban environment, identifying its strengths and weaknesses in sustainable active transport and land use. Secondly, the study aims to propose actionable recommendations based on this assessment to suggest interventions that apply to different locations within the area.

1.3. Research questions

To have a clear direction and structure, a general guiding research question is asked, followed by sub-questions to explore different variables, factors, and perspectives that contribute to the overall understanding of the leading research question. This approach helps to provide a framework for conducting a detailed analysis of findings and accurate outcomes.

General question:

How can walking and cycling be promoted and enhanced as active modes of transportation to develop a sustainable neighborhood in Niederrad?

Guiding questions:

1. Which assessment framework can be employed to have a better understanding of the study area?
2. Which specific walking and cycling attributes and features characterize the theoretical basis?
3. What is the current evaluation of the existing walking and cycling conditions in the study area?
4. What are the opportunities regarding walking and cycling in the key aspects of the study area?
5. What strategies in urban planning, design, and management can be employed to empower the study area in walking and cycling?

1.4. Thesis outline

This research begins by framing the background problem and understanding its significance, outlining clear study objectives, and formulating research questions aligned with the study's aims in the first chapter. Afterward, in the second chapter, a detailed methodology section, including data collection, assessment, and analysis methods, addresses the first research question. The following sections in the third chapter investigate the theoretical basis of sustainable neighborhoods and active mobility. Then case study is assessed in the fourth chapter by evaluating the current built environment, transport infrastructure, and urban design in Niederrad, as well as elaborating a SWOT analysis, which each targets specific research questions 2, 3, and 4. To answer the last research question, chapter 5 serves as a

detailed proposal and comprehensive plan to address the current situation in the study area within Niederrad. The thesis closes in the sixth chapter with a conclusion summarizing the key findings and their implications, as well as providing suggestions for further research.

2

Methodology

2. Methodology

This chapter presents the methodology applied in this research, focusing on utilizing quantitative data collection and assessment methods accompanied by mapping techniques and SWOT analysis. Through this process, this research aims to assess the urban fabric of the study area and present strategic recommendations for empowering walking and cycling in Niederrad.

2.1. Data collection methods

2.1.1. Desktop research

It is crucial to access relevant statistical data from government databases, surveys, and research institutions in the desktop research to understand the current state of walking and cycling in the study area. This data should contain various aspects such as walking and cycling patterns, mode share, and other relevant indicators. Additionally, including maps and up-to-date satellite imagery will provide a visual representation of the study area's infrastructure and surroundings, helping the data analysis. With these resources, a comprehensive perspective of the walking and cycling landscape will contribute to feasible suggestions at the end of the thesis.

Additionally, within desktop research, exploring good practices is vital. Analyzing case studies from diverse neighborhoods or cities that have effectively implemented active mobility initiatives or sustainable development strategies regarding walking and cycling involves a comprehensive examination of their methodologies, outcomes, and the related factors contributing to their success.

2.1.2. On-site observation

Following the initial phase of desktop research to establish a fundamental understanding, the following stage involves on-site observation as a systematic workflow. This approach allows the author to directly witness pedestrian and cyclist behaviors, assess infrastructure conditions, and gain an overall understanding of the environment. The author's residence in the same area as the case study provides a distinct advantage, as their familiarity with the local context, personal experiences, and daily interactions with the surroundings contribute valuable insights that complement the on-site observations.

2.2. Data assessment methods

The study aims to propose recommendations based on the strengths and weaknesses of sustainable transport to empower walking and cycling in Niederrad. The core indicators for assessment of the current condition are land use, mobility, and walkability within the neighborhood.

- Comprehensive consideration of diverse elements is crucial for land use assessment, like mixed land use, built environment, accessibility, amenities, and the balance between public and private spaces. Additionally, elements such as population, residential diversity, and visual cues in district elements play pivotal roles in the quality and functionality of vibrant urban fabric.
- Sustainable mobility assessments focus on commuting choices, emphasizing the quality of streets and the availability of cycle lanes and sidewalks. Evaluations consist of public transportation availability, emphasizing the continuity and accessibility of active mobility infrastructure, particularly eco-friendly modes like bicycles.
- The assessment of walkability in pedestrian-friendly environments. It involves evaluating the ease of movement and considering factors such as pedestrian amenities, permeability, block sizes, accessibility, safety measures, and building edge designs.

In the context of examining active transportation in Niederrad, this research employs the urban design framework from Bentley et al (1985) and Lynch (1960), which is explained further with examples in (Schiller & Kenworthy, 2018). This framework is a comprehensive tool to assess the fundamental elements influencing sustainable transportation and fostering healthier communities within Niederrad's urban fabric. Its systematic organization of indicators, tools, and measures allows for a detailed examination of urban elements impacting sustainable transport. Despite these strengths, potential limitations may arise from extensive data requirements and the complexity of analysis due to the framework's broad range of indicators.

Table 1 provides a comprehensive framework for evaluating urban areas. Indicators serve as the foundational factors for evaluating the attributes and quality of an urban area. Also, key tools and methodologies are employed to analyze and assess these characteristics, utilizing the indicators as a guiding framework. For understanding the study area, mapping, photography, and diagrammatic methods are used to visually assess walking and cycling-related aspects of the study area. This research will include self-generated maps obtained from a combination of desktop-based work, field surveys, and data collected from diverse sources, including Geoportal Frankfurt, OpenStreetMap, Google Erath, and Google Maps. Mapping highlights infrastructure, points of interest, and barriers, while diagrams illustrate relationships and processes. This comprehensive framework answers the first research question by including a diverse range of indicators aimed at obtaining a better understanding of the study area.

Table 1. Assessment framework for analyzing urban areas for active transport

Source: Elaborated by the Author, adapted from the framework presented by Schiller and Kenworthy (2018, pp. 209-224).

	Indicators	**Key Tools**	**Measures**
1	District structuring of an area	Urban structure map	A snapshot of the workings of a sub-region in terms of efficient movement and exchange of goods and services
2	Permeability	Ped-shed mapping	Walkability and energy efficiency
		Street network/block size and type mapping	Ease of movement around an area
		Street connectivity mapping	Choice of movement
		Blind frontage mapping	Surveillance by building fronts of the public realm
3	Variety	Land-use mapping	Single land-use versus mixed land-uses
		Figure-ground mapping	Scale of the built form
		Residential density	The number of people resident in the area
		Residential lot size mapping	Residential land sizes: in varying bands
		Dwelling type mapping	Dwelling types (single versus mixed)
		Community facilities mapping	Local facilities and amenities (Few and far away versus many and close by)
		Parkland mapping	Type, size, location, and accessibility of parkland
		Travel mode mapping	Car versus foot or public transport, long commute versus short commute
4	Legibility	Legibility analysis mapping	Intelligible aspects of the district, neighborhood, street, building and public places
		SAFE Walk Assessment mapping	Pedestrian amenity, low quality versus high quality
5	Robustness	Robust lot and building mapping	Lot types and sizes (for future redevelopment) Robust building mapping
		Solar orientation mapping	Number of lots orientated north-south and east-west alignment
		Building edge mapping	Publicly usable versus privatized or ambiguous space
6	Visual appropriateness	Visual appropriateness photography	Visual cues, and ease of interpretation as a publicly relevant building of a particular use/s
7	Richness	Day/night use mapping	Balance of uses that keep active day and night (24-hour city and suburb)
		Visual interest photography and mapping of public buildings and places	The quality of detail on publicly relevant buildings and landmarks
8	Personalization	Sense of place photography and mapping of shopping places	Scale, familiarity, and variety of the town center

This framework contains a comprehensive range of indicators. However, considering the focus of this thesis on land use, mobility, and walkability with time limit consideration, the analysis will mainly concentrate on the first six key tools within the framework. This selective approach allows for a more targeted examination aligned with the study objectives. Following this, a brief explanation of the elements within the framework is presented, with a more in-depth explanation provided in chapter four:

1. **District structuring of an area:**
   Urban structure map: It illustrates the location of Niederrad within the city of Frankfurt and its role in connecting various areas of the city on a map.
2. **Permeability:**
   Block size mapping: Block size assessment based upon desk work analysis shows road connectivity within an area, regarding the ease of movement for shorter and more walkable routes for individuals on a map.
   Street connectivity mapping: This desk work data analysis assesses the road network's junctions as a crucial element in guiding users along their chosen routes and will be presented on a map.
3. **Variety:**
   Land-use mapping: The evaluation of land use, achieved through on-site observation, outlines a diverse range of land utilization to be presented on a map.
   Residential density: As the study area includes only a portion of the Niederrad neighborhood, accurately determining the resident population is challenging. Therefore, this thesis relies on the demographic statistics of the entire neighborhood to assess residential density.
   Travel mode mapping: The mapping of travel modes will display overall transport infrastructure and public transport services across various maps.
4. **Legibility:**
   SAFE Walk Assessment mapping: This assessment is grounded in on-site observations, accompanied by visual illustrations through photographs and subsequent mapping. The SAFE walk assessment is designed to evaluate the safety, appeal, friendliness, and efficiency of streets leading to significant destinations.
5. **Robustness:**
   Building edge mapping: The evaluation of building edges examines the ground-level activities of buildings. This examination involves a visual comparison of active, medium, and blind building frontages, both visually and on the map.
6. **Visual appropriateness:**
   Visual appropriateness photography: The visual appropriateness of the built environment enhances individuals' understanding, making it easier to identify essential destinations and facilities, as demonstrated through photos taken by the author.

2.3. Data analysis methods

SWOT analysis is highly valued for its efficient evaluation of Strengths (S), Weaknesses (W), Opportunities (O), and Threats (T). It forms an essential part of a toolkit in planning and formulating strategies for various objectives (Pereira, et al., 2021). The research presents a SWOT analysis table to evaluate the internal and external factors influencing walking and cycling in neighborhood development in Niederrad. The analysis includes maps to visually illustrate relevant areas and routes, while pictures are included to provide concrete examples of strengths, weaknesses, opportunities, and threats. This combination of elements enhances the presentation and engages the reader in understanding the dynamics of the topic.

2.4. Chapter summary

The methodology chapter outlines a comprehensive methodology combining quantitative data collection, mapping techniques, and qualitative assessments to investigate the urban fabric of the study area within Niederrad. The dual focus on desktop research and on-site observation provides an understanding of the current state of walking and cycling in the study area. Considering both hard data, such as statistical insights obtained from government databases, and subjective-based assessments, like the SAFE Walk Assessment, evaluate the strengths and weaknesses of sustainable transport. The proposed SWOT analysis further improves the methodology, providing a structured framework to determine internal and external factors influencing neighborhood development. The combination of quantitative and qualitative factors ensures a comprehensive assessment of land use, mobility, and walkability in Niederrad.

3

Theoretical Basis

3. Theoretical Basis – Promoting active mobility in sustainable neighborhoods

3.1. Sustainable neighborhoods and land use

The concept of a sustainable urban neighborhood integrates various elements, including environmental, social, and economic factors. The term sustainable shows its ability to function into the future while preserving ecological balance. Urban indicates its location and physical layout, while neighborhood contains the built environment and socio-economic considerations (Rudlin & Falk, 1999).

Sustainable neighborhoods emphasize a vibrant mixed-use, promoting social and environmental consciousness, prioritizing community interactions, local connections, and a balanced arrangement of land uses. Ultimately, they aim to elevate residents' quality of life through eco-friendly and socially engaging design principles (Khemri, et al., 2021). So, a varied mix of land uses with a commercial ground floor can lead to greater community cohesion, interaction, and a stronger sense of belonging (Dempsey, et al., 2011).

In parallel, the idea of livability has surfaced alongside sustainability. Planners and policymakers focus on establishing and preserving livable cities regarding the urban environment. This environment is characterized by its physical attributes, surrounding the built infrastructure and ecosystems that support the city's essential goods and services, critical for the livelihoods of its inhabitants (Ruth & Franklin, 2014).

According to Farr's perspective (Farr, 2007) in the Charter of the Congress for New Urbanism, a sustainable neighborhood aims to meet individuals' needs for housing, work, and leisure within environmentally friendly, compact, and interconnected urban layouts. This approach seeks to enhance walkability and promote social interaction through design principles.

Mixed physical attributes not only contain residential areas but also include commercial, cultural, and industrial functions, all of which play a crucial role in fostering sustainable development (Shen & Sun, 2020). Williams et al (2000) stated that achieving a sustainable urban form involves various configurations characterized by a mix of uses, interconnected street layouts, and environmental control measures (Williams, et al., 2000).

The UN-Habitat (2014) outlined five core principles essential for having sustainable urban development by creating livable and efficient neighborhoods (UN-Habitat, 2014):

- Adequate space for streets and an efficient street network: Create an efficient street network accommodating various modes of transport, prioritizing pedestrians and cyclists while reducing reliance on cars.
- High density: Promote high-density urban growth, reduce urban sprawl, and maximize land efficiency.
- Mixed land-use: Ensure efficient land use and provide an interconnected network of streets which provides safe, efficient, and pleasant mobility.

- Social mix: Encouraging social interaction among diverse social groups within the neighborhood by offering a range of lot sizes and housing types that meet the diverse community's needs while supporting local service provisions at sustainable densities.
- Limited land-use specialization: Integrate compatible land uses within neighborhoods and blocks, introducing mixed land-use zoning in alignment with market demand and urban context.

The five principles are interrelated and support each other in sustainable neighborhood planning. They offer a comprehensive indicator for neighborhood analysis with quantitative measurements. Emphasizing the crucial role of land use in sustainable neighborhood development lays the groundwork for empowering walkable communities and reducing reliance on cars. This approach contributes to enhanced livability, reduced environmental impact, and improved community well-being.

3.2. Active mobility – walking and cycling

3.2.1. Definition and benefits

Based on PASTA (Physical Activity Through Sustainable Transport Approaches) a European-identified conceptual framework of active travel for promoting sustainable modes of transportation, active mobility is a concept that promotes physical activity by utilizing non-motorized transportation modes such as walking, cycling, as well as public transit (Boschetti, et al., 2017). Moura and Kalakou (2019) specifically outlined various active modes in their study, categorizing them as walking, jogging, running, cycling, small-wheeled transport (such as skates, skateboards, push scooters, and handcarts, commonly referred to as micro-mobility), and wheelchair travel.

Active transportation has demonstrated profound links to both physical and mental well-being. As Ranjbarnia et al. (2022) explained walking is associated with improved life satisfaction, while cycling is connected to reduced stress levels, lower illness absences, and improved well-being. Moreover, walking and cycling emerge as key components in health studies focused on physical activity, supporting physical rehabilitation, and tackling modern chronic diseases such as obesity, diabetes, and hypertension, alongside fostering mental health and reducing depression (Baobeid, et al., 2021).

Active mobility is associated with a range of positive effects and is encouraged in urban planning, transportation planning, and public health initiatives (Koszowski, et al., 2018). This perspective aligns with the strategic vision outlined by the World Health Organization, where WHO (2016) lists the promotion of active mobility as one core strategy to overcome the problems of insufficient physical activity.

Encouraging physical activity via non-motorized transport modes such as walking, cycling, as well as public transit characterizes active mobility as an imperative concept. This approach has gained global recognition for its potential to improve health and reduce the harmful effects of

motorized vehicles on the environment. By integrating physical exercise into commuting and other daily activities, active mobility not only enhances well-being in society but also offers multifaceted advantages like reducing pollution, and traffic congestion (Meesit, et al., 2023). Promoting non-motorized and eco-friendly mobility is becoming a central point in sustainable mobility planning strategies for policymakers and researchers due to growing environmental awareness (Mrkajić & Anguelovski, 2016). The Centre for Livable Cities and the Urban Land Institute published a figure in their report in 2014 to show active mobility benefits for all. Figure 1 illustrates active mobility's diverse benefits for all. These benefits are categorized into six indicators: mobility, urban lifestyle, health, economic dividends, social benefits, and environmental sustainability. Each one of these factors contributes to multiple sections, emphasizing the impact on individuals, government, and the private sector, and ultimately promoting a sustainable and vibrant future for all.

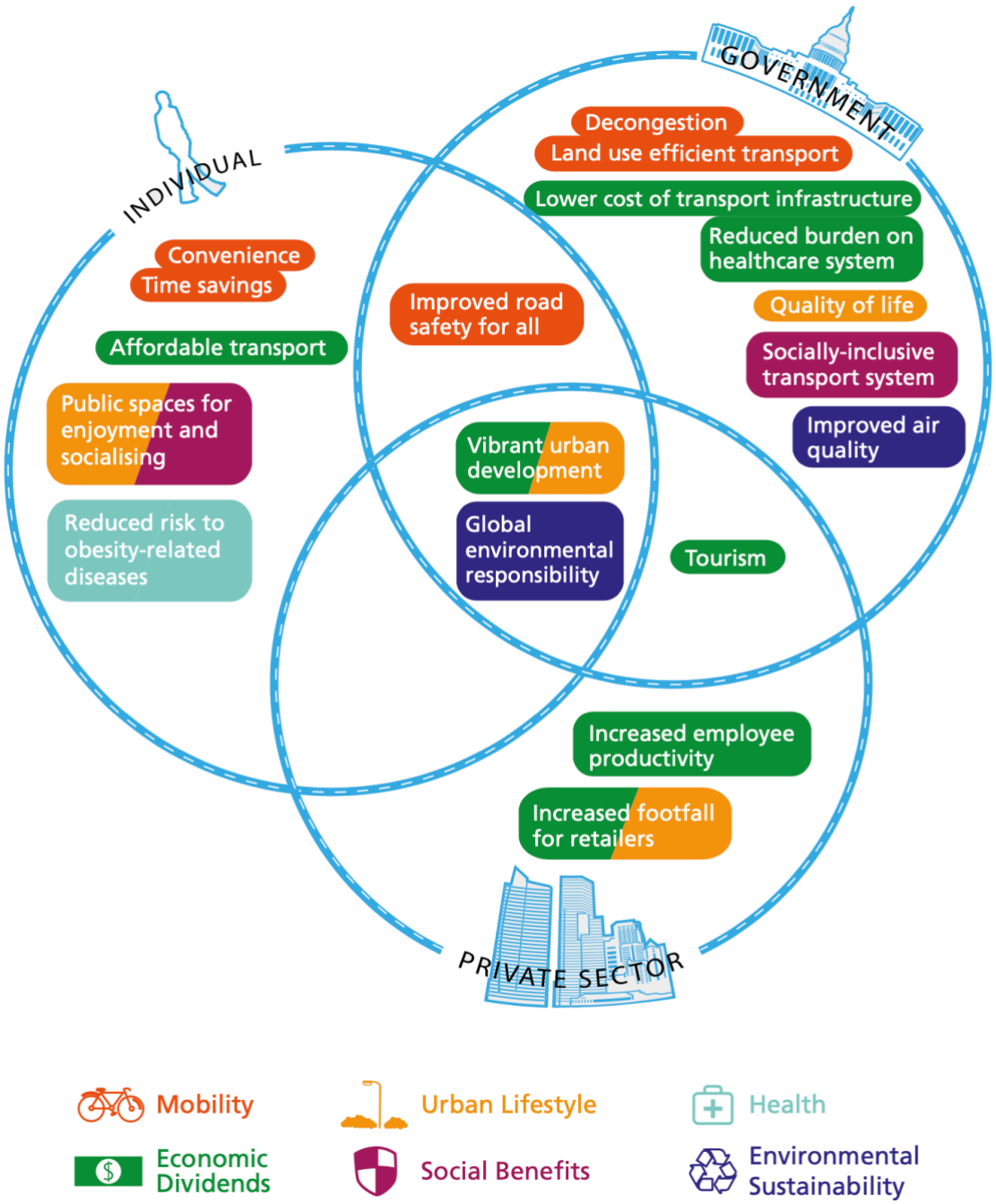


Figure 1. Active mobility benefits for all

Source: Centre for Liveable Cities and Urban Land Institute (2014, p.17)

3.2.2. Predictors of walking and cycling

Promoting walking and cycling as active and sustainable modes of transport depends on a complex interplay of factors that influence individual choices and community preferences (Hughes, et al., 2013). Cameña and Castro (2019) produced a table about predictors of walking and bicycle use based on the framework developed by Pikora et al, (2003) (Table 2). Within the physical environmental factors, functional features include characteristics of the pathway, such as its type, width, the presence of streets, traffic volume, speed, and traffic type, as well as the directness of routes leading to one's destination. Moreover, the physical environment factors also contain attributes related to safety and convenience. Aesthetics, another element of the physical environmental category, offers a broader perspective, including not only elements that provide visual pleasure but also the overall sense of well-being stemming from features like shaded sidewalks. The study also considers other influencing factors, including security, external elements such as climate and weather, as well as psychological and socio-economic aspects.

This table serves as a comprehensive framework, covering a wide range of factors influencing walking and cycling behaviors. The categories employed here are not only grounded in the characteristics of the physical environment but also contain psychological, safety, and socio-economic considerations. Importantly, these categories have been intentionally selected to align with existing studies, providing a basis for comparison, and contributing to the broader discourse on predictors of walking and bicycle use.

Table 2. Predictors of walking and bicycle use

Source: Cameña and Castro (2019, pp. 58-59)

Factors and Features			Elements and Items: Cycling (23 predictors)	Elements and Items: Walking (26 predictors)
Physical Environmental Factors	1	Functional	Traffic • Shared lanes with motor vehicles • Traffic volume • Traffic Speed • Cycling is the quicker way to get around	• Traffic volume • Traffic speed • Walking is the quicker way around
			Walking/cycling surface • Presence of segregated bike lanes	• Presence of sidewalk • Well-connected sidewalk • Well-paved sidewalk
			Permeability • Alternative routes for bikes	Permeability • Alternative routes • Access points
	2	Safety		Traffic • Pedestrian road crossing facilities Personal • Well-lighted streets
	3	Destination (Convenience)	Distance • Destinations are within biking distance	• Facilities are within walking distance
			Facilities • Bicycle parking facilities	• Vehicle parking
	4	Aesthetics	Streetscape • Tree-line streets	• Shaded sidewalks
Security	5	Peace and order	Neighborhood crime rate	
External factors	6	comfort	• Climate • Weather	
Psychological factors	7	Personal capacity or self-efficacy	• Preference for bicycle as mode • Bicycle for physical fitness • Skill/capacity to use bicycle • Cycling is safe	• Preference for walking as mode • Walking for physical fitness • Capacity to walk
Socio-economic	8	Individual attributes	• Gender • Age • Income • Employment status • Education level • Owns bike • Owns car	

3.2.2.1. Physical environmental factors

Wei et al. (2016) explained the influence of the built environment on travel demand in the 5D theory. They stated, “In order to promote walkability, the “5D” theory, which includes population density, pedestrian-friendly design, diversity of destinations, destination accessibility, and distance to transit, is proposed as a measure of urban form, and walkability increases with the increase in the values of the “5D” variables.” (Wei, et al., 2016, pp. 2-3). This theory not only acknowledges the relationship between the built environment and travel demand but also focuses on pedestrian-friendly design regarding the global movement toward creating cities that prioritize non-motorized modes of transportation.

Analyzing mobility involves assessing the ease or speed of mobility means in current connections established between specified points within a network (Sinha & Labi, 2007). Mobility outlines not only individual capacities but also the capability of accessibility, including both physical and communicative dimensions (Ferreira, et al., 2012). The ease of reaching socio-economic facilities is measured through accessibility, considering factors like travel distance, associated costs, and the variety of destinations reachable within a set travel distance. These facilities contain essential services such as markets, schools, and social amenities (Labi, et al., 2019). As Kamruzzaman and Hine (2010) explained, mobility empowerment involves ensuring that individuals living in well-connected areas have access to unlimited opportunities, including employment and shopping. Pedestrian-friendly urban design is about creating well-connected and attractive street networks, providing efficient, direct routes between various locations. The essence of mixed-use development lies in its ability to unify diverse walking destinations within a defined area, ultimately enhancing residents' accessibility to broad services and activities within a walkable distance (Brown, et al., 2009).

3.2.2.2. Security

Safety, both perceived and actual, is a core element, as people are more likely to walk or cycle when they feel secure from the risks of accidents (Pucher & Dijkstra, 2003). The intersection of walking and crime is a matter of substantial importance for several reasons. Firstly, walking represents a crucial, universally accessible, and cost-free form of exercise. Additionally, walking within local neighborhoods contributes to a sense of community development among residents (Janke, et al., 2016).

3.2.2.3. External factors

Motorized road traffic stands as a contributor to the prevalence of air pollution and noise pollution, representing major environmental health risk factors in urban areas (Marquart, 2022).

The emissions from motor vehicle exhausts, coupled with the noise generated by engines, pose urban environmental challenges. These challenges not only expose city residents to high levels of air pollution and noise but also increase the risk of traffic-related injuries and health

issues related to urban heat islands. Accordingly, there is a need to increase green spaces to reduce the effects of motorized infrastructure in urban areas (Marquart & Schuppan, 2021), as well as simply eliminate as much private motorized traffic as possible.

3.2.2.4. Psychological factors

Past studies have indicated self-efficacy plays a key role in predicting physical activity. These studies show that individuals with greater confidence in their ability to exercise are more likely to participate in physical activity constantly and report an increased walking distance (Lee, et al., 2007). Choosing a bicycle stem from fitness goals and navigating an eco-friendly mode while walking is favored for its simplicity and accessibility, contributing to both fitness and sustainability. This dual trend highlights a positive move towards healthier and greener urban lifestyles.

3.2.2.5. Socio-economic factors

People's transport behaviors are influenced by a range of social factors, including social norms, economic status, family and household structure, peer influence, cultural attitudes, urban planning and infrastructure, government policies, time and convenience, health, media and advertising, environmental awareness, and accessibility to services. For example, the COVID-19 pandemic has brought about significant shifts in transportation behavior, affecting not only public health concerns but also altering preferences for various modes of transport (Rashidi, et al., 2023). During the pandemic, walking and cycling have seen increased popularity due to safety concerns and the desire for outdoor exercise, alongside the rise in bike-sharing services. This change shows how social factors, influenced by the pandemic, can reshape people's choices in transportation modes (Wali, 2023). If this is further promoted by the increased availability of safe and attractive infrastructure for active travel, then a positive upward cycle can be created (Wen, et al., 2022).

Income, housing location, fuel prices, and inflation are interconnected to influence transportation choices. Higher incomes often correspond with increased car ownership and usage, while lower incomes encourage individuals toward cost-effective alternatives like public transit (Zhang, et al., 2023). Housing location plays a pivotal role by impacting accessibility to workplaces and essential services, which shapes transportation mode preferences. Fuel prices directly affect the affordability of private vehicle use and can trigger shifts in transportation behavior during price fluctuations. Meanwhile, inflation indirectly impacts choices by altering the overall cost of living, thereby influencing car-related expenses, public transit fares, and housing affordability, collectively shaping individuals' daily travel decisions (Maulana & Halley Yudhistira, 2020). On the other hand, with well-marked sidewalks, street-level storefronts, and a slower pace of movement, retail establishments gain visibility, attract purchases, and benefit from social interactions.

3.3. Review of relevant studies and research – good practices

In line with the background problems and theoretical basis, this section aims to offer brief insights into good practices adopted in various cities to address urban challenges. These projects have focused on optimizing opportunities for greater active travel through changes in land use, roads, sidewalks, bike lanes, and public areas. The Chicago Avenue project showcases cohesive mixed land use, while the Dutch cycling projects emphasize diverse cycling needs. Zurich's focus on walking and cycling infrastructure highlights a commitment to pedestrian-friendly spaces. These case studies are chosen to offer valuable insights into creating sustainable, active communities, directly aligning with this thesis investigation on land use, cycling, and walking.

3.3.1. Chicago Avenue, Chicago, United States

The Chicago Avenue project presents mixed land use, accessibility, and a balanced blend of public and private spaces. Its diverse population, coupled with district elements and amenities, demonstrates how cohesive urban planning can promote a vibrant, sustainable community encouraging active modes of transportation and enhancing overall quality of life.

Background:

The Soul City Corridor Development along 1.6 miles (2.6 Km) of Chicago Avenue in Austin, a neighborhood in the City of Chicago, addresses issues of racial injustice, public health, economic inequality, and safety, aiming for completion by 2025. It assesses community structure and corridor observations to investigate accessibility, safety, and overall quality of life. The project seeks to strategically boost strengths, confront issues, and create a safer, more equitable environment in the Austin neighborhood.

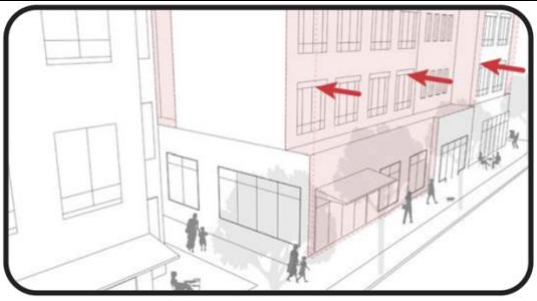
Goals:

The project aims to transform Chicago Avenue in the Austin neighborhood by increasing density, improving walkability, creating diverse retail spaces, and establishing development nodes. This includes integrating everyday retail and community services, providing affordable housing, and promoting "eyes-on-the-street" crime prevention for a safer, more vibrant urban environment.

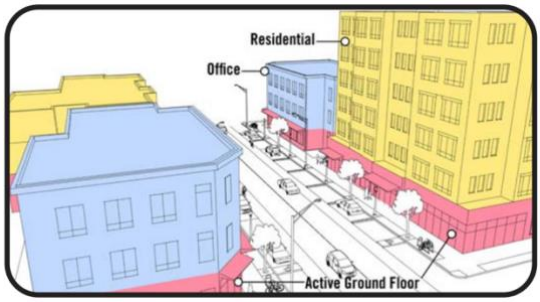
Proposals:

The Soul City Corridor development framework draws inspiration from the Design Excellence Guiding Principles and Neighborhood Design Guidelines of the City of Chicago. These guidelines cover aspects such as massing, facades, site design, public realm, program, and sustainability. The project aligns with regulations from the Zoning Ordinance, Landscape Ordinance, and Complete Street Guide, ensuring the promotion of a cohesive and well-designed urban space (Figure 2).

01 Front the street to reinforce the street wall continuity and provide public entrances from the sidewalks



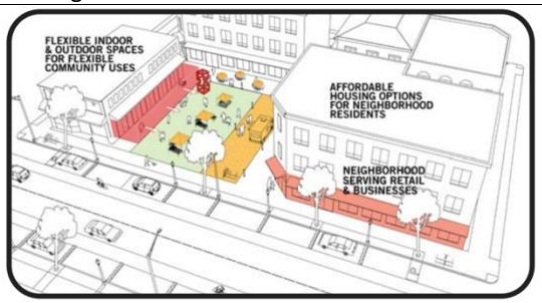
02 Integrate to the existing context uses and fabric with a use of setbacks and breakdown in mass



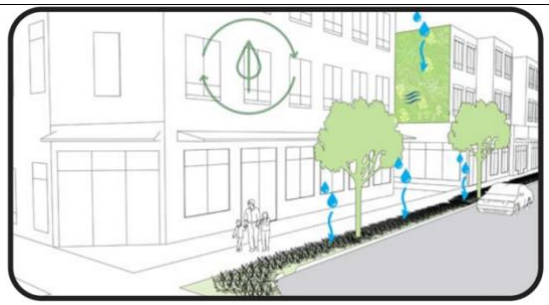
03 Promote the creation of density with a mix of uses between and within buildings

04 Promote active ground floor uses with transparency along streets and public spaces, and encourage a blend between interior and exterior

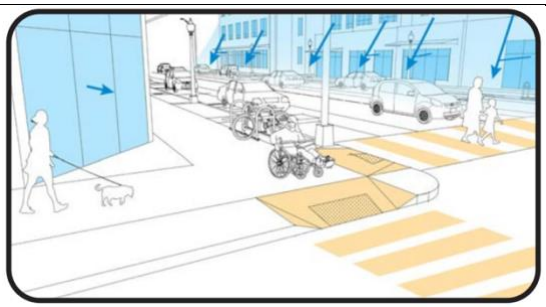
05 Encourage walking, biking, and public transit use through site and building design



06 Offer public spaces with amenities that accommodate active uses or to otherwise engage pedestrian interest, and provide flexible programs that directly cater to and support daily needs for Austin



07 Support sustainable building interventions, landscapes, and street trees, including best practices to reduce stormwater run-off on site



08 Prioritize accessibility and safety by bringing more “eyes on the street”, increasing the feeling of security through visible and transparent activity between indoor and outdoor environments

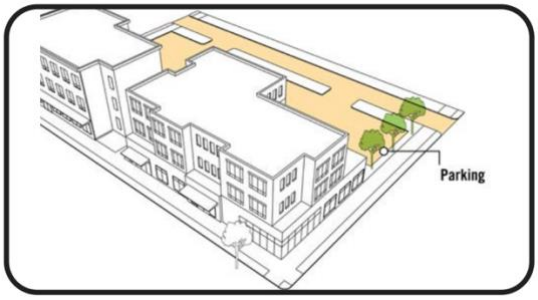
 09 Screen parking lots either behind buildings or with greenery in midblock locations	

Figure 2. Soul City corridor development: recommendations for a vibrant urban environment
Source: Elaborated by the Author, adapted from the development framework by City of Chicago (2020, pp. 37-39)

The Chicago Avenue project presents a cohesive urban plan that integrates mixed land use, accessibility, and a diverse population, which fosters a vibrant and sustainable community. The interconnected nine proposed initiatives demonstrate a ripple effect, where activating ground-floor frontages and providing public spaces with active-use amenities not only invites more people into the neighborhood but also enhances surveillance. These initiatives create an engaging environment that encourages active transportation and improves the quality of life.

3.3.2. Dutch cycling projects, The Netherlands

The Dutch Cycling Embassy published examples and practices of Dutch cycling in 2021, addressing a wide range of cycling purposes, from logistical and everyday commuting to recreational and sports-oriented cycling. The examples highlighted different cycling groups' infrastructure catering to the multifaceted needs of diverse cycling communities (Figure 3).

1. The Hague, Plesmanweg and Nieuwe Parklaan: 2008-2012, (Dutch Cycling Embassy, 2021), pp.15-16	
Before Intervention 	After Intervention 
Background: • Inefficient left turns: Cyclists faced two crossings due to inadequate road markings. • Poorly marked bicycle facilities. • Outdated traffic signals: The system required an update for improved road safety.	Interventions: • The intersection is redesigned as a roundabout with green plants. • Separated walking and cycling infrastructure. • The curve is large enough to serve cars, buses, and larger traffic.

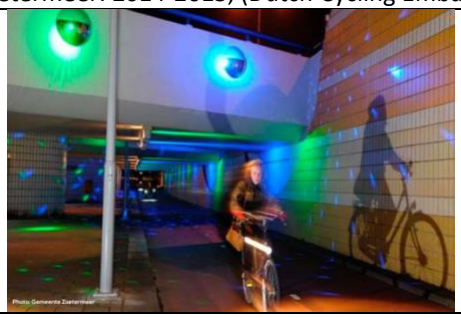
<table>
<tr><td colspan="2">2. Utrecht: 2017-2018, (Dutch Cycling Embassy, 2021), pp.25-26</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>Background:
• The student population needs connected routes.
• Utrecht municipality aims for attractive, safer, and faster infrastructure.
• The route lacks clear direction and priority.</td><td>Interventions:
• The streets were converted into bicycle streets (recognizable by the red asphalt).
• Car drivers are still allowed to drive but are obligated to reduce speed.</td></tr>
<tr><td colspan="2">3. Zoetermeer: 2014-2015, (Dutch Cycling Embassy, 2021), pp.59-60</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>Background:
• Despite an extensive, traffic-safe cycle network with tunnels and bridges, cyclists express safety concerns on specific sections in the evenings.</td><td>Interventions:
• A night network connects schools, shopping centers, sports facilities, and entertainment venues with residential areas.
• The route is in sight of houses so that there is more social control.
• Cyclists can use a free app, which shows the routes of the night network and enables users to share their location with friends.</td></tr>
</table>

Figure 3. Dutch cycling practices: A showcase of active mobility interventions
Source: Elaborated by the Author, adapted from a book by (Dutch Cycling Embassy, 2021), pp. 16-60.

Dutch cycling initiatives emphasize active mobility, prioritizing safety and accessibility with strategic sidewalk and bike lane infrastructures, intersection enhancements, and night networks to promote sustainable neighborhoods. These initiatives are often rooted in regulations prioritizing bicycles over motor vehicles, such as converting streets into bicycle streets.

3.3.3. City center, Zürich, Switzerland

The City of Zurich's website (Stadt Zürich, 2018) highlighted ten selected street spaces within the city center and neighboring areas for detailed examination and improvement regarding walking and cycling. These initiatives prioritize walkability and pedestrian-friendly environments, aligning with ease of movement, accessibility, safety measures, and the presence of pedestrian amenities. By focusing on enhancing infrastructure for walking areas

and integrating more green spaces, both within the city center and neighboring districts, Zurich sets a model for promoting active mobility (Figure 4).

1. Mühlebachstrasse

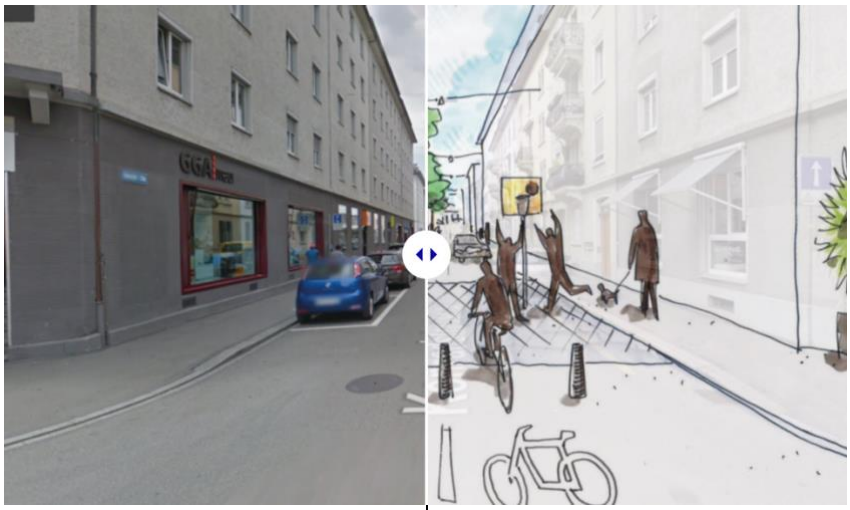
Background:

- Residential with occasional ground-floor commercial use.
- A two-way street with a bicycle lane on one side.
- Features numerous vertical and diagonal parking spaces at the intersection.
- Lacks a continuous planting structure along the street.
- A mixed parking layout creates a dangerous zone.
- Reversing vehicles have poor visibility for cyclists.

Intervention:

- Replace diagonal and vertical parking with parallel parking.
- Introduce a wide gravel strip for climate improvement.
- Plant a tree avenue for enhanced aesthetics.
- Activate the street as a neighborhood meeting point.
- Offer lounge and play opportunities for community interaction.

2. Konradstrasse



Background:

- The road has parallel parking on both sides.
- Parking arrangement severely limits available space.
- Cross streets facilitate motorized transport access.
- Connect to numerous restaurants and apartments.

Intervention:

- Transform the street into a meeting area.
- Narrow the roadway to facilitate the transformation.
- Reduce parking spaces to allocate a row of trees.
- Trees aid in unsealing and improving the urban climate.

3. Köchlistrasse

Background:	Intervention:
1. A high proportion of sealed areas on the road. 2. The current zigzag tree arrangement acts as a parking enclosure. 3. The district identified as a current heat island. 4. Lack of public green spaces. 5. The residential area lacks play and sports opportunities. 6. Insufficient areas for leisure or staying on the street.	• Need for green spaces and effective water management. • Aim to reposition parking spaces parallel on the right edge. • Goal: Open streetscape, enhance visibility of play street. • Increasing existing tree rows and scatter them as islands in the play area.

Figure 4. Active Mobility in Zurich: Urban space initiatives
Source: Elaborated by the Author, adapted from The City of Zurich's website (Stadt Zürich, 2018)

Initiatives for Zurich's city center focus on local alleys with narrower widths in residential and mixed-use areas. The approach aims to reduce on-street parking, emphasizing walkability and creating pedestrian-friendly environments. It aligns with ease of movement, accessibility, safety measures, and the incorporation of pedestrian amenities, contributing to enhanced community engagement and livability.

3.4. Chapter summary

The theoretical basis chapter presented the fundamental relationship between sustainable neighborhoods and land use. Central to sustainable urban neighborhoods is the emphasis on mixed-use spaces, community connections, and eco-friendly design principles aimed at enhancing residents' quality of life. This focus centers on physical attributes and essential city services, laying the groundwork for vibrant and sustainable living environments.

Afterward, the theoretical basis extended to active mobility, specifying six indicators influencing urban sustainability. These indicators contain aspects such as urban movement, accessibility, health benefits, economic influences on transportation choices, and mobility behaviors. This approach includes the need to reduce motorized traffic and integrate green spaces, in shaping sustainable urban landscapes.

Finally, the chapter presented indicators impacting walking and cycling. It addressed built environment elements, alongside factors related to attractiveness, comfort, safety, gender, age, income, employment, and education. These factors play a role in shaping transportation choices and individual mobility patterns in the livable urban fabric.

Exploring diverse urban projects shows the significance of cohesive urban planning that integrates mixed land use, accessibility, and a balance between public and private spaces to promote vibrant, sustainable communities. Additionally, safety measures and strategic allocation of pedestrian and bike-friendly infrastructures lead to promoting active mobility infrastructure in sustainable neighborhoods. Lastly, the emphasis on walkability, pedestrian-friendly environments, and the integration of green spaces demonstrates how urban design enhances accessibility and encourages active modes of transportation, setting a model for sustainable urban living improvement.

In conclusion, Figure 5 outlines the main features, considerations, and good practices interventions, which are the essence of the thesis focus on land use, cycling, and walking to answer the second research question. These insights aim for Chapter 4 to have a focused assessment and contribute to strategic formulation in Chapter 5 for building sustainable communities with active mobility.

Figure 5. Comprehensive theoretical basis overview: features, considerations, and good practices for sustainable urban interventions

Source: Figure by author designed with Adobe Illustrator

4

Case Study: Niederrad

4. Case Study: Niederrad

This chapter analyses the study area, focusing on essential indicators to assess its current condition. The primary factors include land use, mobility patterns, and overall walkability within the neighborhood to answer the third research question. By understanding the current dynamics of the area, the analysis contributes to shaping recommendations aligned with specific needs for sustainable neighborhood empowerment.

4.1. Historical development

According to Stadt Frankfurt am Main (2023), table 3 illustrates the historical development of Niederrad that helped shape its current landscape and identity. Throughout its evolution, the district went through industrialization, advancements in transportation, and various urban planning initiatives. Its history began in 1151 as "Rode" and went forward in the 20th century, experiencing quick development, population growth, and integration into Frankfurt's urban landscape.

Table 3. Niederrad: historical development

Source: Elaborated by the Author, adapted from Stadt Frankfurt am Main (2023)

1151	Niederrad is first mentioned as a 'Rode' (Rodung in German, defined as clearing the forest to develop urban areas) in the Reichswald forest between Sachsenhausen and Schwanheim.
1372	Frankfurt acquires the city forest.
1500	Frankfurt has around 10,000 inhabitants.
1616	A fire destroys almost all Niederrad.
1800	Frankfurt has around 35,000 inhabitants.
1839	With the opening of the Taunus Railway to Wiesbaden, the railway arrived in Frankfurt.
1850	Niederrad has 2,000 inhabitants.
1867	Frankfurt has around 78,000 inhabitants.
1877	With the incorporation of Bornheim, Frankfurt's urban expansion began in the 19th century.
1880/81	Construction of the Niederräder railway bridge.
1883/84	Construction of the Main-Neckar railway bridge.
1887	The Niederrad sewage treatment plant goes into operation.
1887/89	Construction of the Frankfurt-Niederrad Forest railway line
1890	Frankfurt has around 180,000 inhabitants. Niederrad has 5,400 inhabitants.
1900	Niederrad is incorporated into the Frankfurt urban area on July 1st with 292 hectares of land and 8,800 residents
1905	Frankfurt has around 400,000 inhabitants.
1907	Tram line 15 was established to Triftstraße.
1912	Development of the residential area between Waldstraße and Waldfriedstraße.
1928	Frankfurt becomes the third largest city in Germany in terms of area. The city has 548,000 inhabitants.
1930	Niederrad has 14,000 inhabitants.
1932	The “Mother of Good Counsel” church was built. The church tower shapes the image of Niederrad
1939/1945	During the war, Rhine-Main is almost destroyed by bombing and explosions.
1949	Frankfurt and the Rhine-Main area are quickly developing into an important economic center. Frankfurt subsequently becomes one of the leading financial centers in Europe.
1950	Niederrad has 18,000 inhabitants.
1955	Frankfurt has more than 600,000 inhabitants for the first time.
1961	Niederrad has 25,000 inhabitants.
1963/64	Site development for the “office city in the countryside”, Niederrad-West.

1968	Opening of the first U-Bahn line in Frankfurt.
1969	Bus line 72 goes into operation between Niederrad and the office district
1977	Opening of the Niederrad S-Bahn station in Frankfurt.
1973	Start of track construction work for the tram connection to the office district on Triftstraße and Adolf-Miersch-Straße.
1978	Motorway connection from the office town of Niederrad to the A5 autobahn opened.
1985	The tram line 15 goes into operation between Louisa and Niederrad-Hardtwaldplatz, running through Sachsenhausen.
2012	Frankfurt grows to over 700,000 inhabitants.
2022	Redevelopment project turned a mono-functional office quarter of the past into an integrated and mixed-use city district for 3,000 new residents.

The historical timeline outlines the development of Niederrad within the broader context of Frankfurt's growth and transformation. Niederrad's rich history grows within the broader narrative of Frankfurt's development. Initially emerging as a 'Rode,' or forest clearing, Niederrad played a role in the city's growth. Frankfurt's acquisition of the city forest and further urban expansion set the stage for transformative developments. The arrival of the railway and the incorporation of Bornheim marked milestones in Frankfurt's progress. Moreover, railway bridges as mobility infrastructures, contributed to connectivity within the city. Niederrad joined Frankfurt in the late 19th century, becoming a part of the city. Additionally, the construction of the iconic Mother of Good Counsel church and post-war reconstruction shaped Niederrad's identity. Transportation enhancements, including the Niederrad S-Bahn and a motorway connection, further integrated Niederrad into Frankfurt's network. Finally, the recent redevelopment project in the office district has built up Niederrad, turning it into a dynamic, mixed-use district and welcoming new residents. Throughout this journey, Niederrad's narrative remains connected with the broader story of Frankfurt's dynamic history.

4.2. Current demographics and geographic overview

Niederrad, located on the southern banks of the Main River within Frankfurt am Main, holds a geographical significance as it interfaces between Frankfurt's vibrant city center and the international accessibility provided by Frankfurt Airport. The district's integration within these two influential nodes of Frankfurt's transportation networks has facilitated its role as a transitional zone. Figure 6 shows the location of Niederrad within the city of Frankfurt.

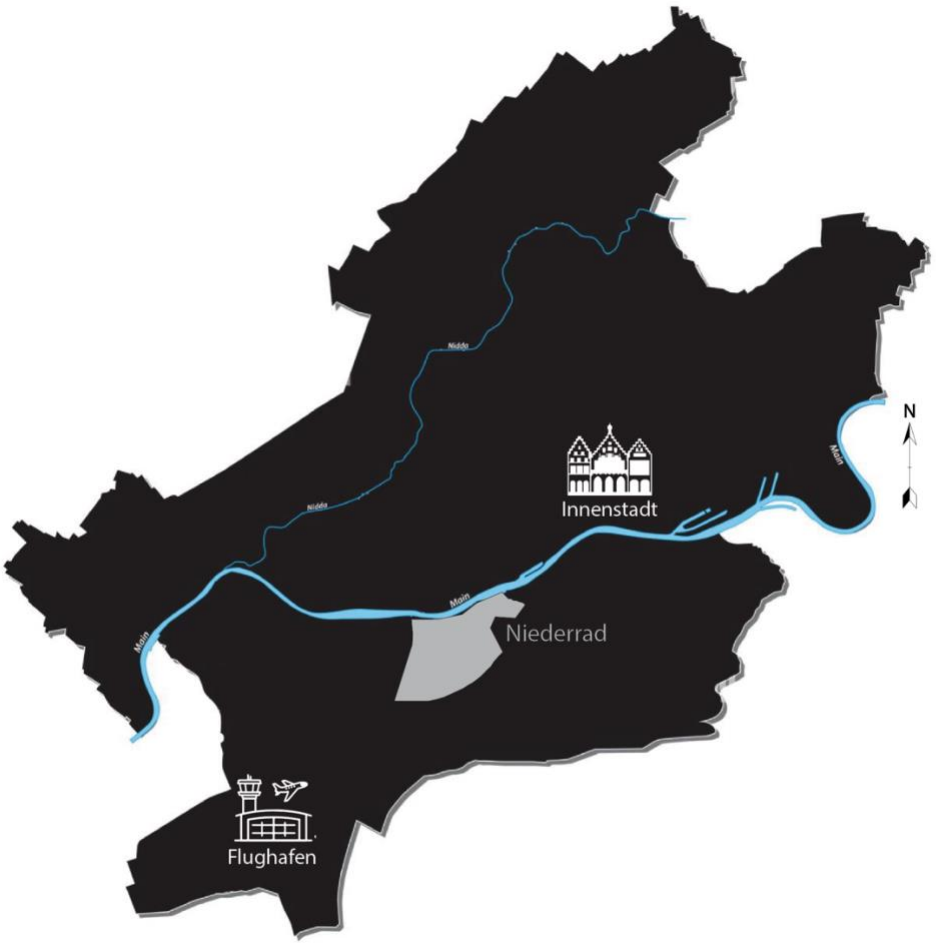


Figure 6. The location of Niederrad within the City of Frankfurt
Source: Figure by author designed with Adobe Illustrator with the base map from Statistics-Frankfurt am Main (2020)

Based on Statistics-Frankfurt am Main (2020), Niederrad's total settlement area is 384.4 hectares, its total population is 27,043 and its density is 70.35 persons per hectare. In comparison to Frankfurt's overall metrics, Niederrad's area is about 4% of the city's total area, while its population represents approximately 3% of the city's residents. Additionally, Niederrad's density is lower than Frankfurt's city-wide density, which stands at 80.93 persons per hectare (Figure 7).

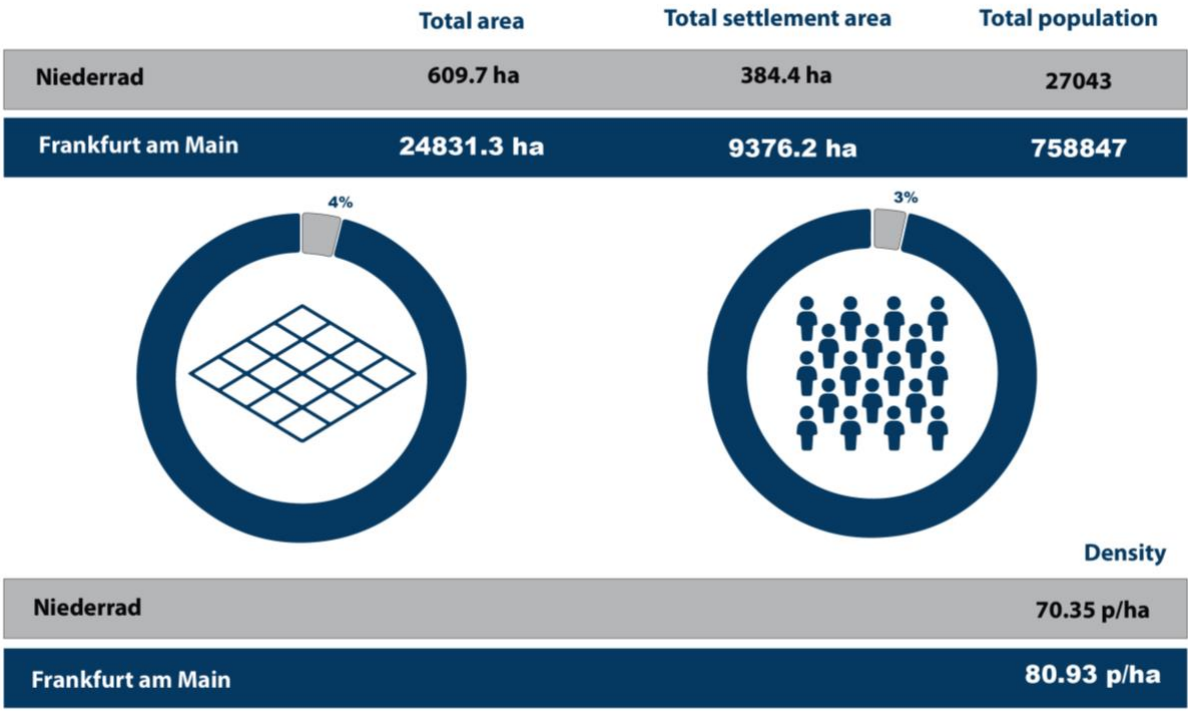


Figure 7. Comparative analysis of population and area statistics: Niederrad and Frankfurt
Source: Diagram by author designed with Adobe Illustrator based on Statistics-Frankfurt am Main (2020)

According to the guidelines established by the Congress for New Urbanism, the concept of neighborhood functionality is defined within a radius of 0.4 km (a 5-minute walking distance) and should contain essential amenities catering to daily needs, such as grocery stores. Expanding further to a radius between 1.2 km and 1.6 km (equivalent to a 15-minute walk or a 5-minute cycling distance), the 15-minute Ped-Shed should contain vital services like schools, parks, and commercial centers (Knap, 2022).

In alignment with the objectives of this thesis, the study area within Niederrad was strategically outlined into two distinct Ped-Sheds. The first Ped-Shed spans a radius of 400 meters, emphasizing the immediate catchment for walking (5 minutes), while the second extends to an 800-meter radius, accommodating both a 10-minute walk as well as short cycling possibilities. These circles serve as functional catchment zones, essential for analyzing walking and cycling patterns, as well as understanding the distribution of land use within the Niederrad neighborhood. Figure 8 shows the 400-meter and 800-meter radius Ped-Sheds in the Niederrad neighborhood. The chosen Ped-Sheds centered around Niederrad Bahnhof and including daily-life streets and parts of the office district, strategically facilitate the analysis of walking and cycling behaviors within a mixed-use urban environment. This area's mix of transportation nodes, daily-life pathways, and varied land uses offers a rich context to explore the interconnections between built structures, mobility patterns, and land utilization. This aligns with the assessment's focus on walking, cycling, and land use dynamics.

Figure 8. The 400-meter and 800-meter radius Ped-Sheds in Niederrad
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

4.3. Land use characteristics

Statistics from Frankfurt am Main (2020) provide a comprehensive overview of land use patterns in Niederrad. The neighborhood's landscape is mostly dominated by its settlement area, including a significant portion of the total area. Within this settlement area, most land uses are dedicated to sport, leisure, and recreation. Following closely, residential areas, emphasize the neighborhood's focus on providing living spaces. Industrial and commercial spaces occupy 14% of the whole neighborhood, contributing to Niederrad's office area. Conversely, the least amount of land within the settlement area includes the cemetery and the mixed-use zones (Figure 9).

	Niederrad	Frankfurt
Sport, Leisure and Recreation	128.1 ha	1874.8 ha
Residential	110.6 ha	3677.3 ha
Traffic area	102.6 ha	5160.2 ha
Vegetation	96.7 ha	9765.8 ha
Industrial and Commercial	88.2 ha	2178.3 ha
Special Character	37.1 ha	773.3 ha
Water	26.0 ha	529.1 ha
Mixed Use	15.9 ha	622.2 ha
Cemetery	4.3 ha	250.4 ha
Total area	**609.7 ha**	**24831.3 ha**

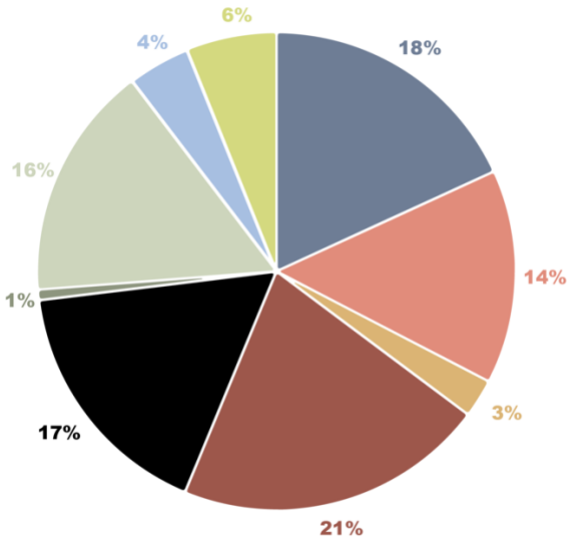


Figure 9. Niederrad neighborhood land use characteristics
Source: Diagram by author designed with Adobe Illustrator based on Statistics-Frankfurt am Main (2020)

The assessment of land use in Niederrad, undertaken through on-site observation, outlined a diverse range of land utilization categories. These categories contain residential, public, recreational, mixed-use, green spaces, commercial, institutional, cemetery, common garden, and religious spaces, each contributing to the neighborhood's fabric.

Figure 10 illustrates the distribution of land use within the chosen Ped-Sheds in Niederrad. It outlines an inequality in land allocation, particularly within the office area. The left side of the Ped-Shed illustrates an imbalanced concentration of commercial land, consisting of mono-functional commercial spaces. This dominance of singular commercial activities creates an environment that lacks diversity, potentially contributing to a less vibrant and engaging atmosphere. The limited presence of smaller shops or restaurants further highlights this commercial monotony. This office-centric zone is separated by the S-Bahn rail as a divider between the commercial domain and a portion of the residential area.

In contrast, the right portion of the figure shows a contrasting design. A network of pathways passes through daily life settings, integrating a mix of residential and diversified land use. The prevalence of mixed-use buildings, hosting retail stores, characterizes this zone, contributing to a more mixed environment compared to the office area on the left side.

The segregation of land use in Niederrad, particularly the mono-functional commercial areas in contrast to the residential and versatile mixed-use spaces, not only shapes the physical landscape but also influences the livability within Niederrad.

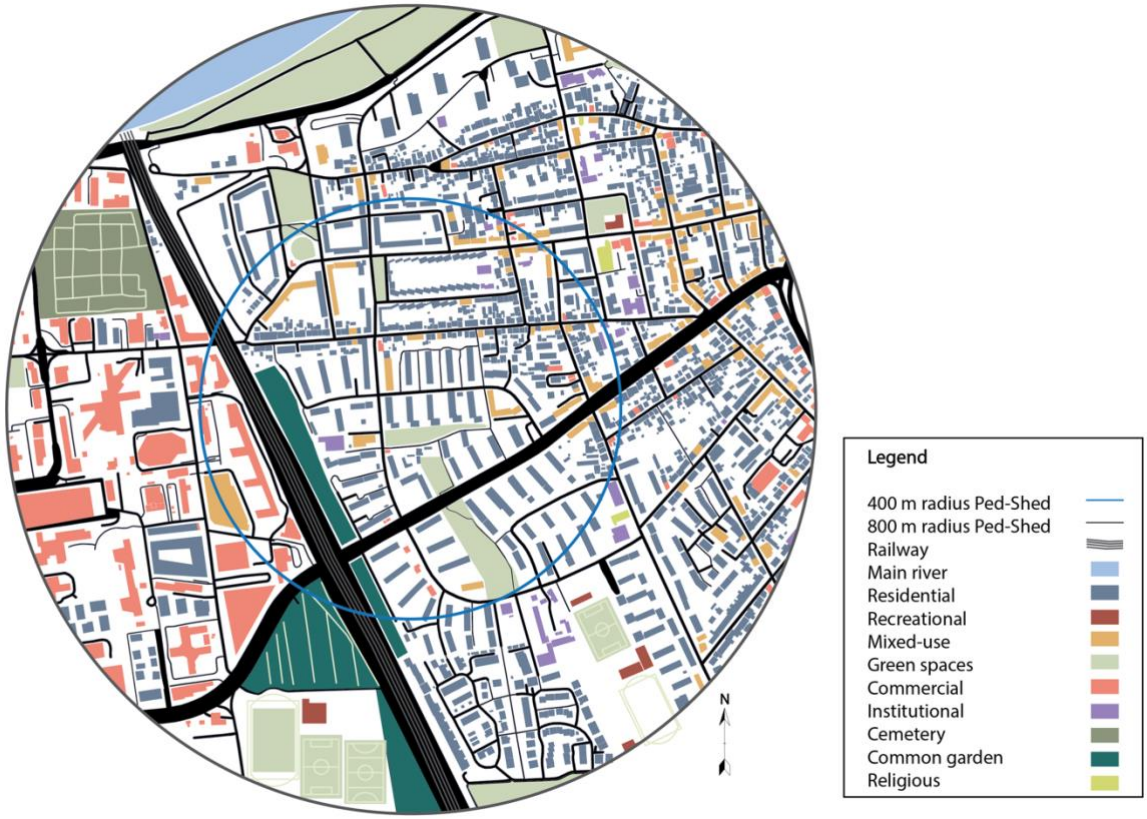


Figure 10. Land use within Ped-Sheds in Niederrad
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

To emphasize the residential aspect of land use, a central component is understanding the household dynamics of the community. Figure 11 illustrates the distribution of households in Niederrad based on the number of rooms they contain based on Statistics-Frankfurt am Main (2020). The data shows that households in the neighborhood are diverse in terms of their spatial configurations. Among these, residences with three rooms hold the highest majority, closely followed by four-room dwellings. Meanwhile, single-room households include the least common type and five-room residences are relatively fewer. Residences with three or four rooms appear to be the most prevalent, potentially indicating a balanced demand for moderate-sized housing options suitable for families.

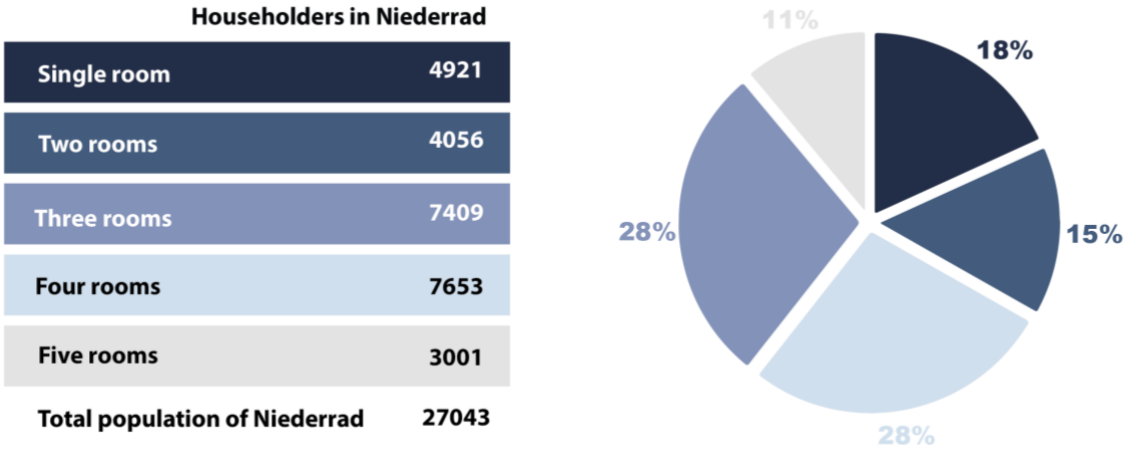


Figure 11. Householders in Niederrad per the number of rooms

Source: Diagram by author designed with Adobe Illustrator based on Statistics-Frankfurt am Main (2020)

The land use analysis of Niederrad shows a mainly residential landscape, with a significant focus on sport, leisure, and recreation. Within the Ped-Sheds, commercial spaces contribute to the office area, while mixed-use zones and the cemetery represent smaller portions. On-site observation highlights diverse land utilization categories. To address the imbalance in land allocation within Ped-Sheds, there is a need for a shift toward a more mixed environment. The residential aspect demonstrates a diversity in spatial configurations, with three and four-room residences. This suggests a balanced demand for moderate-sized housing suitable for families. Overall, the mixture of mono-functional commercial areas with mixed-use spaces not only shapes Niederrad's physical landscape but also significantly influences the neighborhood's livability.

4.4. Transport infrastructure

4.4.1. Modal split in Frankfurt

Nobis et al. (2020) conducted a study across 35 cities in Germany to examine mobility patterns. Their findings revealed that in Frankfurt, one-third of journeys are undertaken on foot, a higher proportion compared to other cities surveyed. Moreover, Frankfurt records the lowest usage of motorized private transport among the surveyed cities.

Figure 12 illustrates Frankfurt's modal split, with walking occupying the highest position, followed by public transport, private cars, bicycles, and finally, car sharing. Furthermore, the study highlighted that the majority of commuting to workplaces in Frankfurt relies on public transportation, whereas daily shopping and leisure trips mostly occur on foot.

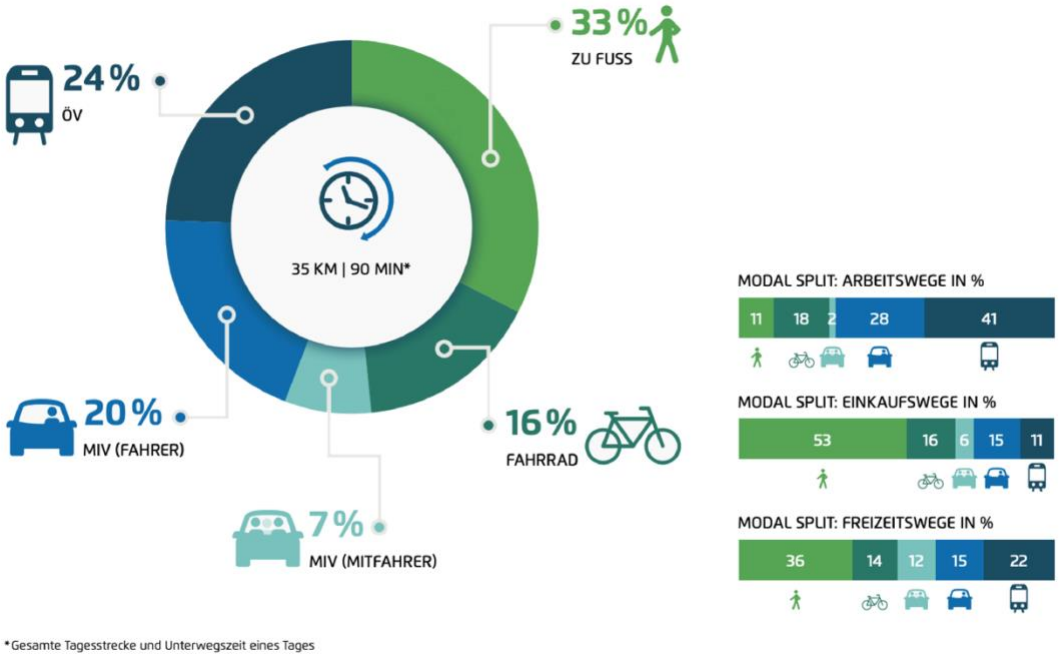


Figure 12. Overall modal split in Frankfurt am Main: A breakdown by trip type
Source: Nobis, et al (2020, p. 44)

In the low share of motorized private transport, Frankfurt has the second-highest share of households without a car of all 35 cities that stayed after Berlin (Nobis, et al., 2020). Figure 13 presents the motor vehicle rates in both Frankfurt and Niederrad. In Frankfurt, this rate stands at 543 private cars per 1000 inhabitants, while in Niederrad, it slightly exceeds this number at 546 per 1000 inhabitants. When considering the broader spectrum of private car prevalence across neighborhoods in Frankfurt am Main, Niederrad ranks 16th out of the city's 47 neighborhoods.

	Private car	Motorcycle	Utility vehicle	Motor vehicles per 1000 inhabitants	
				Total number	
Frankfurt am Main	342431	22625	29010	625	543
Niederrad	12559	636	770	607	546

Figure 13. Comparing motor vehicle rates: Frankfurt vs. Niederrad
Source: Diagram by author designed with Adobe Illustrator based on Statistics-Frankfurt am Main (2020)

4.4.2. Traffic area characteristics

Within the framework of urban dynamics, the characteristics defining traffic areas are essential components of urban life. Figure 14 presents the characteristics of traffic areas within Niederrad, illustrating its diverse infrastructure. Among these, roadways cover the largest portion of traffic areas. Railway infrastructure occupies a smaller proportion, with pathways and plazas including smaller segments within the traffic area. The least extensive feature is the air and ship traffic zones.

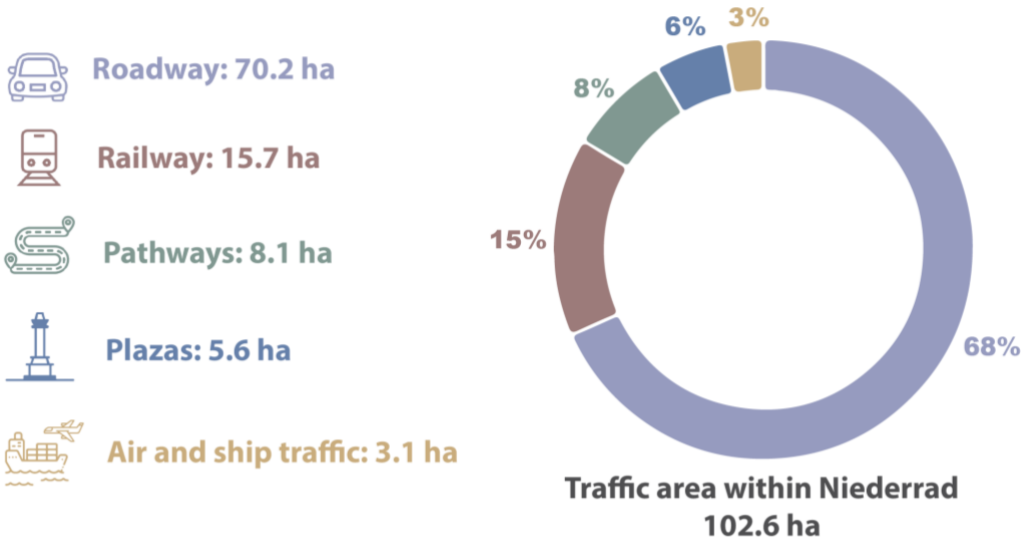


Figure 14. Traffic area characteristics in Niederrad
Source: Diagram by author designed with Adobe Illustrator based on Statistics-Frankfurt am Main (2020)

In the urban landscape of Niederrad, the roadway covers 70.2 hectares, including 18.27% of the total settlement area, which spans 384.4 hectares. Simultaneously, all traffic land extends over 102.6 hectares, representing 26.68% of the total urban area. These calculated percentages offer valuable insights into the spatial distribution of transportation infrastructure in Niederrad, emphasizing the significance of road and traffic-related land use within the neighborhood's overall urban fabric.

4.4.3. Bicycle infrastructure

Within the Ped-Sheds of Niederrad, the absence of designated bicycle lanes presents a significant challenge across both the established and newly constructed urban areas. Without these lanes, cyclists are sharing the routes with motor vehicles, elevating the potential for accidents in a car-dominated landscape. This absence not only leads to safety risks but also encourages individuals toward less eco-friendly alternatives (Figure 15).

	The majority of marked signs specifying the shared bike lane with the car lane are faded and not easily visible, leading to potential safety issues. This lack of clarity reduces driver awareness, leading to a decreased expectation of sharing the street with cyclists.
	In some streets with shared paths between cars and cyclists, the on-parking leads to a safety risk for all street users, especially vulnerable groups such as children. This risk increases at intersections where there is insufficient visibility for drivers. The exit of vehicles from parking spaces poses a risk, as drivers may not adequately observe the presence of cyclists. Furthermore, the prospect of car doors being opened poses an additional safety concern.
	In some one-way streets, the bicycle sign permits movement in both directions, which increase the potential for accidents.

Figure 15. Visual examples of cycling infrastructure quality

Source: Author

Additionally, the presence of 13 bike-sharing stations facilitates access to E-bikes and scooters. The system operates on a free-floating model, with various companies providing the vehicles, enhancing the availability and accessibility of sustainable transportation options in Niederrad. However, there is one charging station located within the Ped-sheds area. Figure 16 illustrates the distribution of bike-sharing and charging stations within the Ped-sheds in Niederrad.

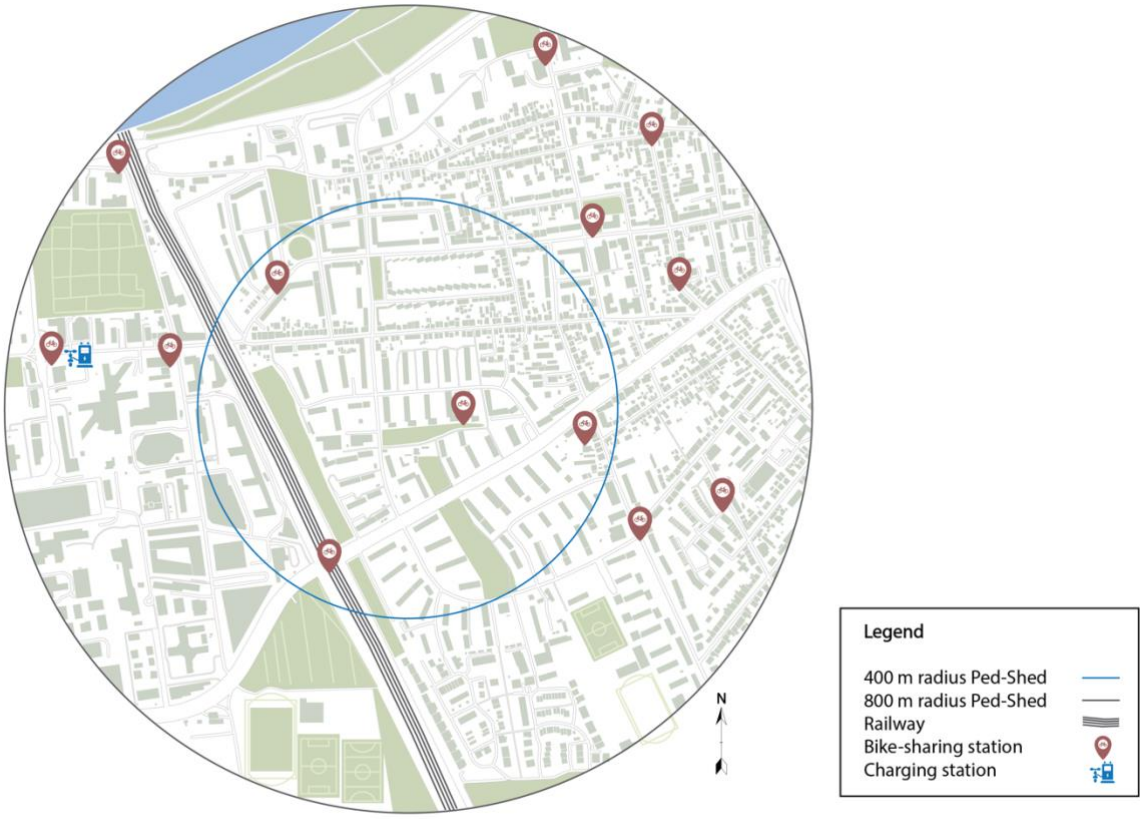


Figure 16. Distribution of bike-sharing and charging stations within Ped-Sheds in Niederrad

Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

The shared paths between cars and bicycles provide cyclists with the freedom to navigate and ensure their accessibility throughout the area. This layout eliminates the necessity for cyclists to alter their route, adding to the overall convenience and promoting cycling as a preferred mode of transportation. However, these shared paths raise safety concerns, particularly at intersections, arising from potential conflicts related to the confusion in route choices.

	Bike rack in front of residential building
	Bike rack in front of mixed-use building
	Bike rack close to an intersection in the office district

Figure 17. Visual examples of bicycle parking facilities

Source: Author

Niederrad has widespread bicycle parking facilities, enhancing its appeal to residents and visitors. Figure 17 illustrates the allocation of bicycle racks placed in front of residential buildings, providing convenient parking options. Furthermore, many shops in the area contribute to this cyclist-friendly environment by installing bike racks, catering to the convenience of their customers. Moreover, plenty of bike racks near intersections further promote and facilitate cycling in the neighborhood within the office district.

4.4.4. Parking infrastructure

While assessing on-street parking patterns, the map considers the orange color for one-side street parking and red for two-side street parking, capturing parking locations (Figure 18). The focus lies on general parking trends, besides restricted zones near bus stops or designated parking entrances are not accounted for.

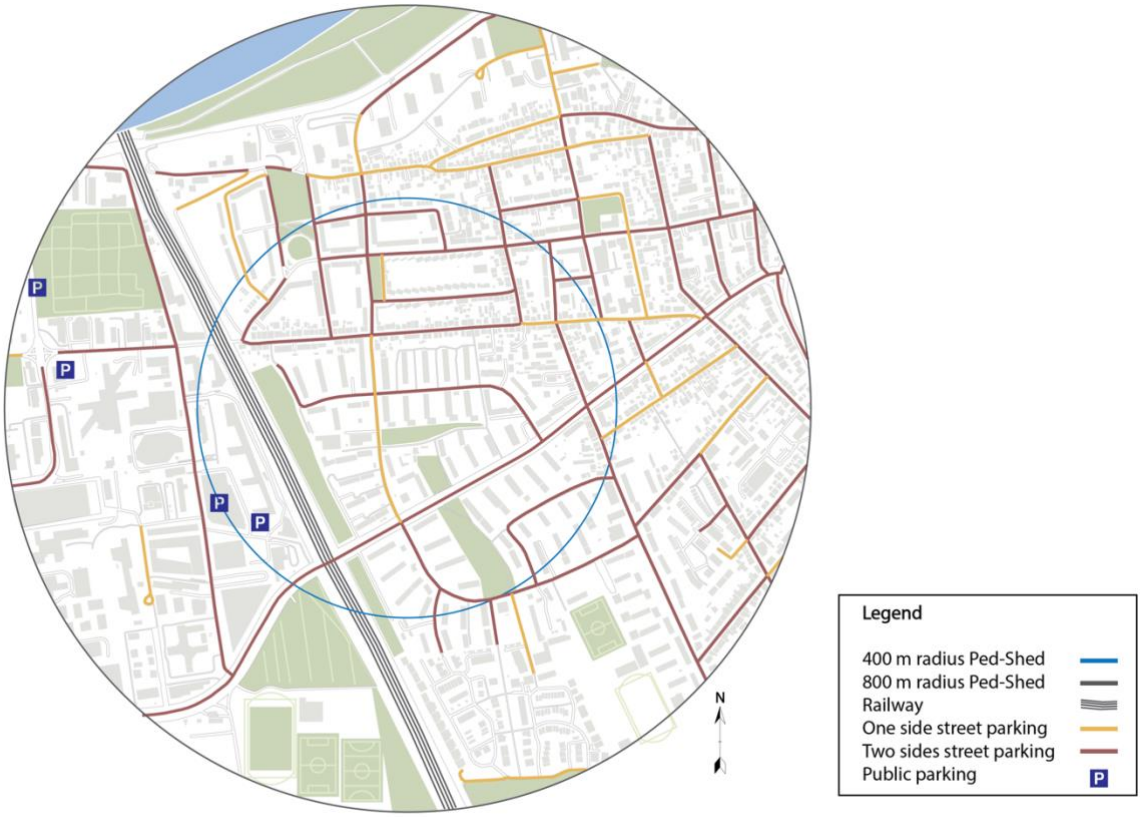


Figure 18. On-street parking within Ped-Sheds in Niederrad
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

Figure 19 illustrates a comparison of on-street parking between one-side and two-side configurations.

Two-side street parking		
One-side street parking		
		The image shows on-street parking, with cars parked in their designated lanes highlighted in green. A car parked in a prohibited area on the sidewalk is marked in yellow, while a car parking on the street and temporarily blocking the road is indicated in red.

Figure 19. On-street parking comparison: One-side vs. two-side configurations

Source: Author

The assessment shows areas showing older buildings lacking dedicated parking as well as areas with mixed land use showed a greater reliance on on-street parking. Moreover, residential zones equipped with designated parking demonstrated reduced dependence on on-street parking. Regions near the office area show fewer on-street parking due to larger blocks and newer buildings with adequate underground parking provisions. The absence of allocated bicycle lanes further emphasized a car-centric environment, potentially influencing and encouraging higher car usage due to the availability of on-street parking. This encouraging design leads to unconventional parking practices, like vehicles partially occupying sidewalks due to limited street width.

4.4.5. Public transport services

An effective public transport infrastructure is characterized by its accessibility, reliability, and user-friendly design, which includes well-placed transit shelters to provide passengers with comfortable waiting areas and protection from the elements. Figures 20 and 21 illustrate the public transport routes and nodes within Ped-Sheds in Niederrad.

The Ped-Sheds shows drawbacks in their public transportation infrastructure. Figure 22 visually illustrates the quality of some public transport stations in the study area.

The Niederrad Bahnhof station, serving S-Bahn and regional trains, is situated on an elevated platform adjacent to the railways. Tactile guiding systems on the nearby street assist disabled individuals in finding their way to the station. The open-air station lacks shelter but has ticket machines, digital boards displaying real-time arrival information, and voice announcements. While the elevated platform does not have an escalator, elevators are available for accessibility.

Tram line 12 features three double stations situated along Adolf-Miersch-Straße within the study area. These stations, positioned beside the tram lines, are equipped with shelters, ticket machines, digital boards displaying real-time arrival information, and a tactile system.

There are six stations for Tram line 15 within the study area, situated on both sides of Bruchfeldstraße. These stations are positioned in the middle of the street, requiring pedestrians to cross the traffic lane to reach the trams, leading to increased safety concerns and interruptions in the flow of vehicular traffic. Additionally, these stations lack elevated platforms, presenting challenges for users with wheelchairs, strollers, or shopping wagons. Given the street's frequent use by people visiting retail shops, these accessibility considerations are crucial. Some of these stations are shared with bus lines. Automatic ticket machines are available only at stations shared by both trams and buses with no tactile guiding systems.

The majority of bus stations within the study area lack essential amenities such as shelters, tactile systems, ticket machines, and digital boards displaying live arrival times. These stations are integrated with the sidewalks, providing minimal transport information to passengers.

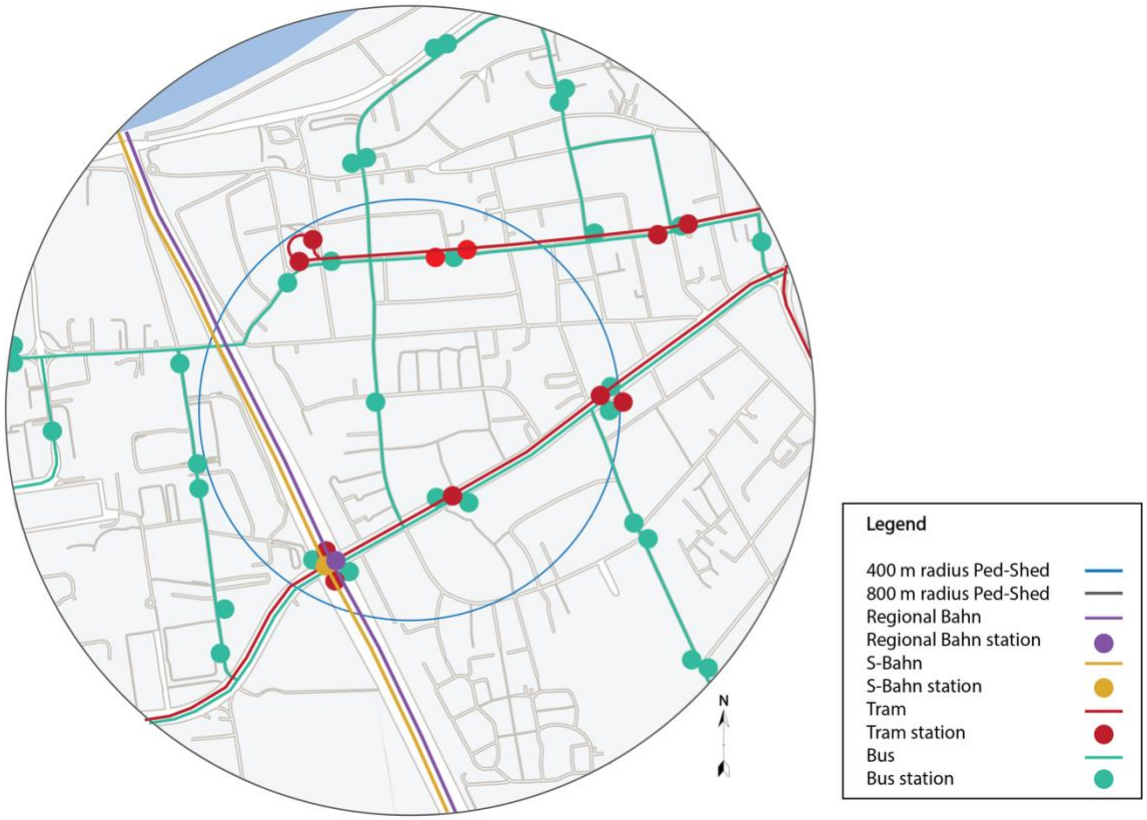


Figure 20. Public transport network within Ped-Sheds in Niederrad

Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

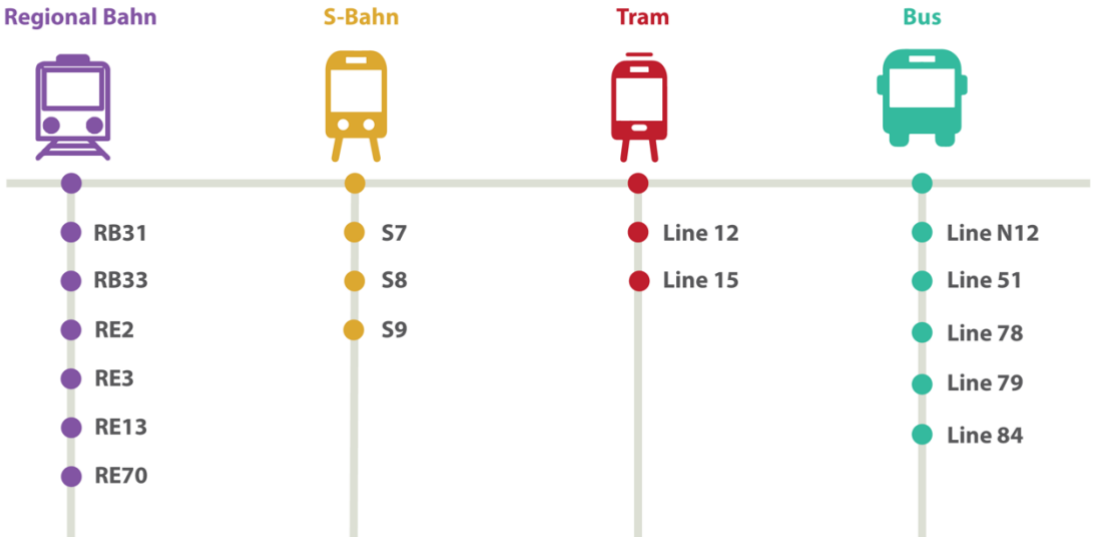


Figure 21. Overview of public transport lines within Ped-Sheds in Niederrad

Source: Diagram by author designed with Adobe Illustrator

Some bus stops are integrated with sidewalks, lacking a designated separate space. This integration leads to congestion in the waiting environment for passengers.

An issue arises from the absence of shelters at some bus stops, particularly in severe weather conditions such as rain or snow. The lack of shelter impacts the comfort and convenience of individuals waiting for buses at these stops.

While some bus stops are equipped with appropriate shelter, a dedicated bench, and station information, there is a absence of a tactile path for guidance.

	Tram stations along Bruchfeldstraße lack elevated platforms, posing difficulties for various users such as those with wheelchairs, strollers, or shopping wagons. Additionally, their placement in the middle of the street raises safety concerns. These stations lack tactile guiding systems, and only those stations shared by trams and buses are equipped with automatic ticket machines.
	Placing the bus stop at the corner of a crossing road presents drawbacks. Visibility and safety issues arise, and conflicts between turning vehicles and parked cars lead to traffic disruptions. Moreover, the lack of an elevated platform, tactile system, and shelter decreases accessibility, and the overall aesthetics are not visually appealing.
	The bus stop lacks paving and a tactile system, and there are no chairs available. Additionally, it lacks an elevated platform, making it difficult for individuals with disabilities or those using shopping wagons or strollers to access it.

Figure 22. Visual examples of bus stop shelter quality
Source: Author

The regional Bahn network, including six lines, serves as a connection to the main station and other cities. Additionally, the three S-Bahn lines provide direct links to Frankfurt's central

station and key locations like Frankfurt Airport. Niederrad's tram system includes two lines, one linking to Südbahnhof and the other to the city center, facilitating local travel. Moreover, four bus lines navigate within and around Niederrad, offering local connections. There is limited availability of night buses, as the area serves only one route during nighttime hours. Towards the southern region, closer to the forest, there's a decrease in public transport nodes. Similarly, the office area has a lower density of transport nodes. These areas experience comparatively fewer transport connections within the neighborhood.

While the public transport services in the study area are accessible, the situation at their stations are challenging. Overall, improvements are needed at public transport stations to enhance the overall quality of public transport services within the study area.

4.5. Permeability

Exploring the interconnected network of streets within the 400 to 800-meter Ped-Sheds is the focus of permeability. An effective network prioritizes direct routes for road users while ensuring multiple route choices reach their destinations efficiently. A key aspect is establishing a permeable network that minimizes obstacles and promotes optimal access across the entire center. To assess permeability in this case study, the analysis will focus on elements such as accessibility, junctions, and block sizes. Analyzing these components aims to provide a comprehensive understanding of the street network quality in these specified Ped-Sheds.

4.5.1. Accessibility

The essence of accessibility lies in aligning walking distances with linear routes, encouraging pedestrians to walk over driving. In the Ped-Sheds for pedestrian-centric commuting in the case study, the selection of routes within these zones was based on pedestrian preferences. The criteria include avoiding poorly lit paths despite their potential proximity to destinations.

Figures 23 and 24 are showing the accessibility within the 400 and 800-meter Ped-Sheds. Within the 400-meter Ped-Sheds, accessibility to destinations accounted for 30.38% of the total area. Additionally, the 800-meter Ped-Sheds showed a more encouraging design, with accessibility expanding to 50.16% of the total area. However, a significant challenge was the S-Bahn rail cutting through these zones, obstructing the left side of the Ped-Sheds, and affecting pedestrian access.

Figure 23. Accessibility within Ped-Sheds in Niederrad
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

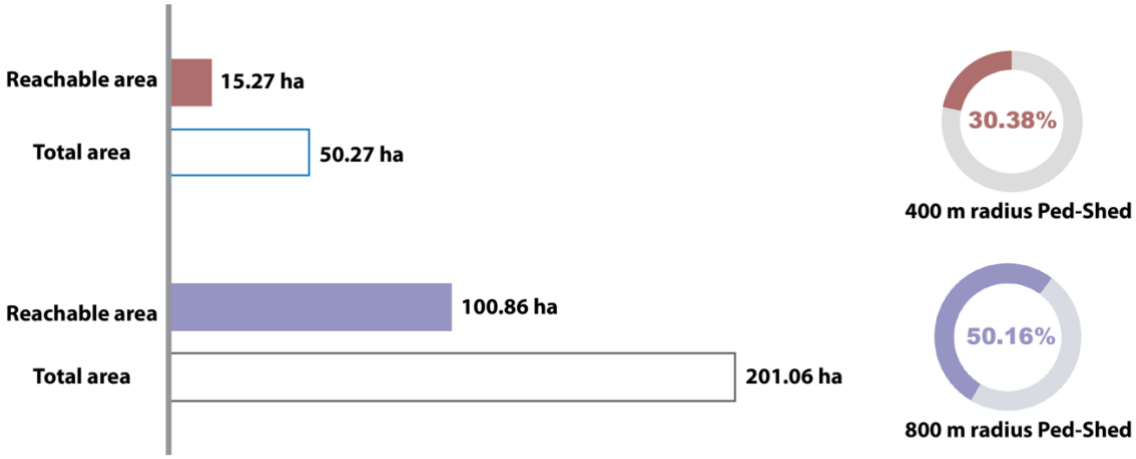


Figure 24. Distribution of accessibility within Ped-Sheds in Niederrad
Source: Diagram by author designed with Adobe Illustrator

4.5.2. Junctions

The road network's junctions play a crucial role in guiding users along their chosen routes. These junctions, in both number and design, influence navigation choices. When users encounter fewer directional changes to their destinations, the network's connectivity improves significantly. Enhanced connectivity leads to better wayfinding, minimizing disorientation among users.

Figure 25 offers an insight into junction distribution within the 400 and 800-meter Ped-Sheds, displaying various junction types for all users of the street. Among these, the four-way junctions (highlighted in red) present optimal options as they offer unrestricted movement in all directions, eliminating the need for forced directional changes. Additionally, the T-way junctions (shown in blue), allowing movement in three directions, encourage users to change their path. The cul-de-sacs (shown in yellow) limit users to a single turning option, making them the least favorable. A well-designed network aims to maximize four-way intersections while minimizing cul-de-sacs.

Figure 26 illustrates the desk work data analysis outcomes, presenting the following within the selected area:

- 49 Four-way intersections
- 235 T-way intersections
- 115 Cul-de-sacs

To assess the efficacy of movement choices within Ped-Sheds, the junctions considered a rating system. This evaluation methodology provides a metric for evaluating the navigational efficiency within Ped-Sheds based on junction types and their frequency. Four-way junctions received 2 points, T-way junctions received 1 point, and cul-de-sacs received a -1 point. The total score for the designated area reached 218 points, translating to 108 intersections per km^2.

The assessment shows 49 four-way intersections, encouraging direct and efficient movement options. However, these intersections are unevenly distributed within the area. Moreover, the relatively high number of well-distributed T-way intersections (235) creates potential areas where users might experience frequent directional changes. The presence of 115 cul-de-sacs raises concerns about overall connectivity and legibility.

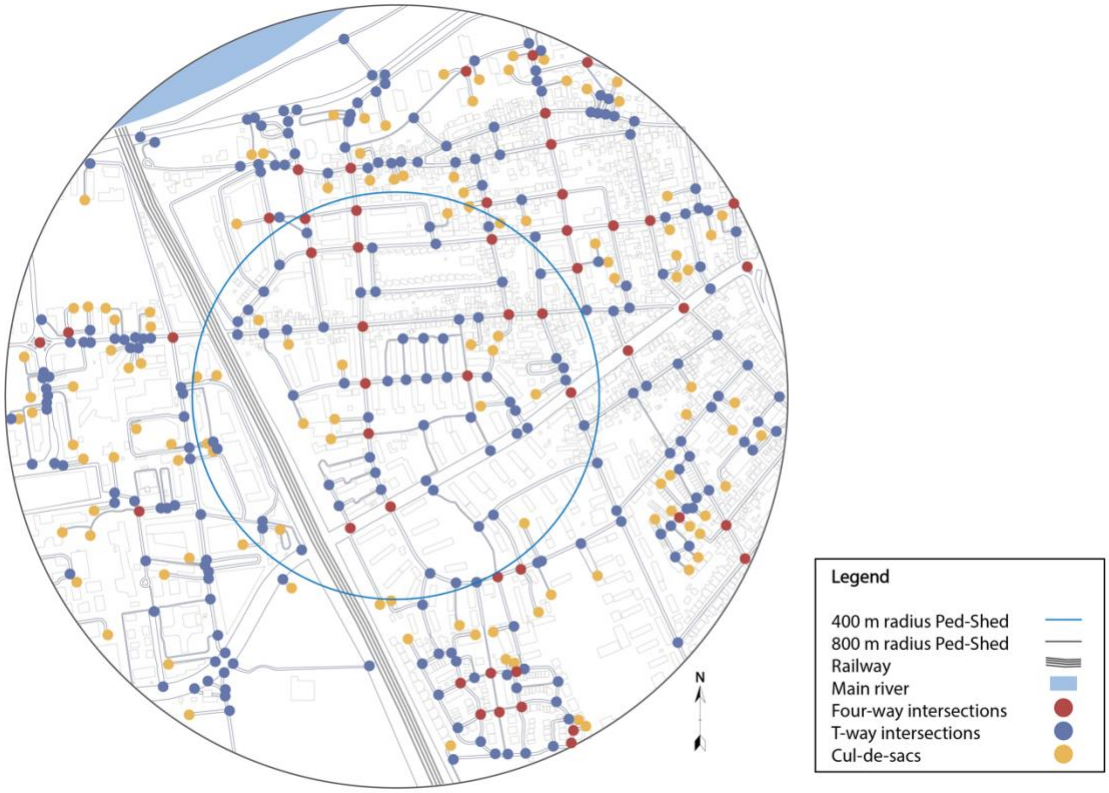


Figure 25. Junctions within Ped-Sheds in Niederrad
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

	Number of intersections	Points	Subtotal
Four-way intersections	49	2	98
T-way intersections	235	1	235
Cul-de-sacs	115	-1	-115
Total points			218
Intersections/ha			1.08

Intersection scoring in the selected area in Niederrad

108 per km²

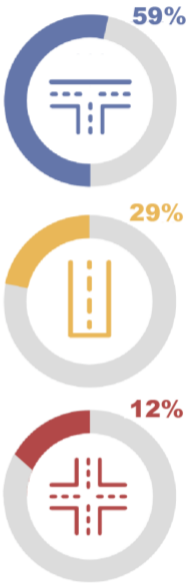


Figure 26. Distribution of junctions within Ped-Sheds in Niederrad
Source: Diagram by author designed with Adobe Illustrator

4.5.3. Block size

Block size and type affect road connectivity within an area, regarding the ease of movement. Larger blocks affect road network connectivity and lead to longer distances for commuters. Shorter paths are encouraging pedestrian and cyclist travel over car usage. Therefore, maintaining smaller block sizes enables the creation of a dense and interconnected road network, facilitating shorter and more walkable routes for individuals.

The visual representations in figure 27 shows an overview of block sizes within the 400 and 800-meter Ped-Sheds, regarding the interconnections of the street network. These blocks were categorized based on size, outlining five distinct categories:

Blocks smaller than 1 hectare (shown in purple)

Blocks varying from 1 and 2 hectares (shown in orange)

Blocks varying from 2 to 3 hectares (shown in light green)

Blocks varying from 3 to 5 hectares (shown in dark red)

Blocks larger than 5 hectares (shown in dark green)

Figure 28 visually represents the number of blocks within each size category. Upon desk work analysis, it becomes evident that a majority of 59%, is the category of blocks smaller than 1 hectare within the Ped-Sheds. Moreover, the larger blocks, exceeding 5 hectares, are located in the western and southern regions of the study area. The presence of the S-Bahn rail network cutting the area impacts pedestrian accessibility concerning block sizes.

Figure 27. Block sizes within Ped-Sheds in Niederrad
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

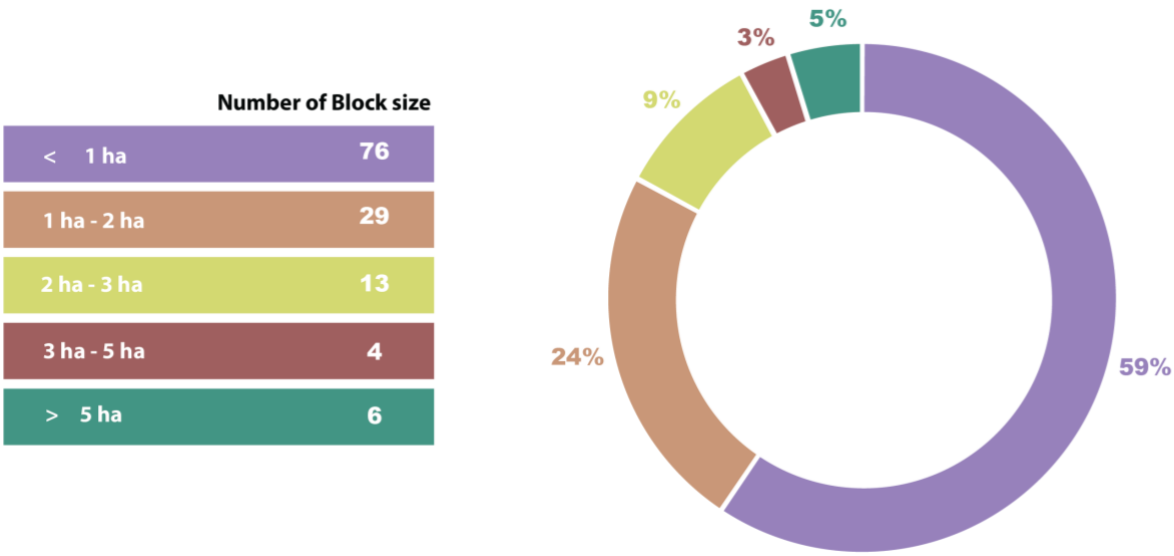


Figure 28. Distribution of block sizes within Ped-Sheds in Niederrad
Source: Diagram by author designed with Adobe Illustrator

4.6. Landmarks

Landmarks serve as external point references, easily identifiable physical objects like buildings, signs, stores, or mountains. They are often chosen to stand out from various possibilities and may be seen from multiple angles and distances. Whether within the city or at a distance, landmarks like isolated towers, golden domes, and prominent hills symbolize directions for orientation (Lynch, 1960).

Figure 29 illustrates the locations of these significant points in the landscape. Within the Ped-Sheds, three prominent landmarks stand out: the mother of good counsel church, the office area characterized by towering buildings and the Mainfeld residential buildings, reaching up to 23 floors (Figure 30), visible from afar.

Figure 29. Landmarks within Ped-Sheds in Niederrad
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

Mother of good counsel church
(German: Mutter-Vom-Guten-Rat Kirche)

Mainfeld residential buildings

Office area

Figure 30. Landmarks in the study area for visual orientation
Source: Author

4.7. SAFE walk assessment

The SAFE walk assessment aims to evaluate the safety, attractiveness, friendliness, and efficiency of streets leading to major destinations. This assessment is based on on-site observation within the 400-meter Ped-Shed. The findings show that streets have lower speed limits, having safer environments for pedestrians and cyclists. The presence of buildings with medium frontages contributes to adequate oversight, enhancing the overall sense of safety and surveillance.

Despite the presence of sidewalks on both sides of the streets, numerous pathways are blocked by parked cars, reducing pedestrian access. The lack of lively commercial corners along these routes, both in office areas and residential zones, reduces their appeal for evening use. Moreover, insufficient buffer between traffic and pedestrians' further compounds safety concerns. Also, there are challenges in wayfinding due to the lack of prominent landmarks. Additionally, the absence of dedicated cycle lanes throughout the Ped-Shed reduces the neighborhood's accessibility and appeal to cyclists. Lastly, the paving's layout presents challenges for individuals using wheelchairs or strollers.

Figure 31 presents some visual examples of pedestrian infrastructure quality within the Ped-Sheds. Figure 32 shows the scoring system used in the assessment, where streets receive scores based on specific criteria. Due to this scoring system, the total score in most of the routes in the study area ranges between 0 to 15 points, which represents low-quality walk infrastructure.

Figure 33 illustrates the total scores given to streets, represented in green, purple, and orange, obtained by summing up individual criterion scores. Among the streets assessed, two received relatively higher scores. Triftstraße, highlighted in green on the map, has the highest score. Bruchfeldstraße, highlighted in orange on the map, obtained a score spanning between 15 to 30. Both streets have well-defined sidewalks, offering a clear path for pedestrians. Their layout facilitates easier wayfinding, ensuring a more direct route. Moreover, the diversity of daily commercial land use with active frontages contributes to these streets being more frequented during evening hours. Additionally, allocated shelters and better paving enhance the pedestrian experience, creating an inviting atmosphere conducive to pedestrian traffic.

Within blocks, buildings are interconnected to the surrounding streets through arch tunnels. Regarding the inadequate lighting, the tunnel lacks visibility and limited surveillance.

The ground-level passage serves as a route for vehicles and pedestrians, running beneath the elevated railway track. The crossing lacks visual appeal due to narrow sidewalks on both sides and insufficient lighting within the tunnel. This creates an unwelcoming environment for pedestrian use.

Within this route, a bare wall marks a corner while cars densely line the path, engaging in unconventional parking practices. Additionally, the building edge fails to convey attractiveness and friendliness, lacking adequate space for pedestrian safety.

The sidewalks are blocked by parked cars, and there is no buffer zone between traffic and pedestrians Furthermore, the lack of shelters along these routes increases the overall inadequacy of amenities for pedestrians.

The residential area fabric lacks sufficient signs and landmarks to aid in wayfinding. Additionally, the buildings' uniform appearance makes navigation challenging.

The facade lacks aesthetic appeal, especially on the corners where there is a lack of friendliness and inviting elements. Additionally, there is limited surveillance.

The pavement is uneven, leading to puddles forming on sidewalks during rainy weather. This layout poses difficulties for people using wheelchairs or strollers. Also, adequate observation is lacking regarding the blind frontage.

The sidewalk's width has been diminished, with a substantial portion allocated for car parking. These factors lead to an unwelcoming environment for pedestrian use.

	The restrictions on the sidewalks make walking difficult and unpleasant for pedestrians. The sidewalk is restricted by parked cars and bicycles, which leads pedestrians to walk in a line rather than side by side.
	The absence of safety features is notable regarding pedestrians' vulnerability on street crossings. It includes the lack of floor markings, warning signals, traffic lights, and acoustic release signals, collectively compromising safety. This limitation raises concerns, especially for vulnerable groups like children, the elderly, and individuals with disabilities.
	The community gardens within the study area lack lighting infrastructure, contributing to poorly lit pathways neighboring them. This absence of lighting significantly reduces the friendliness and safety of these areas for pedestrians and cyclists. The photograph is captured from the elevated platform of Niederrad Bahnhof.
	Within the office district, towering structures dominate the landscape. These skyscrapers have blind or medium frontage at ground level. The absence of distinctive landmarks at eye level adds an element of disorientation. Additionally, the area has a shortage of pedestrian crossings.

Figure 31. Visual examples of pedestrian infrastructure quality
Source: Author

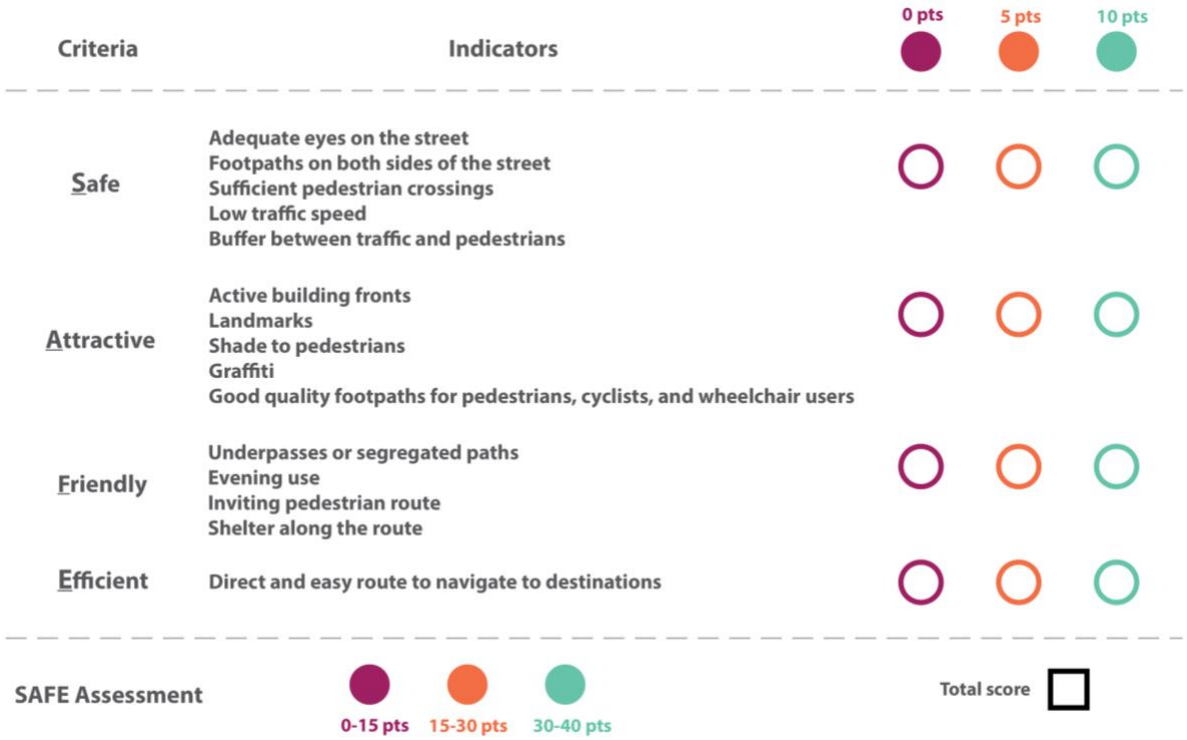


Figure 32. SAFE walk assessment map scoring system for Niederrad
Source: Diagram by author designed with Adobe Illustrator adapted from the framework presented by Schiller and Kenworthy (2018, pp. 209-224).

Figure 33. SAFE walk assessment within the 400-meter Ped-Shed in Niederrad
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

The neighborhood assessment shows various interconnected challenges affecting the overall pedestrian experience. These include insufficient lighting, unpleasant corners, unattractive facades, uneven pavements, unconventional parking, the absence of buffer zones and shelters, and wayfinding difficulties.

Insufficient lighting in arch tunnels, ground-level passages, and community gardens compromises visibility and safety and leads to an unwelcoming environment for both pedestrians and cyclists. Some routes present challenges with unattractive corners, unconventional parking, a lack of pedestrian-friendly elements, and the absence of buffer zones and shelters, which lead to overall safety issues.

In the residential area, inadequate wayfinding signs impact navigation, and unfriendly landscapes arise from uninviting facades, uneven pavements, and limited observations. Restricted sidewalk widths due to parked cars contribute to an unpleasant walking experience and safety concerns at street crossings, especially for vulnerable groups.

Within the office district, skyscrapers with blind or medium frontage and a shortage of pedestrian crossings create a disorienting and less pedestrian-friendly environment. Addressing these challenges is crucial for enhancing safety, aesthetics, and the overall pedestrian experience in the study area.

Regarding the 400-meter SAFE walk assessment, it is reasonable to conclude that the challenges and shortages identified within this radius may extend to the broader 800-meter Ped-Shed. The issues, such as inadequate lighting, unfriendly pedestrian environments, and safety concerns due to unconventional parking and wayfinding difficulties, are likely to continue in the larger context. This observation is supported by a comprehensive analysis of various parameters in other sections, pointing to interconnected challenges within both Ped-Sheds. Therefore, a holistic intervention is crucial to address these issues across the entire study area to a create more pedestrian-friendly and livable urban spaces.

4.8. Building edge

The assessment of building edges examines the ground-level activity of buildings. Figures 34 and 35 are illustrating three classifications of how the facade interacts within the 400-meter Ped-Shed:

- Active frontage (marked in green) displays an engaging relationship with the street.
- Medium frontage (highlighted in yellow) shows a moderate level of interaction with the street.
- Blind frontage (indicated in red) shows no engagement with the street.

Figure 34. Building edges activeness within the 400-meter Ped-Shed in Niederrad
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

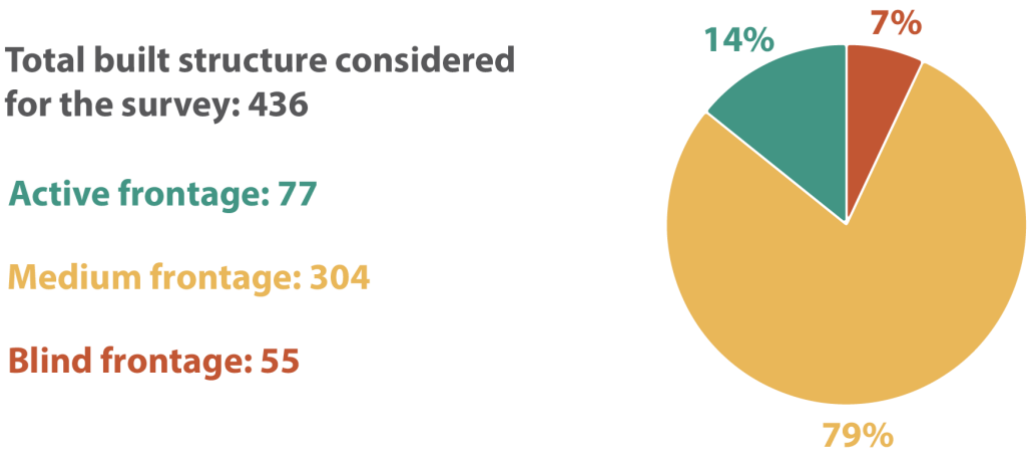


Figure 35. Distribution of building edges activeness within the 400-meter Ped-Shed in Niederrad
Source: Diagram by author designed with Adobe Illustrator

The on-site survey including 436 structures was assessed, showing that the medium frontage category contains the majority of buildings (Figure 36). Also, the office buildings situated on the left side of the study area mostly have inactive ground floors.

Figure 36. A visual comparison of active, medium, and blind building frontage in Niederrad
Source: Author

The assessment of building edges within the neighborhood shows a diverse range of ground-level activities. Most structures are in the medium frontage category, showing a moderate level of interaction with the street environment. Within mixed-use land uses, certain buildings have active frontage with commercial ground floors, having an engaging relationship with the street. On the other hand, others covered their frontage, showing no interaction with customers. Blind frontages in office buildings on the left side of the study area have inactive ground floors, potentially influencing the overall liveliness and pedestrian experience in the urban fabric.

4.9. Visual Appropriateness

Visual appropriateness enhances individuals' comprehension of the built environment, simplifying the identification of necessary destinations and facilities. Figure 37 presents examples of visual appropriateness within Ped-Sheds, showing how the built environment generally facilitates quick recognition of functions through frontage observation. The buildings simplify interpretation for their intended purposes.

Supermarket

Bakery

International supermarket

Drugstore

Hotel

Kindergarten

Kiosk

Beauty shop

Figure 37. Illustrative examples of visual appropriateness in Niederrad's Ped-Sheds
Source: Author

The built environment effectively communicates the functions and purposes of various commercial land uses, such as local retailers, banks, and supermarkets, to residents. While the examples in Figure 37 show positive instances, most structures in Niederrad contribute positively to individuals' comprehension of the neighborhood. Their design promotes an environment where residents and visitors can identify the functions of different facilities from their exteriors. This visual clarity promotes a positive and user-friendly experience for the community.

4.10. SWOT analysis

This chapter undertook a comprehensive assessment of the 400 and 800-meter Ped-Sheds in Niederrad, starting with an exploration of its historical development and the analysis of its demographics and geographic layout. The chapter went through the comprehensive details of land use and household characteristics, providing insights into the area's fabric.

The assessment of transport infrastructure explored the modal split in Frankfurt and investigated traffic area characteristics, expanding to bicycle infrastructure and parking provisions.

Public transport infrastructure was examined to comprehend its availability, accompanied by a detailed exploration of permeability factors. This includes an assessment of accessibility, junctions, and block sizes, crucial elements in defining movement and connectivity within the area.

Moreover, the chapter investigated the significance of landmarks, playing a crucial role in the SAFE walk assessment. The analysis extended to building edges and visual appropriateness, acknowledging their impact on the overall aesthetics and functionality of Niederrad's urban landscape.

As mentioned in the second chapter (methodology chapter), the study aims to propose actionable recommendations to empower walking and cycling in Niederrad. Considering the

comprehensive assessment of land use, mobility, and walkability within the case study, a detailed analysis has been undertaken in this chapter to summarize the strengths, weaknesses, opportunities, and threats (SWOT) to address the fourth research question. This comprehensive SWOT analysis forms the foundation for proposing actionable strategies and recommendations (Figure 38).

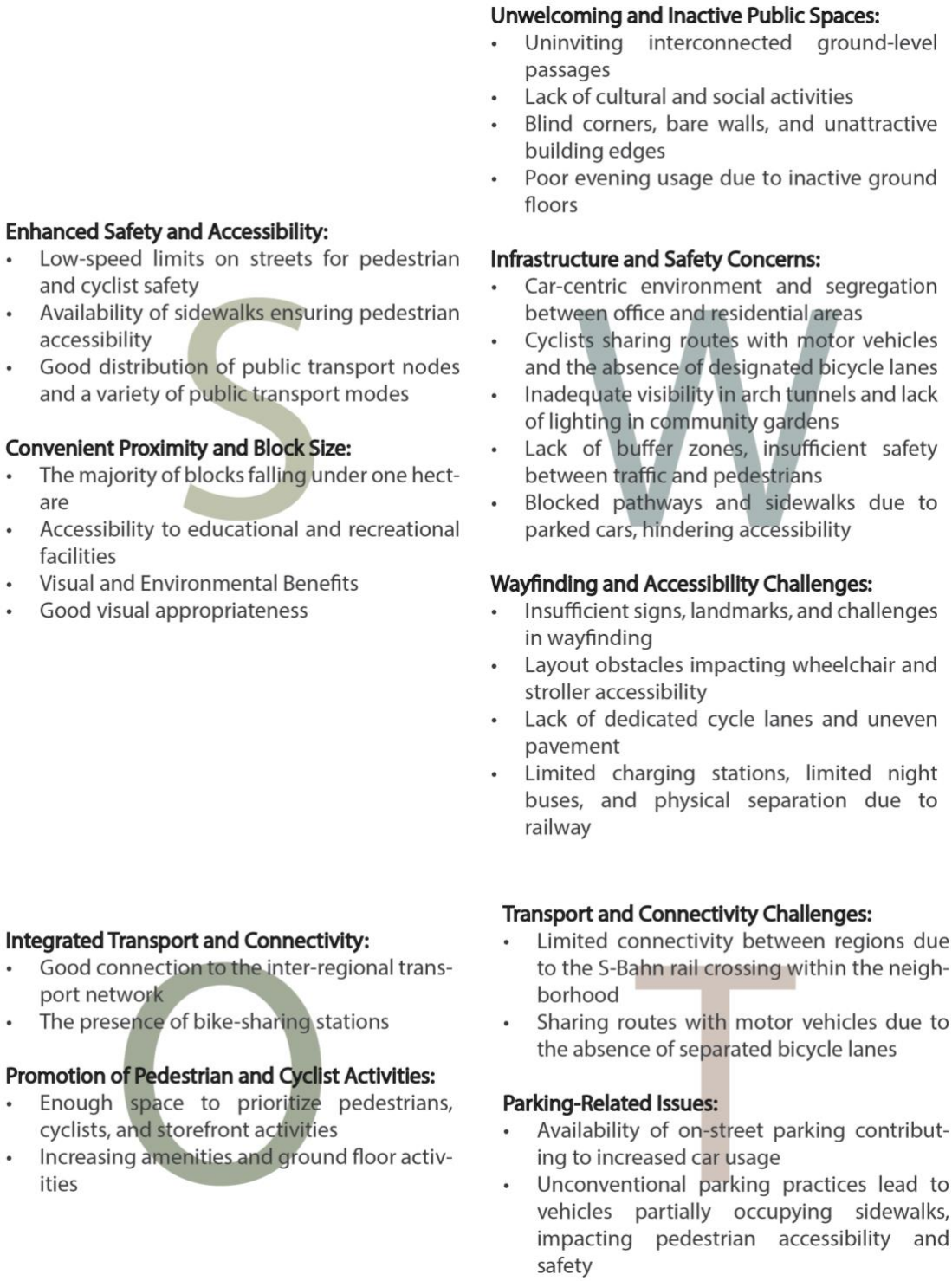


Figure 38. SWOT analysis of the study area
Source: Figure by author designed with Adobe Illustrator

5

The Proposal

5. The Proposal

5.1. Goals

Based on the literature review in chapter three and the comprehensive assessment in chapter four, this study's proposal aims to empower active mobility in Niederrad to develop a sustainable neighborhood. Figure 39 illustrates the goals of the proposal.

Figure 39. Goals of the final proposal
Source: Diagram by author designed with Adobe Illustrator

5.2. Strategies

In line with the goals in Figure 39 and addressing the fifth research question, this chapter provides a detailed description of the strategies needed in Niederrad to promote active transport, based on the wide variety of evidence gathered throughout the work. These interconnected strategies are formulated to achieve the five goals in the proposal, which seek to empower active mobility in Niederrad and contribute to sustainable neighborhood development.

1. Prioritizing pedestrians and cyclists over car-centric designs for safety and convenience.
2. Improving community engagement by developing public spaces and active corners.
3. Integrating green infrastructure, pocket parks, and green spaces into urban planning to enhance environmental sustainability and quality of life.
4. Implementing adequate street lighting, surveillance, and well-designed public spaces.
5. Empowering the commercial ground floor with active frontages for people to interact and connect.

These strategies demonstrate a ripple effect, where lively environments and prioritizing pedestrians and cyclists not only invite more people into the neighborhood but also enhance safety and vibrancy. These initiatives create an engaging environment that encourages active transportation and improves the quality of life.

5.3. Measures and actions

The proposal provides actionable recommendations aligned with this study's goals and strategies. The proposal concentrates on specific areas that are considered to be generic types of examples and thus presents them as potential models applicable to similar locations throughout the study area.

The urban street layout recommendations and measurements outlined in this thesis are referred to the "Richtlinien für die Anlage von Stadtstraßen (RASt 06)," translated as Guidelines for the Design of Urban Streets (2006). Recognized as a fundamental reference for urban planning and transportation infrastructure in Germany, this guideline played a role in shaping the proposed standards. However, it is crucial to note that the recommendations in this study are modified to address specific circumstances, cater to local needs, and reflect the evolving practices in urban planning, as discussed in Chapter 3 and illustrated in Figure 5.

5.3.1. Adolf-Miersch-Straße

The Adolf-Miersch-Straße character area provides connectivity and accessibility, serving as a connection road with the highest-width (32-meter) street within the study area. A section of the street (Figure 40), spanning 466-meters in the east of Niederrad Bahnhof, is designated as a high-traffic zone and hosts various public transport stations (Figure 41).

Figure 40. Geographical overview: Adolf-Miersch-Straße
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

The surrounding land use is a residential area characterized by green private frontages. The street experiences high levels of pedestrian and cycling, as well as car traffic, making it a key point for targeted interventions.

Figure 41. Current layout of Adolf-Miersch-Straße
Source: Author

This proposal suggests implementing the interventions over a short-term period spanning 2 to 3 years. The approach involves a gradual implementation of interventions to study the traffic impacts, allowing for clear communication about the proposed alterations and their impact on traffic to be communicated to residents. The illustration in Figure 42 shows the proposed plan for the street layout.

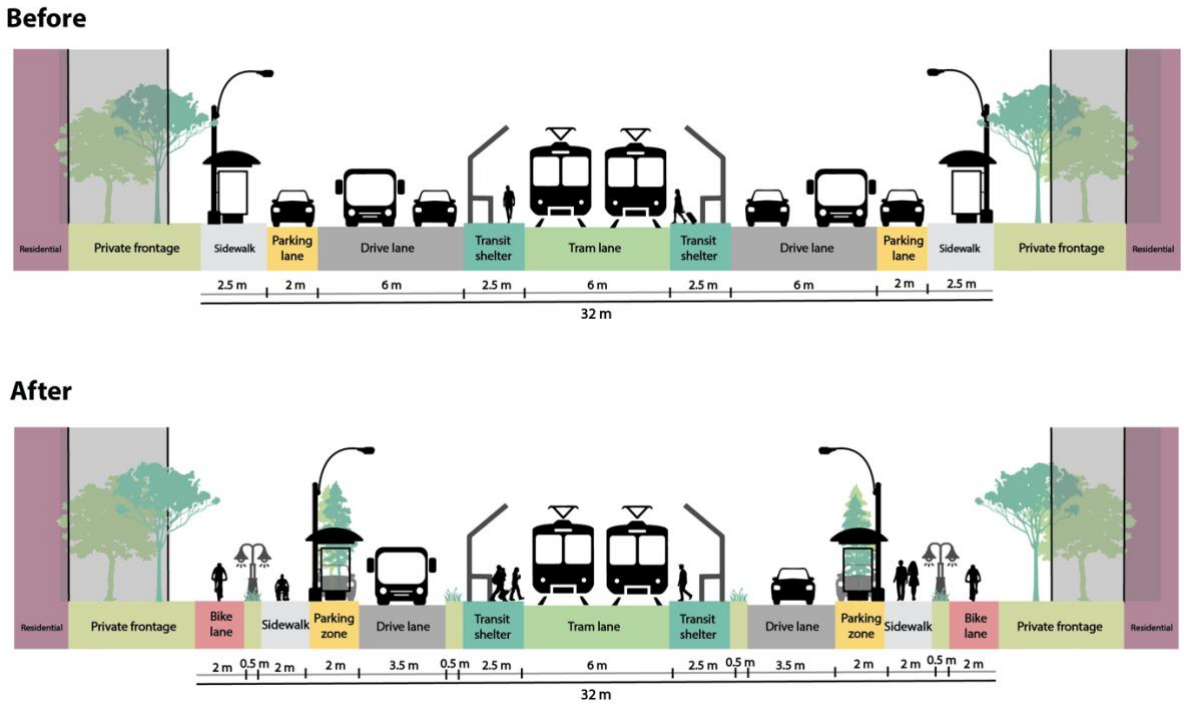


Figure 42. Transformation cross-section of Adolf-Miersch-Straße

Source: Figure by author designed with Adobe Illustrator

1. **Sustainable street redesign:**

The proposal merges two 6-meter-wide driving lanes into two single 3.5-meter-wide lanes on both sides. This reduction aims to create a street design that is more accommodating and inclusive for various users, allowing for specific spaces for pedestrians and cyclists. Additionally, the transition to a single driving lane promotes traffic calming, promoting a safer and more comfortable environment for vulnerable users within the landscape.

2. **Optimizing the sidewalks:**

The existing 2.5-meter-wide sidewalks are designed to be integrated with the bus stops along the road. Additionally, delivery bikes, such as post-deliveries, commonly park on the sidewalk for convenient access to the residential area. In contrast, the proposed sidewalks are continuous, safe, and comfortable pathways, free from disruptions. It presents a 2-meter width only for pedestrians on both sides to ensure smooth flow without interference.

3. **Creating bike lanes:**

Currently, the road lacks specified cycling lanes, and there is a shared pathway for both bicycles and cars. In order to have a well-defined, continuous, and protected network of bike

lanes, the proposed plan allocates dedicated cycling lanes, each with a 2-meter width, situated on both sides of the street. These lanes are marked with red coloring and accompanied by signage along the roadside. Placing the bike lane adjacent to the curb ensures a well-defined and predictable path.

4. **Partial removal of car parking:**

The current street layout includes on-street parking lanes on both sides. The proposal does not seek to eliminate all parking spaces. Instead, it recommends a reduction in parking spaces, with the introduction of bus stop platforms and the incorporation of trees positioned between the parked cars. It not only creates a specific space for bus stops that remains integrated with the sidewalk but also enhances the street's aesthetics by introducing more greenery.

The proposal may face opposition to reducing parking spaces, potentially encountering resistance from the community. To address this concern, the recommendation is to introduce changes gradually, monitor traffic patterns and study the traffic impacts, and adjust as needed. Therefore, there is a need to implement community engagement strategies involving public meetings, surveys, and workshops to collect valuable input and address residents' concerns. By emphasizing the benefits, such as improved traffic flow, enhanced aesthetics, and the introduction of green spaces, the successful implementation of the initiatives is increased.

5. **Green infrastructure boost:**

Enhancing the layout with additional greenery not only elevates the visual aesthetic of the landscape but also acts as a physical barrier between lanes, improving environmental quality, such as reducing noise and air pollution. The proposal introduces three new sections of green infrastructure:

- Separating the tram lanes from the driving lane with bushes.
- Adding trees to the on-street parking lane.
- Integrating a green buffer between the bike lane and the sidewalk.

6. **Improving lighting:**

To ensure personal safety on the pedestrian lane and enhance physical security on the bike lane, a dual street light installation is recommended to be positioned between the sidewalk and the bike lane.

5.3.2. Frauenhofstraße

Frauenhofstraße is one of the connecting streets linking Bruchfeldstraße and Triftstraße. It is characterized by commercial establishments at both ends, with residential apartments distributed in between, covering 118 meters. Additionally, it serves as the starting point for Bus Line 51. Figures 43 and 44 show the geographical overview and the current layout of Frauenhofstraße.

Figure 43. Geographical overview: Frauenhofstraße
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

The street currently has diagonal on-street parking on both sides within its 18-meter width, leading to cars interrupting the sidewalk space. This layout not only leads to safety and barrier issues but also reduces the overall aesthetics.

Figure 44. Current layout of Frauenhofstraße
Source: Author

The proposed plan aims to address these issues through interventions scheduled over a short-term period of 2 to 3 years. Figure 45 shows an illustration of the proposed street layout.

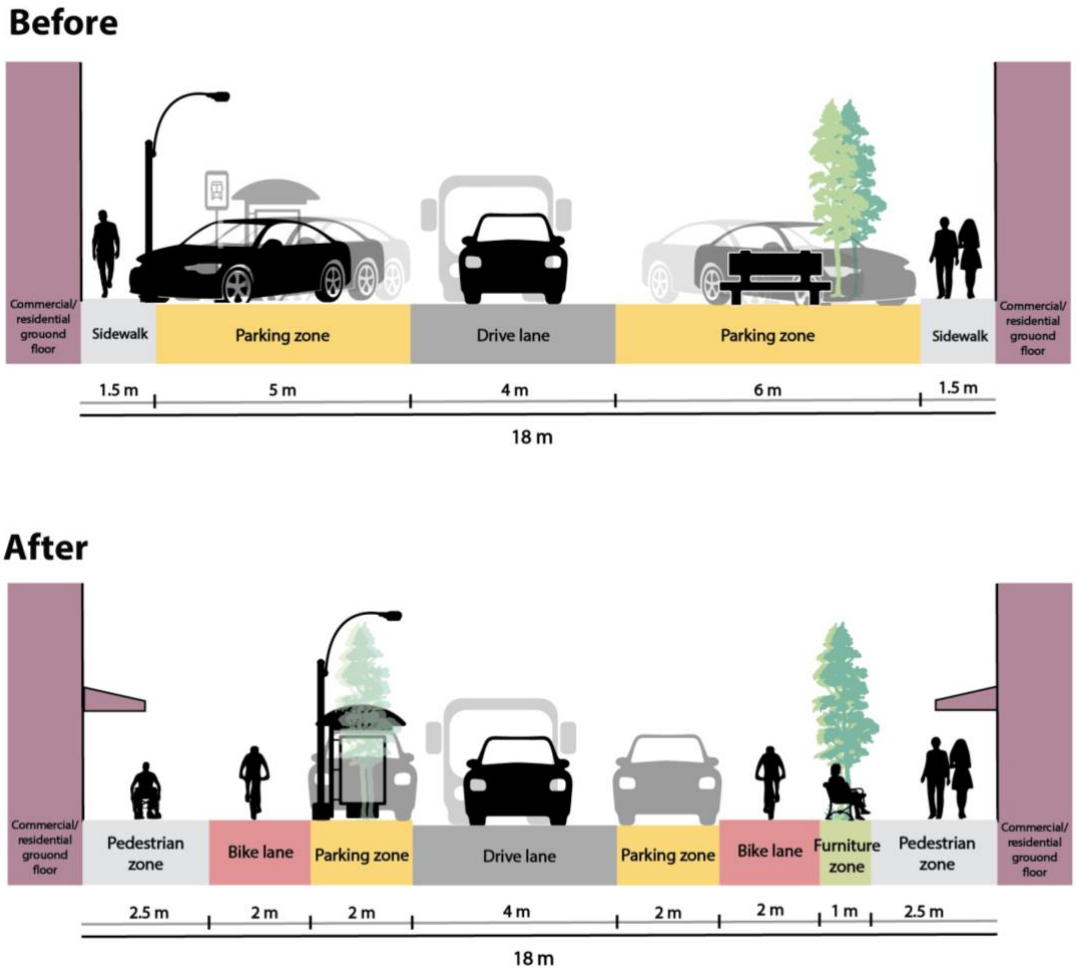


Figure 45. Transformation cross-section of Frauenhofstraße
Source: Figure by author designed with Adobe Illustrator

1. **<u>Elevating non-motorized lanes:</u>**

The recommendation maintains the existing car lane, which remains at a width of 4 meters. Unlike the current layout, the proposal suggests a slight elevation for both the sidewalks and bike lanes. This initiative aims to enhance safety and visibility for pedestrians and cyclists along the route.

2. **<u>Prioritizing pedestrians and cyclists over parking:</u>**

The street currently has a car-centric design, emphasizing the convenience of motorized users. Approximately 11 meters of the street's 18-meter width is allocated to diagonal on-street parking, with some vehicles blocking the sidewalk. The proposed intervention involves replacing diagonal parking spaces to parallel and reallocating these spaces to prioritize pedestrians and cyclists. This initiative aims to enhance safety, promoting a more livable and pedestrian-friendly environment.

To implement these interventions successfully, it is crucial to engage with residents and store owners, seeking their opinions and obtaining their agreement. Clear communication ensures that people understand the benefits of the proposed changes for retailers, emphasizing potential positive impacts on foot traffic, community engagement, and overall aesthetics.

3. **Creating bike lane:**

Currently, Frauenhofstraße lacks a specific bike lane. Regarding the importance of interconnected bike lanes throughout the urban landscape and considering Frauenhofstraße's role as a connector between Bruchfeldstraße and Triftstraße, the proposal suggests transforming parking spaces from diagonal to leaner on-street parking. This initiative provides a space to establish a specific lane for cyclists. The proposal recommends the creation of a 2-meter wide on each side, marked in red, to facilitate movement in both directions. This layout not only enhances accessibility but also promotes safety and convenience for cyclists.

4. **Widening the sidewalks:**

Widening the current sidewalks into a 2.5-meter width improves pedestrian access to other streets and commercial frontage, fostering a barrier-free environment.

5. **Introducing furniture zone:**

The street currently has a single bench positioned at the intersection with Bruchfeldstraße and a line of trees located on the right side of the street between parked cars. Regarding the commercial frontage particularly at both ends, the proposal suggests a transformation of the sidewalk into a furniture zone. By encouraging more active and open commercial frontage, the proposed layout enhances the livability of the pedestrian zone. Moreover, the expanded zone accommodates the bus stop platform, making it a versatile and accessible space.

6. **Greening the urban spaces:**

The proposal suggests the incorporation of tree-lined rows within the furniture and parking zones to offer shade for pedestrians, enhance air quality and the overall beautification of the area. This intervention activates ground-floor frontages, making a more welcoming public space that invites people into the area, which is beneficial for commercial interests.

5.3.3. Goldsteinstraße

The study area assessment in chapter 4 showed that some ground-level passages have unwelcoming environments for pedestrians and cyclists. The passage in crossings of the railway and Goldsteinstraße (Figure 46) serves as a route for vehicles and pedestrians running beneath the elevated railway track. The crossing lacks visual appeal, insufficient lighting within the tunnel due to curved route, and visibility issues for cyclists.

Figure 46. Geographical overview: Goldsteinstraße
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

The proposed plan intends to tackle current issues with interventions scheduled for the immediate period of 0 to 1 year. The illustration in Figure 47 shows the suggested street layout.

Before

After

Figure 47. Transformation of ground-Level passage at the crossroads of Goldsteinstraße and the railway: Before and after proposals

Source: Figure by author designed with Adobe Illustrator

1. **Illuminating the pathways:**

The proposal recommends two lighting interventions. Firstly, the installation of overhead lighting brightens the whole passage. Secondly, colorful lights placed on both sides of the passage walls create a shadow effect on the opposite side. This arrangement aids nighttime visibility for cyclists, especially along the curved route, ensuring that cars easily detect their presence. Moreover, the proposal suggests installing a traffic convex mirror to enhance the visibility of vehicles approaching from the opposite side and improve safety.

2. **Renovating the passage environments:**

The present conditions in the passage resemble damp walls with mold and algae, accompanied by ceiling leaks and an unpleasant scent. The proposal recommends renovating the passage to create a livable, inviting, and aesthetically pleasing environment, particularly for pedestrians and cyclists. One proposed solution involves enhancing the environment by installing billboards on the walls, contributing to an overall improvement in the atmosphere.

3. **Implementing greening:**

Regarding the limited sidewalk width, the proposal suggests implementing plants in the sections with wider widths.

5.3.4. Saonestraße

In the office district, towering structures dominate the landscape. These skyscrapers have blind or medium frontage at ground level. The absence of distinctive landmarks at eye level adds an element of disorientation. Additionally, the area has a shortage of pedestrian crossings. Saonestraße is in the office district area (Figure 48) surrounded by diverse land uses, including residential buildings, office towers, daily shopping supermarkets, and restaurants. Implementing strategic initiatives enhances the overall livability, safety, and user experience within the landscape.

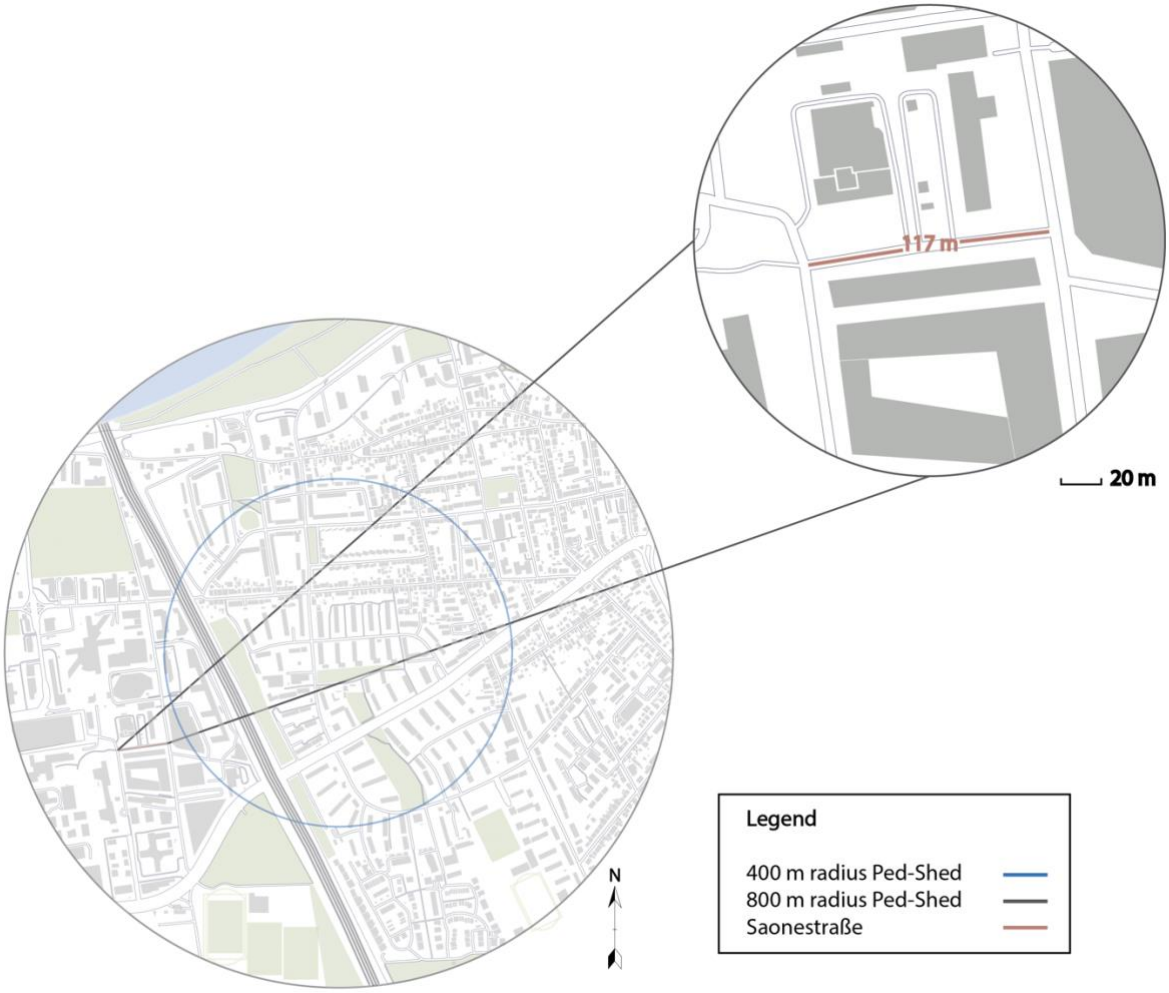


Figure 48. Geographical overview: Saonestraße

Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

To promote a sense of ownership and encourage diverse user participation in the street transformation within the office area, the proposal recommends short-term interventions to study their impact. These alternatives involve implementing temporary changes to streets or open/public spaces, allowing for the observation of their impact and the collection of feedback before committing to permanent alterations. This approach includes testing innovative streetscape concepts, such as integrating public amenities into the tree section in

the street. Temporary interventions, such as pop-up events and installations, are suggested for a limited time to actively engage the community for potential permanent improvements. The alternatives are versatile, designed to be implemented throughout the office area, catering to varying sizes and purposes (Figure 49 and Figure 50).

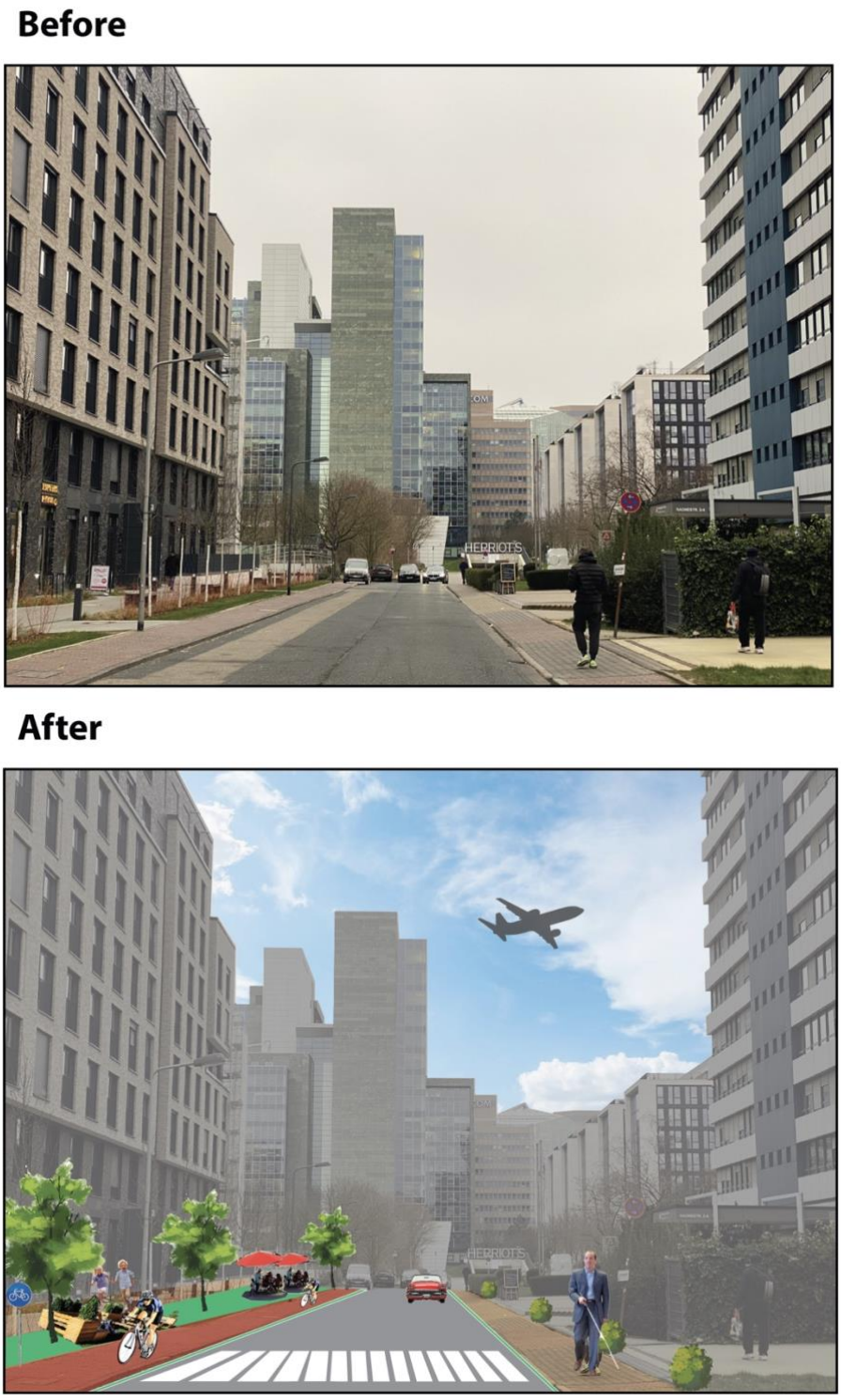


Figure 49. Transformation of Saonestraße within the office area: Before and after proposals
Source: Figure by author designed with Adobe Illustrator

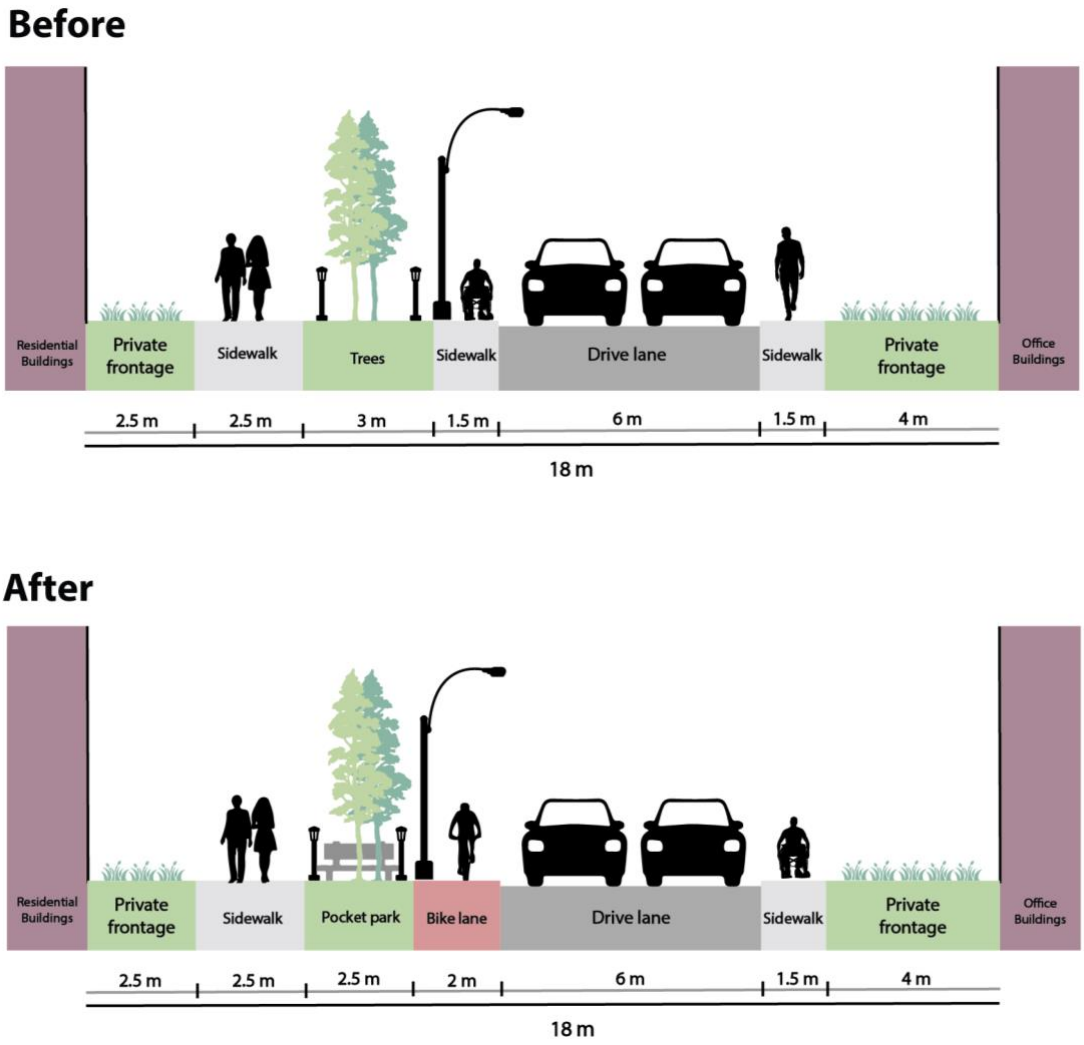


Figure 50. Transformation cross-section of Saonestraße
Source: Figure by author designed with Adobe Illustrator

1. **<u>Pocket parks for community comfort:</u>**

To enhance the livability of the area, the provision of accessible spaces like pocket parks benefits nearby residents, employees, and customers, offering a place for relaxation and communal gatherings. This initiative transforms the green section of the street into a more inviting space, addressing the challenge of blind or medium frontage at ground level. The pocket parks feature amenities such as umbrellas, providing additional shade for people looking to work outdoors with their laptops, contributing to a versatile and welcoming environment.

2. **<u>Relocating the sidewalks and introducing a bike lane:</u>**

In the existing residential zone, there is currently a public sidewalk distinct from the one designated within the street. The recommendation involves redesigning the current route in front of the residential area into a sidewalk and repurposing the existing sidewalk to accommodate a bike lane. Red asphalt and signage are used throughout the street to designate the bike lane.

3. Allocating pedestrian crossing:

The proposal recommends the addition of pedestrian crossings to boost safety and improve accessibility for pedestrians in the area.

5.3.5. Bruchfeldstraße

This study focuses on a specific 241-meter section in the eastern part of the Bruchfeldstraße, which has active commercial frontages. The overall length of the street is 1000 meters. The character area is positioned as a daily destination street for everyday shopping as a location for community interaction. With high pedestrian traffic, it contains high-traffic zones, particularly in commercial section. The mixed-use areas with commercial frontage create a more walkable and vibrant neighborhood. However, the street is shared between tramlines and car lanes without any physical separation, allowing them to move within the same traffic corridor. This shared route leads to high traffic volume, especially during parking situations. The second issue is that a part of the sidewalks is restricted by parked cars. Additionally, there is a lack of greenery implemented in the street. Figures 51 and 52 illustrate geographical overview and current layout of Bruchfelstraße.

Figure 51. Geographical overview: Bruchfeldstraße
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

The street accommodates parked cars, a driving lane, and a tram route. All available on-street parking spaces are occupied by cars, and on the right side of the image, a delivery van is stationed at the bus stop. While commercial establishments and retail shops along the street have open fronts and place chairs on the sidewalk, the presence of parked cars obstructs the visibility of these shops, making them less readable for street users.

This part of the street hosts cafes, restaurants, and a bakery that are open to the sidewalk, providing a sense of place, friendliness, and liveliness to the street atmosphere. Nevertheless, parked cars reduce both safety and aesthetic appeal.

Figure 52. Current layout of Bruchfeldstraße
Source: Author

By prioritizing alternative modes of transportation, such as walking or cycling, the area experiences pedestrian traffic. This shift is advantageous for retail stores, as more people explore shops. In the selected area, where stores are open to the street and place their furniture on the sidewalk, the presence of on-street parking compresses the available space. Creating a more inviting and pedestrian-friendly environment can attract shoppers, fostering a pleasant atmosphere. However, eliminating all parking in this area could have raised concerns about potential customer loss from those who prefer car-based shopping for the store owners. To enhance the success of proposed alternatives, the recommendation is to inform store owners about the benefits of the changes and provide guidance on adapting their businesses. Clear communication about the positive impacts on foot traffic leads to community engagement and overall aesthetics in this section. Additionally, implementing changes gradually helps businesses adapt, minimizing immediate economic impact and mitigating potential dissatisfaction. On the other hand, there are alternative parking options available in other sections of the street and neighboring alleys. The proposed plan intends to tackle these issues with interventions scheduled for the immediate period of 0 to 1 year. The illustration in Figure 53 shows the suggested street layout.

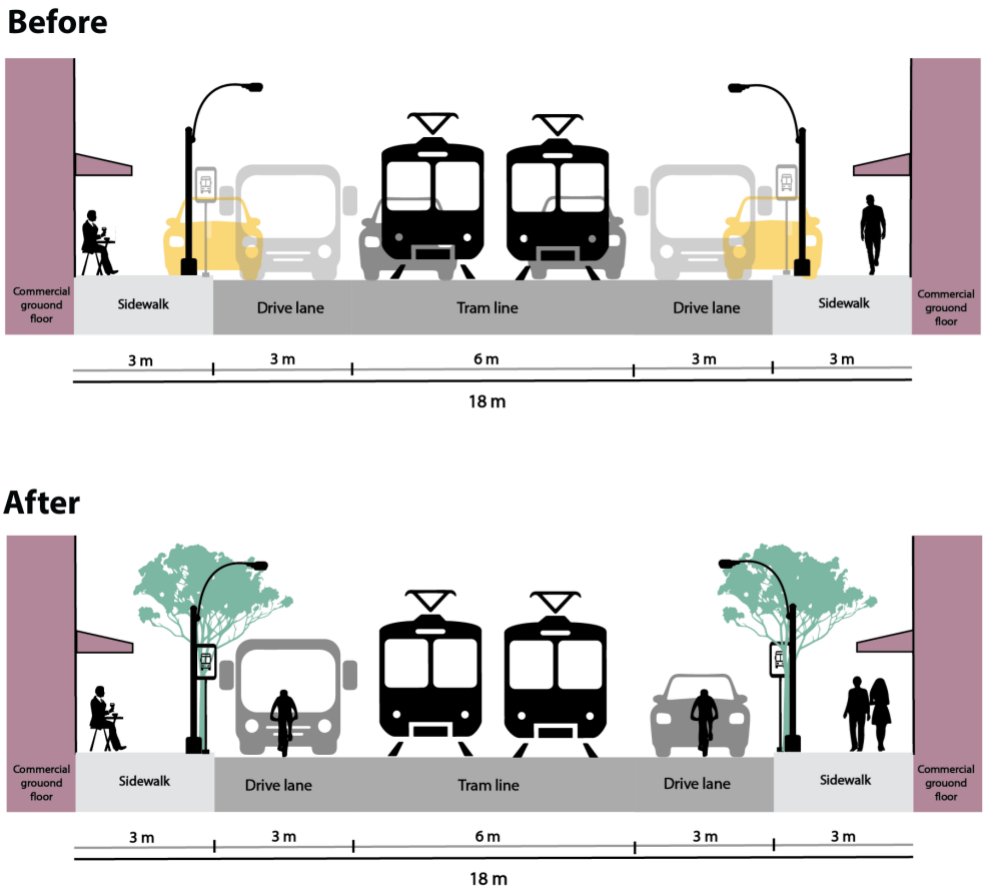


Figure 53. Transformation cross-section of Bruchfeldstraße
Source: Figure by author designed with Adobe Illustrator

1. **<u>Optimizing urban mobility:</u>**

The proposal suggests implementing additional regulations to restore the designated functions to existing lanes in the street. Currently, the street layout includes tram lines and driving lanes, with no parking lanes. However, an issue arises as cars park on both the sidewalk and the street occupying these spaces simultaneously.

In response, the proposal aims to remove on-street parking, intending to reclaim the driving lane for the exclusive use of private cars. By enforcing separate lanes, the proposal aims to enhance safety and ease traffic congestion, emphasizing the importance of separate spaces for different modes of transportation. This approach seeks to optimize urban mobility and contribute to more efficient and secure transport.

Regarding the placement of the tram line within the central portion of the street and the positioning of tram stations along the sidewalk, individuals using public transportation are required to access the street to board the tram. Moreover, the elevated height of the tram presents challenges for specific user groups, such as individuals with disabilities or elderly passengers.

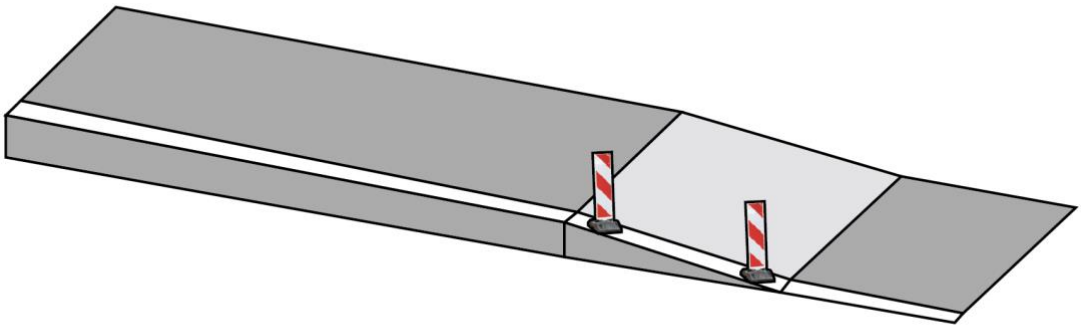


Figure 54. Inclusive elevated tram station design
Source: Figure by author designed with Adobe Illustrator

Figure 54 illustrates the inclusive elevated tram station design. The elevated part of the street allows the tram to align with the platform, making it easier for passengers, especially wheelchairs and strollers, who need mobility aids to enter and exit the tram at the same level as the platform. This design enhances accessibility and comfort for public transportation inclusiveness. This design is marked with warning signs to alert drivers that they are approaching the station.

2. **Enhancing bike network safety:**

To ensure the connectivity and accessibility of bicycle routes and connect the current bike lanes with the wider cycling network in the neighborhood, the proposal recommends incorporating caution signs to address potential hazards and enhance safety. This involves implementing appropriate road markings to alert drivers and cyclists, particularly at intersections, to ensure optimal visibility.

3. **Sidewalk reclamation:**

The proposed street layout allocates a 3-meter width for each sidewalk. However, due to parked cars occupying the sidewalk space, it remains unusable for pedestrians. Eliminating on-street parking not only reclaims the sidewalks but also enhances their safety and aesthetic appeal. Moreover, on-street parking removal provides businesses with more accessible and inviting spaces that contribute to the overall vibrancy of the street.

4. **Greening Sidewalks: Boosting Aesthetics and Commercial Appeal:**

The proposal suggests adding trees and planters to the sidewalks. This intervention not only offers shade for pedestrians and makes the landscape beautiful but also makes a more welcoming public space that invites people into the area, which is beneficial for commercial interests.

5.3.6. Herzogstraße

Herzogstraße is a one-way 12-meter street in a residential land use area with on-street parking on both sides. However, this arrangement results in cars occupying both the drive lane and sidewalk. Despite the sidewalk having a width of 2.5 meters, it is restricted by parked vehicles. The lack of a designated bike lane has led to the absence of continuous and connected bike lanes linking to other parts of the neighborhood. Additionally, the overall aesthetic appeal is compromised by the lack of vegetation and greenery. Figure 55 illustrates current layout of Herzogstraße.

The presence of potholes and uneven surfaces in the street's asphalt poses a risk of tire damage. This condition is unsafe for both cars and bicycles, especially during nighttime travel. Additionally, the lack of greenery contributes to poor aesthetics in the area.

Figure 55. Current layout of Herzogstraße
Source: Author

The residential buildings along this street and its neighboring streets typically provide parking spaces within their ground-floor yards, reducing the reliance on on-street parking. As a result, the on-street parking situation in the surrounding area is less congested. Figure 56 shows the geographical overview of Herzogstraße.

Figure 56. Geographical overview: Herzogstraße
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

The proposal suggests two interventions to address the existing challenges. The first involves narrowing the drive lane and integrating the bike network, while the second is implementing tree-lined parking zones. Given that these interventions reduce current parking spaces, the proposal emphasizes the importance of engaging in discussions with residents and seeking community input when implementing changes to this local street with residential buildings. Although there is a minor reliance on on-street parking spaces for residents, the perspectives of Herzogstraße residents play a crucial role in ensuring that the proposed alterations align with their needs and preferences. The proposed plan aims to address these issues through interventions scheduled for the immediate period, ranging from 0 to 1 year. Figure 57 illustrates the suggested street interventions.

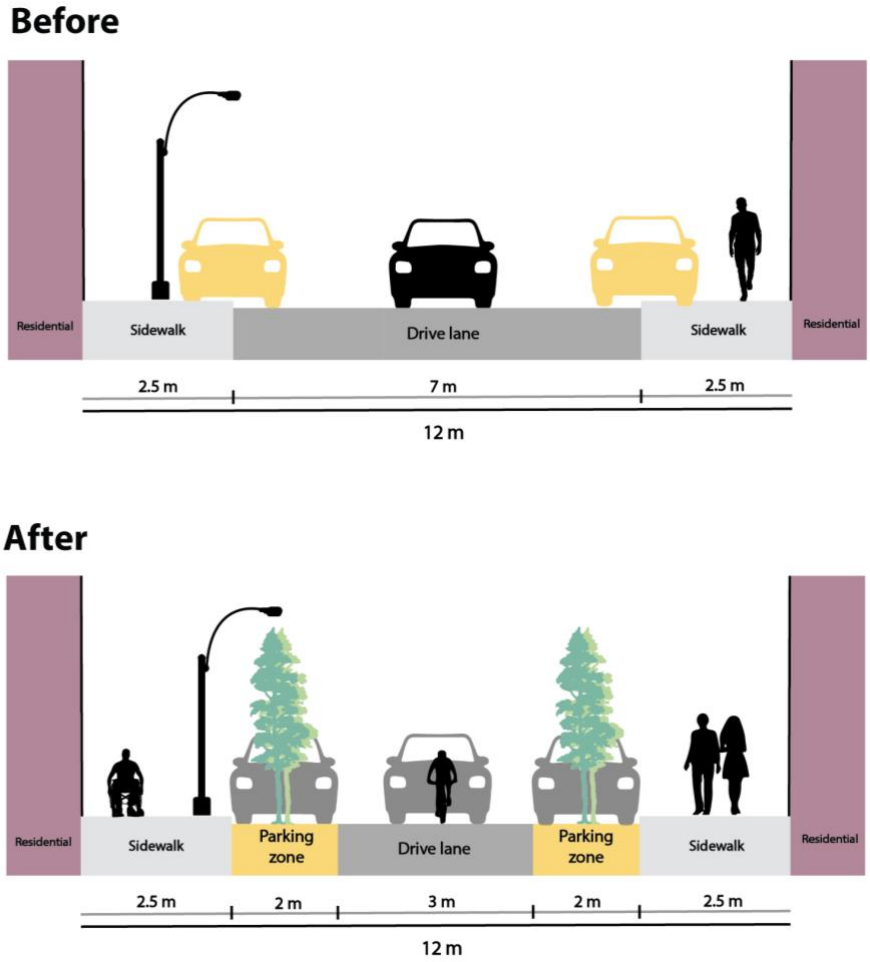


Figure 57. Transformation cross-section of Herzogstraße
Source: Figure by author designed with Adobe Illustrator

1. **<u>Narrowing drive lane and bike network integration:</u>**

In the existing layout, the one-way drive lane has a width of 7 meters. The proposed initiative aims to narrow the drive lane to 3 meters. Simultaneously, the proposal recommends resurfacing the street with asphalt to address potholes and uneven surface issues. Additionally, there is a need for implementing road markings, establishing specific speed limits, and improving the shared path catering to both cars and cyclists. This intervention not only improves the cycling environment for residents but also integrates the street into the broader neighborhood bike network, all achieved without significant infrastructure alterations.

2. **<u>Tree-lined parking zones:</u>**

By reducing the width of the street, there is room to establish 2-meter parking zones on both sides, aiming to eliminate the issue of cars partially occupying the sidewalk. The proposal recommends transforming these parking zones into tree-lined parking lanes, providing designated parking spaces while introducing greenery. This design enhances environmental benefits, street aesthetics, and community well-being and provides shade and comfort for pedestrians.

5.3.7. Kalmitstraße

In the study area, numerous buildings have unattractive facades and a shortage of surveillance, particularly noticeable on the corners where a lack of friendliness and inviting elements are apparent. A notable example is the building situated on the corner of Kalmitstraße, posing safety concerns and diminishing the overall livability of the landscape in the study area. This corner is close to the elevated railway, and Figure 58 provides a geographical overview of its location.

Figure 58. Geographical overview: Kalmitstraße
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

Addressing the current issues is the goal of the proposed plan, which includes interventions for the immediate period spanning from 0 to 1 year. However, there is a need to note that all alternatives within the proposal are designed as short-term modifications. With the ultimate objective of transforming the corner into a vibrant space that invites residents to stay, pause, and contribute to the liveliness of the landscape, gathering input from residents is vital. Understanding their preferences for an appealing corner is essential in promoting a sense of place. Therefore, including alternatives that involve temporary facilities and monitoring

changes leads to potential permanent improvements. The illustration in Figure 59 shows the suggested corner layout.

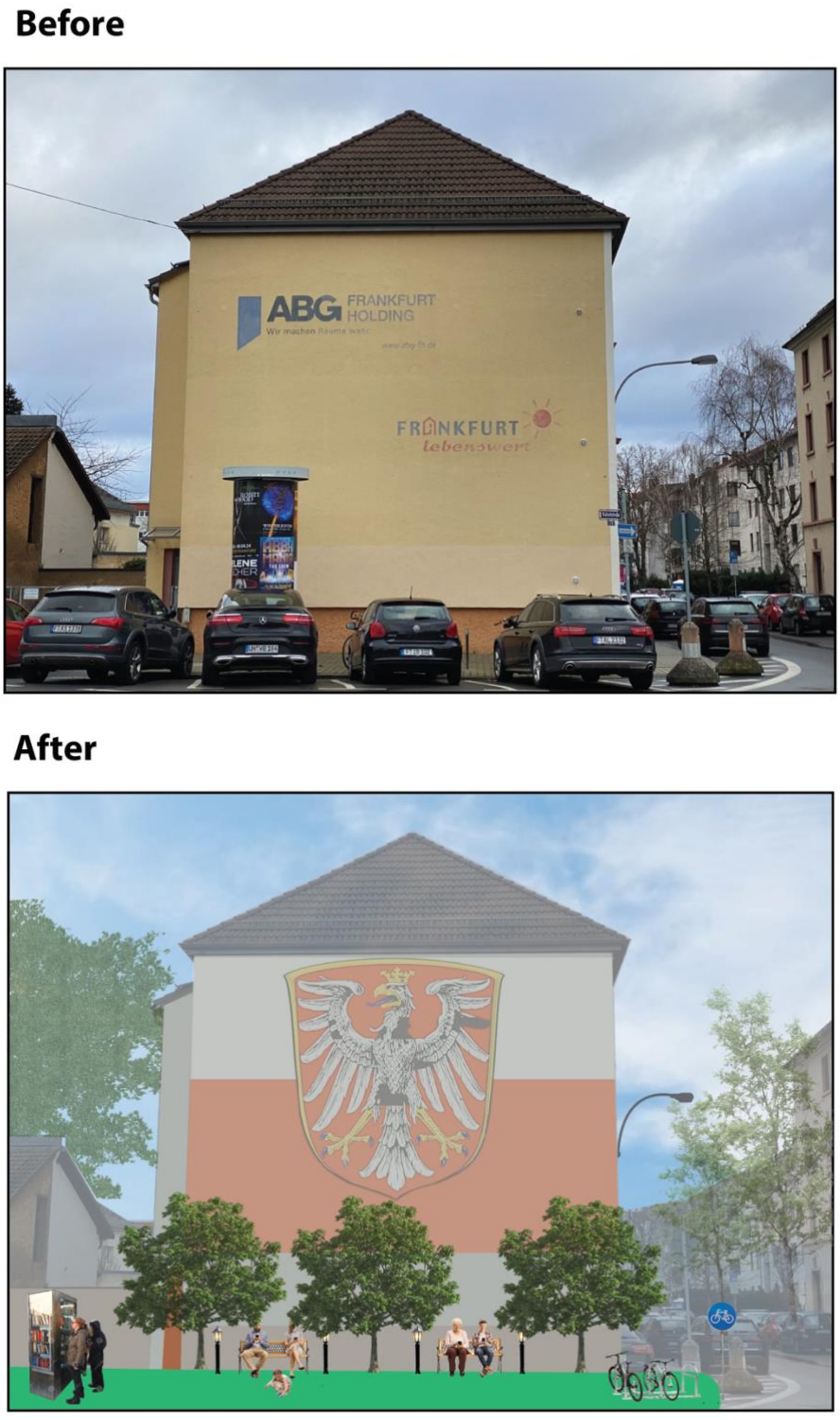


Figure 59. Transformation of street corner in Kalmitstraße: Before and after proposals
Source: Figure by author designed with Adobe Illustrator

1. **Prioritizing pedestrians over parking:**

Currently, parked cars restrict access to bicycle racks and limit visibility on the sidewalk. The proposal recommends the removal of all parking spaces at the corner, allocating this space to pedestrians. This initiative promotes safety, contributing to a more livable and pedestrian-friendly environment.

2. **Enhancing the public space:**

Allocating parking spaces to create a pedestrian-friendly corner on the street not only widens the sidewalk but also enhances the overall public space. By adding benches, residents are provided with a more inviting and comfortable environment. The expanded sidewalk not only offers more room for pedestrians but also contributes to increased community engagement, making the area more livable.

3. **Greening the streetscape:**

In order to create a welcoming environment for pedestrians, inviting people to linger on street corners and contribute to the concept of eyes on the street, the proposal suggests including trees and grass as part of the corner's design. Planting trees not only enhances the streetscape aesthetics but also offers shade for pedestrians. Meanwhile, the addition of grass contributes to aesthetic enhancement and improves overall pedestrian comfort.

4. **Graffiti redesign:**

To enhance the livability of the landscape and encourage community engagement, it is crucial to invite residents to actively participate in neighborhood decision-making. This approach ensures that residents have a voice in shaping the visual identity of their neighborhood, aligning with the broader concept of community engagement. The incorporation of graffiti on a blank wall offers a canvas for residents to contribute ideas and suggestions to the authorities. Beyond adding visual appeal, this initiative fosters sense of place, making the corner more memorable and facilitating wayfinding. By involving local street artists, a connection with the local culture is established and makes the artwork an integral part of the community fabric.

5. **Introducing community bookshelves:**

To enhance community spirit, the proposal suggests including open bookshelves in this corner. These public bookshelves rely on community participation and encourage the residents to actively engage by both taking and contributing books within the neighborhood.

5.4. Chapter summary

The proposal aims to recommend actionable interventions to empower active mobility in Niederrad, promoting sustainable neighborhood development based on a comprehensive theoretical basis in chapter three and case study assessment in chapter four. The goals include improving walking infrastructure, promoting neglected public spaces, providing sufficient, safe, and pleasant space for cyclists, integrating greenery, and creating pleasant, safe, and active streets. Interconnected strategies are introduced to achieve these goals to answer the fifth research question. The proposal recommends specific measures for some areas. The interventions in each area aim to improve mobility, safety, aesthetics, and community well-being to provide a vibrant and pedestrian-friendly urban environment. These enhancements are potential models that can be applied to similar locations within the study area.

Figure 60 illustrates integrated neighborhood transformation interventions. This figure displays the seven recommended geographical locations, each distinguished by a unique color, and illustrated with lines. The corresponding streets are also color-coded, illustrating potential areas for similar interventions through dotted lines.

While unmarked streets also require interventions, the key distinction lies in multi-unit apartment areas, which have designated parking for residents, eliminating dependency on on-street parking. These areas often feature green open spaces in front of apartments yet lack greenery in the street layout and designated bike lanes.

Figure 60. Integrated neighborhood transformation interventions
Source: Figure by author designed with Adobe Illustrator with the base map from Google Maps, 2023

Therefore, the identified issues, including segregation, unwelcoming public spaces, a car-centric environment, low accessibility, and inadequate safety for individuals, have been targeted through these outlined strategies and actions. These approaches are designed to tackle various aspects of community well-being related to land use and active mobility. Prioritizing pedestrians and cyclists create a safer and more inviting environment, promoting social interaction by increasing the presence of people in the landscape. Additionally, adding green infrastructure and amenities aims to enhance public spaces, providing places for people to linger and engage. Implementing street lighting and surveillance is integral to these strategies, ensuring both safety and vibrancy. Overall, these initiatives aim to establish a comprehensive urban space within the neighborhood that prioritizes people and promotes the overall sustainability of the community.

Table 4 presents the suggested actions, phasing, and applicability zones for the designated areas. The actions and phasing are divided into immediate (0-1 year) and short-term (2-3 years) phases. Each street has unique actions, and the applicability zones specify where these interventions align with specific street characteristics.

In future redevelopment, relocating parking underground could create more space for resident communication, pedestrians, and cyclists, contributing to improved neighborhood sustainability and increasing active mobility.

Table 4. Recommended actions, phasing, and applicability zones

Source: Author

	Actions and Phasing		Applicable to
	Immediate 0-1 year	**Short-term 2-3 years**	
Bruchfelstraße	– Enhancing bike network safety – Sidewalk reclamation	– Study the traffic impacts resulting from the removal of parking lanes near commercial stores	Applicable to another section of the street, considering different street widths but similar conditions like tramlines and commercial ground floor land use.
Frauenhofstraße	– Introducing furniture zone – Greening the urban spaces – Widening the sidewalks	– Elevating non-motorized lanes – Creating bike lane – Study the traffic impacts resulting from reducing the capacity of on-street parking near commercial stores	Applicable to areas with diagonal parking, where parking lanes dominate most of the street, and cars partially park on the sidewalk.
Herzogstraße	– Narrowing drive lane and bike network integration – Tree-lined parking zones		Applicable to streets with on-street parking integrated into the sidewalk within a residential area.
Adolf-Miersch-straße	– Partial removal of car parking – Green infrastructure boost – Improving lighting	– Optimizing the sidewalks – Creating bike lanes – Study the traffic impacts resulting from the reducing the capacity of on-street parking	Applicable to other parts of this street with similar layouts but varying widths.
Saonestraße	– Pocket parks and pop-ups for community comfort – Relocating the sidewalks and introducing a bike lane – Allocating pedestrian crossing		Applicable throughout the office area, as street amenities can be applied in different parts of the street with different measures.
Goldsteinstraße	– Illuminating the pathways – Renovating the passage environments – Implementing greening		Addressing the physical divider of the railway, these interventions can apply to the other tunnel, considering limited cross-connections in the neighborhood.
Kalmitstraße	– Enhancing the public space – Greening the streetscape – Graffiti redesign – Introducing community bookshelves		Applicable to open/green areas with the potential to serve as gathering points, enhancing community engagement within the neighborhood.

6

Conclusion

6. Conclusion

6.1. Summary

This study started with exploring the study area, focusing on two Ped-Shed circles with radii of 400 meters and 800 meters. The analysis contained desktop and on-site research, aiming to understand the strengths, weaknesses, opportunities, and threats in the Niederrad neighborhood. In response to the first research question, the analytical framework was structured into three primary categories: land use, mobility, and walkability. Afterward, the thesis underwent a comprehensive theoretical basis related to these main topics, in order to address the second research question. In addressing the third research question, the identified challenges contained a car-oriented environment, issues related to pedestrian and cycling infrastructures, and a lack of livability in the landscapes.

The analysis of land use revealed initial differences in land allocation, particularly evident in the office area. Overall, spaces within the neighborhood tend to be monofunctional. Besides the uneven distribution of commercial land, all other areas are designated for a single function, whether residential, commercial, or recreational. This layout of singular activities results in an environment lacking in diversity, which contribute to a less dynamic and engaging atmosphere. Additionally, the S-Bahn rail serves as a physical divider, separating the commercial zone from a section of the residential area.

The analysis of mobility patterns in the neighborhood showed a predominance of car-centric infrastructure. Parking lanes occupied a significant portion of street width, extending even into local streets. Despite numerous bike and scooter free-floating sharing stations, the absence of dedicated bike lanes posed safety concerns in the urban landscape. Additionally, while various public transport modes were available with stations spread throughout the neighborhood, challenges in station facilities created obstacles for vulnerable users. There is a need for improvements in mobility infrastructure within the study area to enhance the overall quality of sustainable mobility.

The analysis of the walking situation in the study area showed that the neighborhood faced interconnected challenges impacting pedestrian experiences, including insufficient lighting, unattractive corners, unconventional parking, and wayfinding difficulties. These issues, observed in various zones such as arch tunnels, ground-level passages, residential areas, and the office district, highlight the need for a comprehensive intervention to enhance safety and create more pedestrian-friendly urban spaces.

Following a comprehensive analysis, the SWOT analysis addressed the fourth research question, guiding to the recommendation phase. This phase aimed to tackle challenges, especially in problematic zones while offering suggestions based on opportunities within the neighborhood. The initial phase involved establishing five goals to promote active mobility and cultivate sustainability in Niederrad. Afterward, strategic initiatives were outlined, including prioritizing pedestrians and cyclists for safety, engaging communities through

vibrant public spaces, integrating green infrastructure for sustainability, ensuring well-lit streets, and revitalizing commercial ground floors to promote social interaction, in response to the fifth research question.

Major interventions contained a sustainable redesign of streets, optimizing sidewalks for improved pedestrian access, creating dedicated bike lanes, gradually reducing on-street parking spaces, improving street lighting for enhanced safety, widening sidewalks, introducing inviting furniture zones, incorporating green elements for aesthetic and environmental benefits, creating pocket parks for community comfort and engagement, and reclaiming sidewalks for pedestrian use. These multifaceted actions aim to create vibrant, pedestrian-friendly, and environmentally sustainable urban spaces.

The timelines for these interventions span from immediate to short-term, containing both temporary modifications and ongoing monitoring to identify opportunities for potential permanent enhancements.

6.2. Limitations

While completing this study in Germany, the primary challenge stemmed from the language barrier. As a non-native German speaker, gathering and analyzing information posed difficulties.

Moreover, the limited availability of online data posed a significant obstacle. Despite efforts to obtain additional data by reaching out to Region Frankfurt Rhein-Main, only links to their webpage were shared, and extra data could not be obtained. For instance, the inability to access the modal split in Frankfurt by neighborhood restricted the scope of quantitative analysis.

Additionally, the case study focused on a specific section of the Niederrad neighborhood in Frankfurt am Main, making data collection a complex task. Information was often available either at the city or neighborhood level, leading to difficulties in obtaining detailed data.

The reliance on on-site observations for data assessment introduces another limitation. These observations are subject to variation based on different times of the day and varying environmental conditions, potentially impacting the accuracy of data collection.

Due to the time limitation for completing this master's thesis, having interviews with policymakers, or administering questionnaires to residents and local retail business owners was not feasible.

6.3. Suggestions for further research

While the study identified the potential for increased sustainability in the Niederrad neighborhood, the findings may not be universally applicable. For future research, it is recommended to conduct similar assessments across diverse urban contexts to gain a more comprehensive understanding of Niederrad, enabling the development of interventions that

are not only sustainable but also community accepted. In order to achieve this objective, it is recommended to have a comparative analysis with similar neighborhoods facing challenges in active mobility and land use. Researchers can develop adaptable proposals that can be implemented in diverse urban contexts beyond Niederrad.

Additionally, it is recommended for future research to involve interviews with policymakers to develop a more comprehensive understanding of the neighborhood. These interviews not only offer qualitative firsthand information to researchers but also acknowledge potential barriers to implementing interventions. Besides, employing questionnaires for residents and local retail businesses is suggested for future research to understand their needs and perspectives.

A comprehensive evaluation of long-term impacts is essential for interventions. This assessment should include changes in traffic patterns, pedestrian and cyclist behavior, and the overall quality of life in the transformed areas. For instance, it is recommended to address potential economic impacts by changing the street layouts and mobility patterns that might affect local businesses, property values, and the overall economic well-being of the community.

The evaluation revealed an issue in the mono-functionality throughout the neighborhood in Niederrad. While recent city efforts have concentrated on the redevelopment of the business district to transform it from a mono-functional office quarter into an integrated and mixed-use city district, the enhancement of liveliness and friendliness should extend beyond the office district. It is recommended to assess the entire neighborhood, promoting integration at both the neighborhood and city scales.

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