Intermodal Open Spaces

An analysis of inner-city mobility stations in the Rhine-Main region.

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Halblaub Miranda, Marianne: *Intermodal Open Spaces. An analysis of inner-city mobility stations in the Rhine-Main region.* Darmstadt, DE: Technische Universität Darmstadt.

Year of publication of the dissertation on TUprints: 2023

URN: urn:nbn:de:tuda-tuprints-233132

Date of the viva voce: 01.03.2022

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at the Department of Architecture

of the Technischen Universität Darmstadt

submitted in fulfilment of the requierements for the

academic degree of Doctor of Engineering

(Dr.-Ing.)

Doctoral thesis by

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Darmstadt, 2022

Acknowledgements

I am grateful to 'a whole village' who, in one way or another, helped me to carry out this research.
In particular, I would like to thank my supervisor, Prof. Dr.-Ing. Martin Knöll, for his guidance and encouragement. In your young research group, uhg, I was able to learn and develop my skills as a researcher, teacher, designer and manager. I am grateful for the warmth and trust with which you have accompanied each step. I am grateful to Dr.-Ing. Petra Schäfer, my second supervisor, for our discussions and insights into a completely different field than my own.

To the whole uhg/STAPL team, I am grateful that we can support and uplift each other both professionally and personally.
Annett Plümer, Du hast es meisterhaft verstanden, Jahr für Jahr wichtige administrative Hürden aus dem Weg zu räumen, um mir den geistigen Freiraum und die Zeit zu geben, diese Arbeit zu vollenden. Danke dafür!! #IchbinHanna

To my brilliant student research assistants who helped shape parts of this dissertation, Fizza Fatima and Emilia Kühn: Danke fürs mit denken!

I thank my students for their openness, curiosity, strokes of genius, and critical questioning. Your creativity and perceptiveness never ceased to amaze us all. I will miss the bright and curious minds that Mundus Urbano attracted to this "little city" in the middle of Germany.

My deepest gratitude to my friends. I was fortunate to have their unconditional support, patience, and advice. Anaïs De Keijser, Anshika Suri, Nebojša Čamprag, you were there to encourage me every step of the way. Shall we continue to be good partners, steadily moving towards our ambitious goals.
A heartfelt thank you to Geetha Thekkemury, thank you for always being there for me. Even at 2 am drawing maps with me.

To my parents: gracias por haber trabajado incansablemente para proporcionarnme una base estable sobre la cual he podido construir la vida que elegí y alcanzar mis metas. Reconozco y agradezco cada decisión que han tomado a mi favor.
To my brother, with whom I shared this journey on the other side of the world. You have been by my side at every milestone, gracias.

–Por mi Mati–

Abstract

Reducing private motorised traffic (PMT) and its resulting environmental pollution in favour of multi- and intermodal environmentally friendly mobility is essential for the development of sustainable cities. In addition to reducing PMT, intermodal mobility systems address individual mobility needs by integrating active modes such as walking and cycling, with public transport and sharing initiatives, such as car and bike sharing. This dissertation examines current planning strategies aimed at promoting intermodal mobility in urban areas, focusing on one approach presented as *Intermodal Open Spaces* (IOS). IOS are urban open spaces with embedded mobility nodes that support multi- and intermodality and are integrated into the urban context in such a way that an array of activities - beyond the provision of mobility services - can take place in them. Based on an empirical study in five selected cities in the Rhine-Main region, a typology of IOS is presented. The typology is based on the spatial interaction between the morphology of open spaces and the flow of active and motorised traffic. Structured by location and integration, spatial configuration and morphology, and activities and amenity quality, the case studies present spatially and programmatically disaggregated examples of IOS. Methods include desktop and on-site mapping of features identified through literature review, such as morphology, configuration, road network, visual integration, land use and others. This doctoral dissertation serves as a theoretical prelude to the definition of IOS and contributes to the debate on the spatial design and planning of multifunctional mobility stations in urban studies and transport planning.

Kurzbeschreibung

Die Reduzierung des motorisierten Individualverkehrs (MIV) und der damit verbundenen Umweltverschmutzung zugunsten einer umweltfreundlichen multi- und intermodalen Mobilität ist für die Entwicklung nachhaltiger Städte unerlässlich. Neben der Reduzierung des MIV berücksichtigen intermodale Mobilitätssysteme individuelle Mobilitätsbedürfnisse, indem sie aktive Modi wie Gehen und Radfahren mit öffentlichen Verkehrsmitteln und Sharing-Initiativen wie Car- und Bikesharing kombinieren. Diese Dissertation untersucht aktuelle Planungsstrategien zur Förderung der intermodalen Mobilität in städtischen Gebieten und konzentriert sich dabei auf einen Ansatz, der hier als intermodale Freiräume (IF) bezeichnet wird. IF sind urbane Freiräume mit eingebetteten Mobilitätsknoten, die Multi- und Intermodalität unterstützen und so in den urbanen Kontext integriert sind, dass eine Reihe von Aktivitäten über die Bereitstellung von Mobilitätsdienstleistungen hinaus stattfinden können. Auf der Grundlage einer empirischen Studie in fünf ausgewählten Städten im Rhein-Main-Gebiet wird eine Typologie von IOS vorgestellt. Die Typologie basiert auf der räumlichen Interaktion zwischen der Morphologie der Freiräume und dem Fluss des aktiven und motorisierten Verkehrs. Die Fallstudien sind nach Lage und Integration, räumlicher Konfiguration und Morphologie sowie Aktivitäten und Aufenthaltsqualität gegliedert und stellen räumlich und programmatisch differenzierte Beispiele für IOS vor. Die Methoden umfassen Desktop- und Vor-Ort-Kartierungen von Merkmalen, die durch Literaturrecherche identifiziert wurden, wie z.B. Morphologie, Konfiguration, Straßennetz, visuelle Integration, Flächennutzung und andere. Die vorliegende Dissertation dient als theoretischer Auftakt zur Definition von IOS und leistet einen Beitrag zur städtebaulichen und verkehrsplanerischen Debatte über die räumliche Gestaltung und Planung von multifunktionalen Mobilitätsstationen.

Content

Part I: Theoretical background and literature review

1. Introduction

This dissertation deals with urban open spaces that have embedded mobility nodes that support multi- and intermodality (*mobility stations*[1]) and are integrated into the urban context in such a way that an array of activities – beyond the provision of mobility services – can take place in them. While there are several terms for stations that support multi- and intermodality, these spaces tend to be spatially segregated or stand-alone designs that have little to no interaction with public open spaces and other uses around them. I have therefore devised a term and definition that encompasses my research focus through the analytical lens of urban design and one of its main topics: open space. These spaces are referred to throughout the dissertation as intermodal open spaces (IOS).

The research aims to introduce and position *intermodal open spaces* as modern urban components that can promote liveability in (densifying) urban settings, and that are in line with planning concepts and policies that support SDG 11 from the UN[2] (United Nations, 2015, pp.21f), such as sustainable urban mobility (SUM) and transit-oriented development (TOD). This aim is pursued through literature review, spatial description, documentation, and analysis from an urban design perspective, the primary discipline. The case studies are in the more populated cities of the densely urbanised German Rhine-Main region.

This first chapter introduces the reader to the research problem, presenting an overview of challenges and opportunities, and thus the potential contribution that IOS can make to the concepts mentioned above, highlighting the relevance of this work. Having identified the gap within the existing research on mobility stations and their intersection with urban design, I state the aim of this dissertation and formulate research questions to guide the work. This is followed by a description of the research approach and the expected outcome. Finally, the structure of the document and the content of the following chapters are presented.

1.1. Research framework

Problem definition and challenges

As cities around the globe grow bigger, denser, and increase in number, urban dwellers and visitors are increasingly relying on both private and public transport options to move in and through urban space. Cities face the task of adjusting and regulating various areas to meet their inhabitant needs within our planet's limits. In this dissertation, I concentrate on two specific areas: the built environment and mobility systems – areas that mutually influence each other.

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[1] I choose to use the term *mobility stations* instead of the more widely used term *mobility hubs* in English publications, due to my focus on the German context, where *Mobilitätsstationen* is the main term. The reader may see both as interchangeable, depending on her discipline.

[2] Sustainable Development Goal 11: "Make cities and human settlements inclusive, safe, resilient and sustainable" (also https://sdgs.un.org/goals/goal11)

Large or expanding settlements tend to impose longer travel distances on their users, since individual or general points of interest are – with a higher probability than in small towns – scattered throughout the city. And although travel time may have remained constant while cities spread, both distances and speeds have increased substantially, as Banister (2008) points out.
In addition to the expanding urbanisation, the number of urban dwellers is on the rise: a growing proportion of the world's population is nowadays living in urban areas (55% by 2018), and this is projected to reach nearly 68% by 2050 (United Nations, 2019). In contrast to global percentages, Germany's population was 77,3% urban by 2018 and projected to be 84,3% by 2050.
With more people living in bigger urban areas, the demand for mobility services and traffic volumes will probably increase in cities. According to Lerner et al. (2012, p. 4), almost a decade ago, 64% of all travelled kilometres were made within urban environments. The authors estimated that the total amount of urban kilometres travelled will triple by 2050, pointing towards an expected higher demand for urban mobility options. In a follow-up study, Audenhove et al. (2014, p. 6) stated that: "[d]elivering urban mobility to cope with this increasing demand will thus require massive investment in the future."
As long as we follow these trends and practices of urbanisation and lifestyle, accessible transport options and mobility services are and will keep on consolidating themselves as crucial elements to partake in everyday life, especially in large and growing cities.

However, the increasing demand isn't the only motivator to look into how our current mobility and transport systems are performing; mobility needs and preferences are also changing and evolving, prompting us to broaden our understanding and knowledge creation about past, present and future urban mobility. On the one hand, mobility as a service and business must adapt. As Audenhove et al. (2014, p. 6) point out, "[c]hanging travel habits, demand for services to increase convenience, speed and predictability, as well as evolving customer expectations toward individualisation and sustainability will require mobility services portfolio extension as well as business model transformation […]." On the other hand, all these changes must take place and find space in our towns and cities, making urban design and planning a significant component for change.

These ongoing changes pose significant challenges for cities, where new and improved mobility infrastructure and services are demanded and must be offered, but space is limited. Urban space is already under contestation due to the high demand for mobility services and the infrastructure required for them, in addition to the need for more housing. Hence, cities are already being confronted with challenges in terms of infrastructure adequacy and sufficiency. In Germany, 9,3% of the total land area is dedicated to settlements (with 3,8% thereof being housing), while 5% is dedicated to transport infrastructure (Statistisches Bundesamt (Destatis), 2020). How we use, allocate and understand space must be therefore part of the discussion.

While urban researchers widely agree that cities offer a wide range of benefits and opportunities for the development of individuals, "[...] rapid and unplanned urban growth threatens sustainable development when the necessary infrastructure is not developed or when policies are not implemented to ensure that the benefits of city life are equitably shared" (United Nations, 2015, p.3). In other words, if not well planned and executed, cities can bring many disadvantages and even dangers to their inhabitants.
Furthermore, urban design and planning play a significant role in countering possible adverse effects by providing infrastructure and spaces that contribute to a well-functioning, sustainable, and inclusive city with improved quality of life ("liveability"), catering to both functional and social needs.
Sustainable urban development, which aims to prevent a spatially and socially fragmented city, ideally assures access to a well-interconnected mobility system and a variety of open spaces where urban dwellers and visitors can move and meet freely and with low ecological impact. However, cities worldwide are pushing back motorised private transport as the primary mode of transportation and receiving support from national and international governance to do so. These different measures therefore not only aim to also target to strengthen sustainable urban mobility (SUM) but also counterbalance the negative impacts growing motorised traffic (MT) may have on people and the environment (e.g., emissions and pollution, traffic accidents, noise, and sealing of natural open spaces, amongst others.).

On-going and future developments in urban mobility, such as our strive for more sustainable mobility, define functional requirements for the spaces that provide access and transitions to and between different modes of travel (*intermodality)* and vice versa, influencing the city on an urban design level. An optimisation towards a more sustainable urban mobility is a significant cornerstone for liveable cities and improving public health. The consensus amongst urban researchers is that this can be done by promoting sustainable transport alternatives and therefore facilitating a modal shift (e.g., Banister, 2011; Lanzendorf & Busch-Geertsema 2014; Pucher & Dijkstra, 2003). This entails strengthening the *Umweltverbund* (ecomobility), which involves increasing the share of active mobility (such as cycling or walking), public transport, and sharing concepts. It also entails reducing car-dependency through spatial planning policies of "short distances" (Canzler & Knie, 1998). From an urban design and planning perspective, this can be done by densifying, diversifying uses, and reallocating space and therefore making it easier or more attractive to use public transport or active mobility.

Intermodal Open Space as an opportunity

The challenges mentioned above reinforce how essential mobility systems are for engagement and participation in social and economic exchange, and critical for environmental protection. Higher mobility demand and supply, and continuing urbanisation require transformations for both mobility and urban systems. Similarly, urban open space is vital for communal life and interaction in cities. It can have various functions and manifest in different forms and types – e.g., streets and plazas are crucial in allowing movement, encounters, events, etc. Open space creates connections between buildings, systems, and dwellers, amongst others, increasing liveability. Furthermore, public transport stations act as the interface between the user, the city, and mobility services, and signal its users which services are available; thereby representing a city's attitude and commitment towards sustainable mobility. Stations' design and configuration impact the experience and interactions between space, services, and users. Expectations are high on mobility stations' contribution to sustainable urban mobility because they serve as a bundled "pull measure" (Miramontes, 2018, p. 302) by providing various alternatives to private cars.

Thus, based on above mentioned nexus of mobility systems, urban open spaces and public transport stations, I suggest that IOS are at the centre of these two challenges since they bear the potential of integrating the desired type of mobility system – i.e., intermodal – with a sustainable spatial distribution – i.e., multifunctional.

While the development of mobility stations, in general, has been mainly studied and guided by transportation planning research and norms, and their impact on society is currently human geography's domain, the analysis of their spatial design and qualities has been left unattended. Hence, an opportunity to examine mobility stations through an urban design lens emerges. In this sense, urban design is understood as the process "which involves shaping and transforming the urban environment as a large composition of buildings, public spaces, roads and other natural or artificial elements" (Kamirimi ,2012, p. 298).
From an urban design perspective, understanding the configuration and design of multifunctional open space that allows intermodality is the most significant potential.

Research focus

The research object is defined based on three specific properties as follows:

Intermodal

Intermodality allows users to combine different modes of transportation within one rout or a chain of routes (cf. Clond, 2013). This transport system makes an effort to combine the different modes in order to achieve an interconnected solution.
Additionally, this project distinguishes between motorised transport such as buses, trains, trams and private cars, and "active" modes such as walking and cycling, e.g.

Urban and inner-city

This property relates to the spatial range of the mobility options (*modes*) within the transport network that will be analysed: services that operate mainly within the inner-city and have their carrying infrastructure located within a certain radius. In contrast to stations in rural and fringe areas, urban stations are usually highly frequented, have more activity and offer different modes with higher frequencies. They also differ from interregional stations (e.g., train stations) in their general spatial configuration.

Interregional stations traditionally have a somewhat strict division between the transport-related area (the closed station) and the open space.

In open space

The third discipline-affine property a research object must comply with is its location in open space. Open space is understood as any undeveloped land, i.e., urban ground space without buildings (although infrastructure may be present), and publicly accessible. I will examine open spaces in dense urban space – squares, streets, parks or even smaller fragmented "residual areas". At the same time, the study focuses on the multifunctional urban open space. It functions as a social space for urban life and a place of recreation (cf. Gehl & Gemzø, 2003), which caters to further needs of the population (e.g., amenity qualities, recreation, retail, and others).

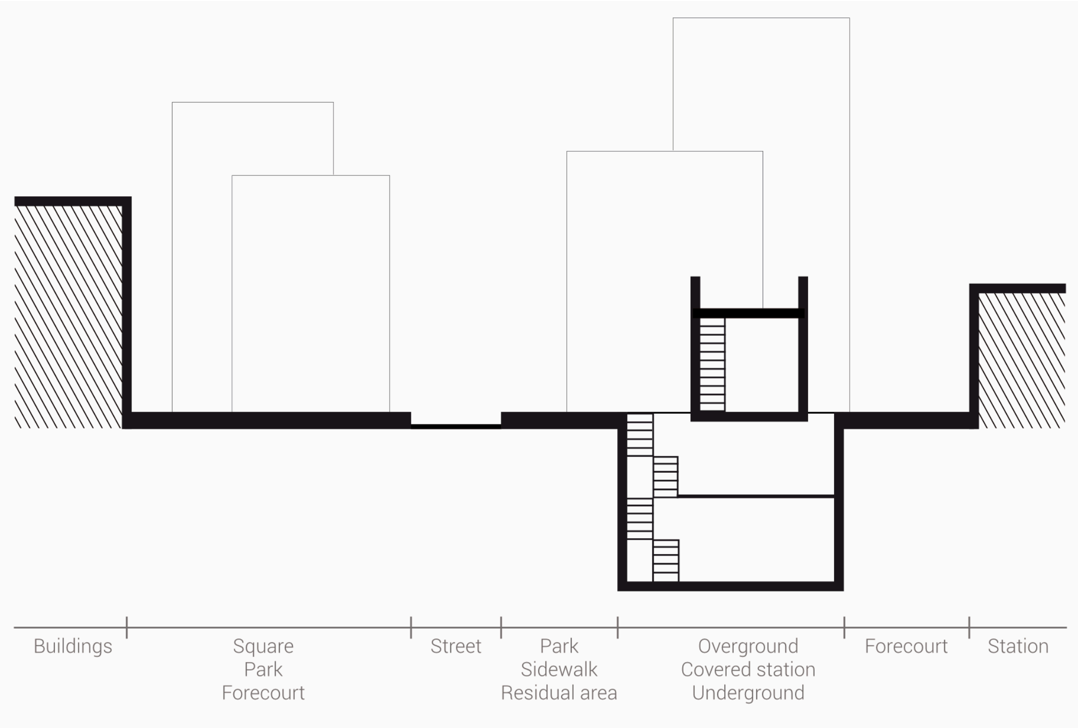

Figure 1. Diagram of the analysed spaces: the focus is on urban open spaces where mobility take place and are publicly accessible. Built areas, such as stations, are taken into account as only when they are part of the transport system that supports intermodality in the analysed area.

Scope and limitations

The scope of this work is on a European level with focus on German urban design and transport planning. I elucidate European strategies and examples of good practice. The presented empirical data is based on German cities. However, this does not mean that other models will not be analysed or contrasted with European ones to better define my own.

This study takes place within the IDS LOEWE Research Cluster "Infrastructure—Design—Society" framework and focuses on the German Rhine-Main region. As part of the project area CITY[3], this research is constructed within the framework of urban design. Thus, the concepts, theoretical approaches and methods used here relate to urban scale and theory. Additional discourses complement my analysis and understanding. I utilise scientific literature on the city from the fields of – but not only – sociology, human geography (more specifically mobility research), and transport planning.

Data-driven, networked and digital ecosystems are being explored in public, private and shared mobility in order to make systems more efficient. I acknowledge the importance and power these technologies have with regards to our perception and understanding of how cities work, look like and can be used. But there is no "digitalisation" focus in this work.

A major unforeseen limitation is the inability to gather homogenic and meaningful on-site data pertinent to users' behaviours and perceptions due to the COVID-19 pandemic. This is apparent in the adaptation of a research question in the following section and the type of conclusions that can be drawn.

1.2. Research aims and questions

This dissertation attempts to define and explore IOS as a discrete category or spatial typology, which hasn't been described as in the here presented manner. Therefore, the main research question is: *how do IOS look like and how can they be described and analysed through the lenses of morphology and performativity as dealt with in urban design?*

This main question hosts several sub-questions that are explored both theoretically and empirically throughout the dissertation:

A. How is the location and integration of IOS within the city?
B. How are IOS spatially configurated, and how is their morphology?
C. Which spatial characteristics support which activities (performative potential) and are tied to high amenity quality?[4]

The sub-questions are structured around three blocks and according to scale. Detailed measures and factors to these sub-questions will be introduced in depth in chapter 4.
The overarching goal of this dissertation is to deliver and apply an analytical framework for urban open spaces where intermodality takes place, and portray the current spatial design and configuration of IOS through the case study cities.

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[3] https://project-mo.de/en/team-en

[4] This dissertation was meant to explore users' perception and behaviour in the selected IOS. Due to the COVID-19 pandemic, systematic observations and on-site surveys were cancelled.
Previously "How does the spatial configuration relate to the users' behaviour and perception?" This question had a particular focus on both amenities and the promotion of active mobility.

1.3. Research approach and expected contributions

The research has its starting point with the observation that several urban open spaces in the Rhine-Main region have an integrated public transport station and further mobility services, which aren't completely spatially segregated. These are situated in dense urban settlements and are very often well-visited spaces. Although "traffic squares" have been described in urban design literature (e.g., Gelh & Gemzøe, 2003; Wolfrum, 2015), I could not find any framework describing different types of open spaces that support multi- and intermodality or the services offered in them and their spatial requirements, let alone a typologisation.
Based on this, I set out to compile the existing approaches and extend the way we analyse and describe open spaces where multi- and intermodality take place, utilising disciplines that deal with urban mobility to do so.

Research design
I explore how these multifunctional spaces may be helpful to counter fragmented and unsustainable cities, contributing to sustainable urban design that supports SUM. The evidence to back this statement up is from literature research, including systematic literature reviews.
The approach is based on the empirical study of mobility in relation to its socio-spatial manifestations and carrying technical infrastructures. The empirical analysis was carried out in a two-step process. First, the methodology was developed in an innovative research design wherein the preliminary data was explored through teaching methods. Related data was first gathered and analysed in a seminar format with three different student groups within three consecutive winter semesters and through one shorter in-depth research module. The intended aim of this empirical design was to get participant observations from the students to elucidate patterns related to IOS in chosen case studies. The second stage, the final empirical analysis, was carried out by myself in the presented stations, which, for the most part, differ from the ones students had chosen.

As dealt with in urban planning and design, the morphological and configurational aspects serve as the primary analytical parameters, informed by and contrasted with measures from the related disciplines. The final goal is to deliver an overview of IOS in the Rhine-Main region that elucidates three aspects. Firstly, the design parameters and built form; secondly, how the design decisions impact the performance of the space in terms of supporting more functions, other than getting into and exchanging modes of transportation; and thirdly, a preliminary overview of how these factors can relate to users' behaviours and perception[4].

The expected contribution is the development and implementation of a framework for describing and analysing public transport and mobility stations, specifically IOS, from an urban design perspective, contributing to the discussion on spatial design and planning in urban studies. The research is seen as a theoretical prelude to the definition of IOS, which could ultimately be completed, discussed and developed by different disciplines and theories. Finally, the project provides practitioners, stakeholders and interested parties with spatially dissected and analysed examples of intermodal open spaces.

Research methods

a) Theoretical framework

An investigation on the state of the art of mobility stations and urban design is carried out through (systematic) literature review[5], guided by the following questions:

- What are existing frameworks to describe and analyse open space's morphological and performative aspects?
- How is amenity quality described and analysed?
- How do mobility and urban design influence each other?
- How is urban space used when it comes to mobility? (Space allocation and usage)
- What exactly are mobility stations, and what are their distinctive characteristics (e.g., which mobility services are offered in them)?
- How do mobility stations fit into the planning concepts SUM and TOD?

b) Empirical analysis

As described in the research design, the empirical analysis consists of two steps: one within the framework of university courses and the second carried out by myself. Data gathered during the courses and the latter case study includes (but is not limited to):

- Mapping the mobility services at city level (radius = 2km)
- Mapping of the existing stations, offered services, and their urban surroundings
- On-site visits
- Mapping how visitors perceive and use space through surveys and observations[4]
- Social media and news outlets data regarding events that take place in each IOS

c) Evaluation and analysis

Analysis of chosen stations and their urban surroundings:

- Description of spatial design and configuration
- Categorisation depending on location and connectivity, morphology, typology, and performativity
- Spatial patterns of use[4]

Material basis

The following sources were taken into account for the literature review:
Published books, scientific papers, academic journals, thesis dissertations, past systematic literature reviews, reports, studies, and grey literature.
The material basis for the empirical analysis is presented and described within the context of the sub questions in section 4.5.

[5] The systematic review is identified as such in the relevant chapter, criteria can be found in the appendix.

1.4. Structure of the dissertation

The dissertation is composed of seven chapters and an appendix, which are structured three main parts:

Part I Theoretical background and literature review
Chapter 1 presented the motivation for working on this dissertation, the aim and research question and sub-questions, as well as research approach and expected outcome. Chapter 2 provides a background introducing the reader to the current understanding and state of the art regarding the conceptualization of the urban built environment, more specifically open spaces. It presents conceptualizations, typologisation and characterisations urban open space and some analytic and descriptive methods, particularly when it comes to the meaning and use of them. Chapter 3 deals with urban mobility and the built environment. It introduces the reader to how transport and mobility shaped settlements' form and sizes through history, further concepts shaping todays understanding of how to plan for and analyse urban mobility, and presents the current understanding and state of the art regarding the conceptualization of new mobility forms, more specifically mobility stations.

Part II Empirical analysis
Chapter 4 presents the study area, the transport association, and the process and criteria for the case studies selection. The research design is elaborated in detail, with a focus on describing the selection of methods used to conduct this research. Chapter four ends by formulating the more specific and deepened sub-questions according to scale. Chapter 5 gives a short introduction to each city and its particularities, and presents the results following the research sub-questions. The results are underpinned with site plans, as it is common in the discipline. Chapter 6 delivers a summary and a descriptive comparison of the results presented in chapter 5.

Part III Final conclusion
Chapter 7, the final chapter, summarizes the steps and results of the project and provides space for discussion on the analytical framework developed and the main research findings and challenges. From this, conclusions are drawn for the field of urban design with focus on urban mobility. Finally, considering the various limitations of this work, recommendations for further research are provided.

The appendix, a detached booklet in the printed version, allows the reader to see the created site plans and maps alongside the text.

2. Urban form and function: studies of open space

This chapter reviews and introduces the reader to the current understanding and state of the art regarding the conceptualization of the urban built environment, more specifically open spaces.

The chapter starts with a brief definition of the term open space, followed by an overview of its role in the urban built environment: conceptualizations, typologisation and characterisations. It emphasises on the significance of open space for urban life and some analytic and descriptive methods. For this, three main bodies of literature are examined. Firstly, formal approaches based on historical examples of traditional open spaces that seek to identify spatial characteristics of successful open spaces are presented. Secondly, functional approaches based on both interdisciplinary theoretical elucidations and applied architectural and urban design classification of modern examples are considered. The common denominator of the first two bodies of literature is their typo-morphological approach. Thirdly, I present works of authors who focus on the geometric configuration of the built environment and its relation to users' behaviour, positioning configuration as the key element of their performance.

In a second section, the concepts of space and place are discussed and linked to the activities that take place in open space. The chapter ends with a summary of the findings in literature research and highlight the attributes that will be taken into account in the empirical analysis.

Defining open space

The built environment can be boiled down to two categories of space: built and unbuilt; or: open space and developed land. According to Hartz (2018), one way to define the term under the German Federal Building Code (*Baugesetzbuch, BAUGB*) is its delimitation from the '*built-up space'* (=developed land). It is the lack of buildings that makes open space existence apparent: "a space that is not significantly occupied by structural works or technical facilities" (Harz, 2018, p.4). But it is much more than "the space that is left over", states Hartz, citing Anders et. al. (2013, p.127 as cited ibid). Published in 2006 by the BBR/BMVBS [Federal Office for Building and Regional Planning/Federal Ministry of Transport, Building and Urban Development], *Perspektiven der Raumentwicklung in Deutschland* outlines guiding principles for spatial development in Germany, which were adopted by federal and state governments the same year. In it, the guiding principle *conservation of resources, shaping cultural landscapes* positions the conservation and development of open spaces as key tasks (BBR/BMVBS, 2006, p. 52 as cited ibid). "The conservation and planning of open spaces are advancing to become central instruments of targeted urban planning and regional planning based on the paradigm of sustainability", Hartz points out. Open spaces' conservation and development are on the public spotlight thanks to the impact they have on the way we live in cities. The interest isn't merely from planning practice and spatial sciences; open spaces are publicly discussed in qualitative and quantitative terms as well. This is particularly evident where prosperous cities continue to grow into the surrounding countryside and at the same time push ahead with interior

densification, or where the expansion of renewable energies is changing landscapes on a large scale. (Ibid, p. 3).
Open spaces, independent of type or function, are being recognised as a corner stone for sustainable urban environments due their social, economic and ecological functions in cities: they are places to meet and connect, for leisure and recreation or to carry out and access commerce, and advance nature conservation and climate protection purposes, while offering urban dwellers –humans, animals and plants alike– access and contact to nature.

But how do we conceptualise and describe urban open spaces and categorised in literature and by urban designers and further spatial planners? How do we operationally define their performance in urban design and planning?

The following section is based on published academic papers and books, which present both theoretical and empirical studies of open spaces. The examples set out to answer the question "what are existing frameworks to describe open space's morphological and performative aspects?"

2.1. Open space morphology and typology: utilised approaches

Morphology

Urban morphology refers to the way the elements of the built environment are configured, how its shapes are formed, and transformed. It describes the formal and spatial dimensions of the urban environment, i.e., metropolitan areas, cities, and towns (see Carmona et. al., 2003; Kropf, 2017).

Kropf (2017) identifies several approaches to describe urban morphology, all of them having three core concepts in common: (1) pattern and structure, (2) process of formation, and (3) type and hierarchies. He identifies four broad approaches, each focusing on slightly different aspects of urban forms and using different methods and tools. The presented two –typo-morphological and configurational approach–, Kropf states, have their origins in the fields of architecture and urbanism, the latter being supported by mathematical methods (ibid, p. 17).

2.1.1. Typo-morphological approach

A typo-morphological approach, as Kropf (2012, p. 17) describes, examines architectural and urban patterns and structures, and the historical process of their formation. The approach derives types in the course of cultural evolutionary processes based on the experience and interpretation of earlier forms in a recursive process. Practically, spatial designers have recorded and categorised the gained knowledge and understanding of the built form, tracing back (and forth) in history repetitive spatial patterns and structures which hint towards derivations of related types. The approach seeks to inform architectural practice and education by examining the detailed structure and process of formation of space into types in order to bundle knowledge in a hierarchical structure to ultimately tackle specific design proposals or systematically analyse the built environment.

The following examples range from formal to functional approaches based on both empirical studies and theoretical conceptualisations.

Empirical architectural and urban design formal approaches

One of the most significant empirical studies and derived frameworks to classify the shape and form of open space in Europe was outlined by Camilo Sitte in his seminal book *The art of building cities: city building according to its artistic fundamentals* (Sitte, 2013). First published in 1889 in German and in 1945 in English, the work is a comparative analysis of the spatial morphology of European urban squares of the medieval and renaissance. The comparison aims to identify *artistic fundamentals* –i.e., characteristics of their composition and used elements– of the open and built space, that contribute to a *successful* square. These are described as squares that best support and promote the dwellers' gatherings.

Sitte identifies two fundamental characteristics: spatial enclosure and irregularity. The principal fundamental characteristic, the "enclosure effect", is defined both by the amount and position of the surrounding buildings shaping the square and the position of the streets leading towards and entering the square. Too much open space without built elements to contain it or an open corner, can weaken the definition of said space. The second fundamental characteristic, "irregularity", advocates for an asymmetrical arrangement of the surrounding buildings in order to offer the observer different views while moving in space. Additionally, Sitte points out the importance of limiting views out of the square and restricting endless perspectives. This is related to the concerns of positioning monuments and other elements in the space.

Based on both characteristic and in relation to the dominant building on site, Sitte enumerates and names types of squares based on their composition. Some well-known ones are the broad-type of depth-type square [*Breitenplatz* and *Tiefenplatz*] and the turbine square [*Turbinenplatz* or *Windmühlenplatz*], which are still familiar terms in German speaking countries.

Several authors have expanded on Sitte's ideas and developed broader models and typo-morphological classification of open space that seek to identify what are successful design principles. The German architect and art historian Paul Zucker regards squares as an important element of urban design which play a vital role in supporting human gatherings and in "humanizing them by human contact" (Zucker, 1959, p.1 as cited by Campos, 2000). Though, while spatial function is acknowledged as a very important characteristic, it is the physical form that is highlighted as a classification tool: the form and the configuration of elements shaping the square and its surrounding elements. This is mainly due to the observation that different functions can occur in differently-shaped squares and that spatial functions change throughout history without the space changing, or conversely. In other words, the activities that take place

in a space do not automatically “produce” the same spatial form, nor does a certain form induce the same type of activities every time. Each activity can be expressed in a variety of forms and one form can bring forth a variety of activities that can be performed in space.
The author concludes that, therefore, the only way to classify urban squares is by its spatial composition, consisting of 1) enclosure, 2) presence and location of important buildings, and 3) the contained artistic elements, such as fountains or monuments. These three characteristics give rise to five types of squares which are derived from medieval town squares: closed, dominated, nuclear, grouped and amorphous.
Zucker's contribution is the observation that the modulation of each one of the three spatial characteristic, as enumerated above, will have a different impact on people's use and behaviour in space and therefore how it is perceived. He suggests the importance of these elements in creating a place and not just a mere space: “specific and visual kinaesthetic relations will decide whether a square is a hole or a whole” (Zucker, 1959, p.3 as cited by Campos, 2000).

With a very strong focus on form and composition, Krier (1979) expands on the abundance of possibilities within the formal typology of urban space with a geometrical matrix of modulating factors. He introduces the street as a second type of open space, making square and street the two basic elements that are being dissected. The base of the typology are the three basic geometric shapes square, circle and triangle, which form three main groups that relate to the geometrical pattern a ground plan can have. By changing the factors angling, segmentation, addition, merging, overlapping and distortion, it is possible to generate and define an infinite number of spatial types. Besides the analysis the ground floor geometry, Krier points out the importance of scale and sections showing the relationship between the open space and the surrounding buildings. Here, the emphasis is not only on the buildings' hight, but the number of voids versus solid area, and the direction of the openings that interact with the open space, taking into account the relationship of this architectural elements at an eye-level and thereby acknowledging the permeability between the open space and the interior of the built space.

Functional approaches

After decades of formal approaches, functional approaches emerged and the typologies expanded. Both new parameters and disciplines were added into varying frameworks, such as Gehl and Gemzø's (2003) five categories of urban squares according to function, Sandalack & Alaniz Uribe's (2010) framework that includes the urban context as a parameter, Stanley et. al. (2012) transdisciplinary analysis from a historical perspective based on form and function, and Wolfrum's (2015) comprehensive categorisation of European squares in a matrix of six factors. While Sandalack & Alaniz Uribe and Stanley et. al. present theory-based frameworks of understanding and classifying urban open space, Gehl & Gemzø and Wolfrum present empirical studies classifying and describing existing open spaces. I will start with the theoretical approach to then introduce the two contrasting architectural applied studies and frameworks.

Theoretical functional approaches

In their transdisciplinary analysis, Stanley et al. (2012) propose a framework for making broad comparisons across extremely diverse time periods, spatial scales, and human cultures based on seven categories of urban open spaces. The categories are "[...] constructed around the conceptual tension between form and function" (ibid, p. 1093) and arranged by scale and land cover.

The seven major categories of open space are: (1) food production areas; (2) parks and gardens; (3) recreational space; (4) plazas; (5) streets; (6) transport facilities; and (7) incidental space at three different scales. These categories are also dubbed as "form" in table 1.

The "city scale" refers to open spaces that are associated with important institutions, have national or communal symbolic power, or are aimed at large population groups. The "intermediate scale" refers to spaces that serve multiple residences in a limited part of the city, such as a district or a neighbourhood.

In the "residence scale", the authors locate opens paces that are destined to users' or residents' private use in individual buildings or dwellings.

Form \ Scale	City	Intermediate	Residence
Transport Facilities	Harbors, Airport and Train Station Parking	Transit Stations, City Gate Areas	Driveways, Parking Areas
Streets	Central Boulevards	Street Space	Pedestrian Alleys, Paths
Plazas	Large Formal Plazas	Smaller Neighborhood Plazas	Interior Courtyards
Recreational Space	Stadiums, Greenbelts, Beaches	Sports Facilities, Playgrounds	Houseyard Playspace
Incidental Space	Natural Features and Semi-Wild Areas	Empty Lots, Transit Borders	Marginalized Space Between Buildings
Parks and Gardens	Major Formal Park and Garden Space	Institutional Gardens, Small Parks, Cemeteries	Household Gardens
Food Production	Orchards, Agricultural Fields	Grazing Commons, Community Gardens	Kitchen Gardens, Small Horticulture

Grey space
Green space
Grey/Green space

Table 1. A transdisciplinary typology of urban open spaces spanning ancient and modern history.
Source: (Stanley et. al., 2012, p. 1094)

Additionally, the typology accommodates a third dimension of analysis oriented around Al-Hagla's differentiation between "green space" and "grey space.", in which green space represents "a subset of open space, consisting of any vegetated land or structure, water, or geological feature within urban areas," and grey space refers to more civic-oriented spaces such as "urban squares, market places and other paved or hard landscaped areas." (Al-Hagla's, 2008 as cited in Stanley et al., 2012)

These are the descriptions of four out of the seven the categories deemed interesting for this study:

- *Transport facilities* are spaces in which the handling and distribution of goods takes place. They are classified as a specialized functional category, which is subject to the mode of transport they serve.
- *Streets* have historically been places for both pedestrian and vehicular movement and important sites of social interaction, political demonstration, ritual, leisure, economic production and trade.
- *Plazas* are defined by the authors as a deliberately laid out open space, framed on most sides by buildings and usually with a hard surface. Squares can accommodate a variety of civic activities and are usually multifunctional. At the urban and intermediate levels, they are usually open to the public.
- *Incidental Space*, also referred to as marginalized or amenity space, can be both grey and green. These spaces are either ignored or appear to have no specific use other than safety, visual amenity or physical separation. The authors locate incidental space on the edges of other spaces or buildings.

In their article, Sandalack and Alaniz Uribe (2010) argue for the introduction of the urban context and its interrelation to the open space as a key characteristic that informs its typification. The authors appeal for the consideration of the surrounding built environment in order develop a deeper understanding of the relationship between the physical form of the open space, the functions it fulfils and its relationship to other built elements to strengthen urban morphology in general. The authors claim that a square or street is in itself meaningless as a public space – "it must be conceived and designed in relation [emphasis added] to its physical and spatial context" (ibid, p. 46). This means taking into account both qualities and characteristics of the open space and its boundary conditions, as its relationship to the rest of the infrastructure of streets and spaces, and how it reacts to the context.
Secondly, the authors argue in favour of the consideration of activities and meaning of open space to city inhabitants. "Typology is not neutral – spaces should be designed and analysed in terms of their viability as containers for public life". With this, the role of the city is established as "[...] to serve all citizens as a matter of public amenity and not just only as a conglomeration of individual functions and destinations, with no function for the city as a whole" (ibid., p.46).

Their typological framework encompasses the following seven types: (1) street; (2) square; (3) park, garden, cemetery; (4) linear system, green corridor, path; (5) outdoor sport and recreation facility; (6) camping ground and picnic area; and (7) natural/semi natural green space.

These are the descriptions of three out of the seven the categories deemed interesting for this study:

- *Street.* From small residential streets to commercial streets, and civic boulevards, the authors position this the basic component and primary interface between the urbanite and the public realm since the "[u]rban experience is necessarily pedestrian" (ibid, p. 47); contrary to being just a structure for moving traffic.
- *Square.* Most squares can be considered either as a plot of land connected to an adjacent building (e.g., a church square, a courthouse square or a collegiate square) or as an independent plot of land. Similar to streets, the urban experience of squares is partly determined by the character and form of the built edge, which consists of both public and private components, usually buildings, that define and structure the public space.
- *Linear system, green corridor, path.* This type encompasses bikeways, trails and rights-of-way corridors alike. They are described as the access points to ecological areas and recreation fields, which should be ideally based on an environmental framework and link major nodes, thus creating an overall interlinked infrastructure of open spaces.

(Sandalack & Uribe, 2010, pp. 55-57)

Applied architectural and urban design studies

As mentioned before, typologies play an essential role in architectural and urban design teachings and the design process. This is why it is customary to have atlases depicting and categorizing spatial typologies of every kind. These are two examples of European literature in English that describe open spaces from a spatial design perspective (architecture and urban design) and include the component of public transport and traffic. Both present European squares and streets, the first also ventures into other continents.

Gehl and Gemzø's (2003) functional approach presents five types of urban squares: main urban square, recreational square, promenade, traffic square and monumental square. These categories derive from the current uses we give to public spaces, which are, according to the authors, combinations to different extents of the traditional uses: public space as (1) meeting place, (2) market place and (3) traffic space.
This is lead to four very different types cities, granted by the authors themselves, based on observations "using a good measure of simplification":

- The traditional city – where the uses coexist, more or less, in balance.
- The invaded city – where single use has taken over space at the expense of other uses.
- The abandoned city – where public space and life have disappeared.
- The reconquered city – where great efforts are being made to find a new viable balance between the city's uses.

(Ibid, p. 12)

Under this first premise, the authors present 39 streets (3) and squares (36) around the planet, describing them by location, type, history and architectural features.

Types of spaces

> *Main city square. The central square in a city, town or quarter.*
> *Recreational square. Public space with the primary function of meeting place or recreational activity. Lively squares as well as spaces with a more passive recreational character come under this category.*
> *Promenade. While this type of public space may provide furniture for stationary activities, it is the momentum of direction that is characteristic.*
> *Traffic square. The main function of this type of public space is to facilitate the circulation of traffic as well as the interchange between different modes of transport. The selected squares emphasize concern for public transport passengers.*
> *Monumental square. This type of public space provides a pause in the city fabric and often has symbolic importance. The forecourts of monumental buildings also fall under this category.*

Architectural features

> *Surface treatment. Squares and streets whose renovation largely involves surface treatment, with furniture and inventory as subordinate elements.*
> *Surface and elements. Squares whose large spacious objects furnish the floor and influence the spatial composition decisively.*
> *Composite character. Public spaces whose varied main elements divide surfaces into areas of distinctly different character, such as a combination of stone floors, water features and green areas.*
> *Combined square and building design. Squares in which both the space and the surrounding buildings were designed as one unified architectural composition.*

(Ibid., p. 87).

Each example is presented with

- Location map in 1: 100 000
- Site plan in 1: 2 000, with bold closed fronts (i.e., buildings) that form the space, floor design, greenery and the public transport trajectory within the square.
- Two maps in 1: 5 000,
    - one figure ground plan, and
    - one highlighting the pedestrian zone.
- Photographic impressions.

Name and city	Location	History	Architectural feature
Gustav Adolfs Torg, Malmö	City centre	Renovated public space	Composite character
Bismarckplatz, Heidelberg	At the edge of the historic city centre	Renovated public space	Composite character
Luisenplatz, Darmstadt	City centre	Renovated public space	Surface treatment
Place de l´Homme de Fer, Strasbourg	City centre	Renovated public space	Surface and elements
Place Charles Hernu, Villeurbane, Lyon	Outside city centre; transitional space between Lyon and Villeurbane	Renovated public space	Surface and elements
Plaça dels päisos Catalans, Barcelona	District outside historic city centre	Renovated public space	Surface and elements

Table 2. Traffic squares presented in the book with their location, history and architectural features.

For this dissertation, I will only concentrate on the type *traffic squares*. There are six examples of traffic squares in the book (see Table 2), Darmstadt's Luisenplatz being one of them.
I present two squares, located in the city centre due to the scope of my work, with their architectural drawings (without scale) and the respective description by the authors with a short additional information about the location and configuration of the public transport infrastructure.

Gustav Adolfs Torg, Malmö, SE

Location: City centre
History: Renovated public space
Architectural feature: Composite character

> *"The renovation [...] features circles, ovals and straight lines that inscribe the old tress on the square and control the slight slope of the floor. This urban space, an important connection in the pedestrian network of the city, is both a square and a park and a bus terminal.*
> *The granite floor weaves its wax between the large groups of trees that give the public space its green character, providing access from all streets. A curved line in the floor marks the connections between the city's two major pedestrian areas."*

(Ibid, pp.104-105)

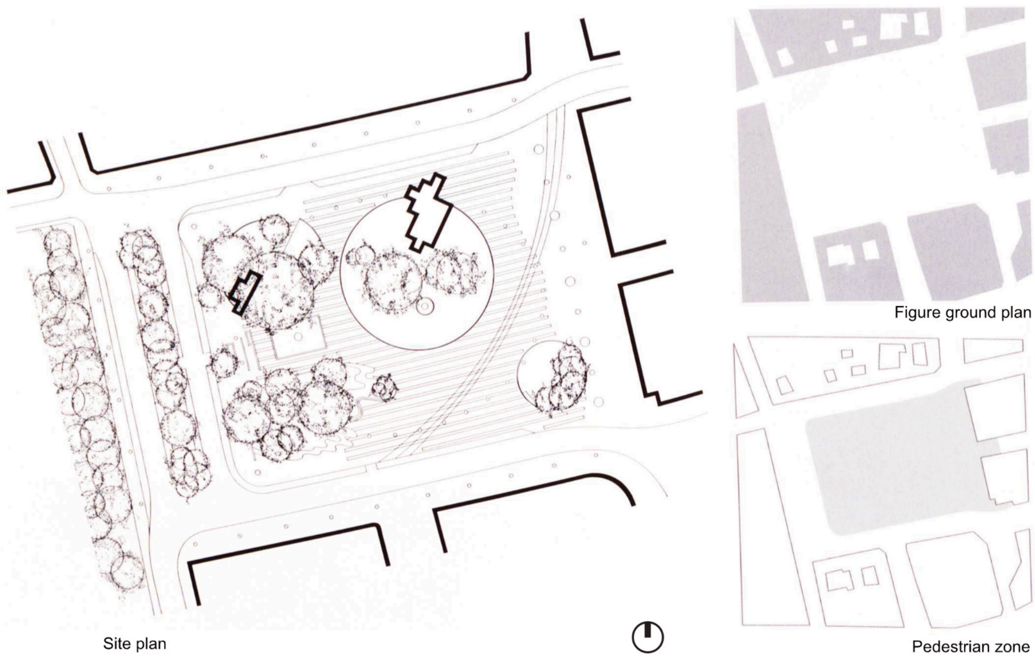


Figure 2. Architectural drawings of the Gustav Adolfs Torg
Source: (Gehl and Gemzø', 2000, p. 104)

There is a large central bus station to the west of the square. The square is exclusively for pedestrians.

Bismarckplatz, Heidelberg, DE

Location: At the edge of the historic city centre
History: Renovated public space
Architectural feature: Composite character

> *"Bismarckplatz is an example of a simple and pragmatic solution to a mundane space, a traffic square. A floor with a rectangular pattern ties the two components of the space, the hardscape and the landscape.*
> *The primary spatial element of the square is the pedestrian axis lined by trees tying the stone floor in the foreground to the softer forms of the park behind."*

(Ibid, pp.126-127)

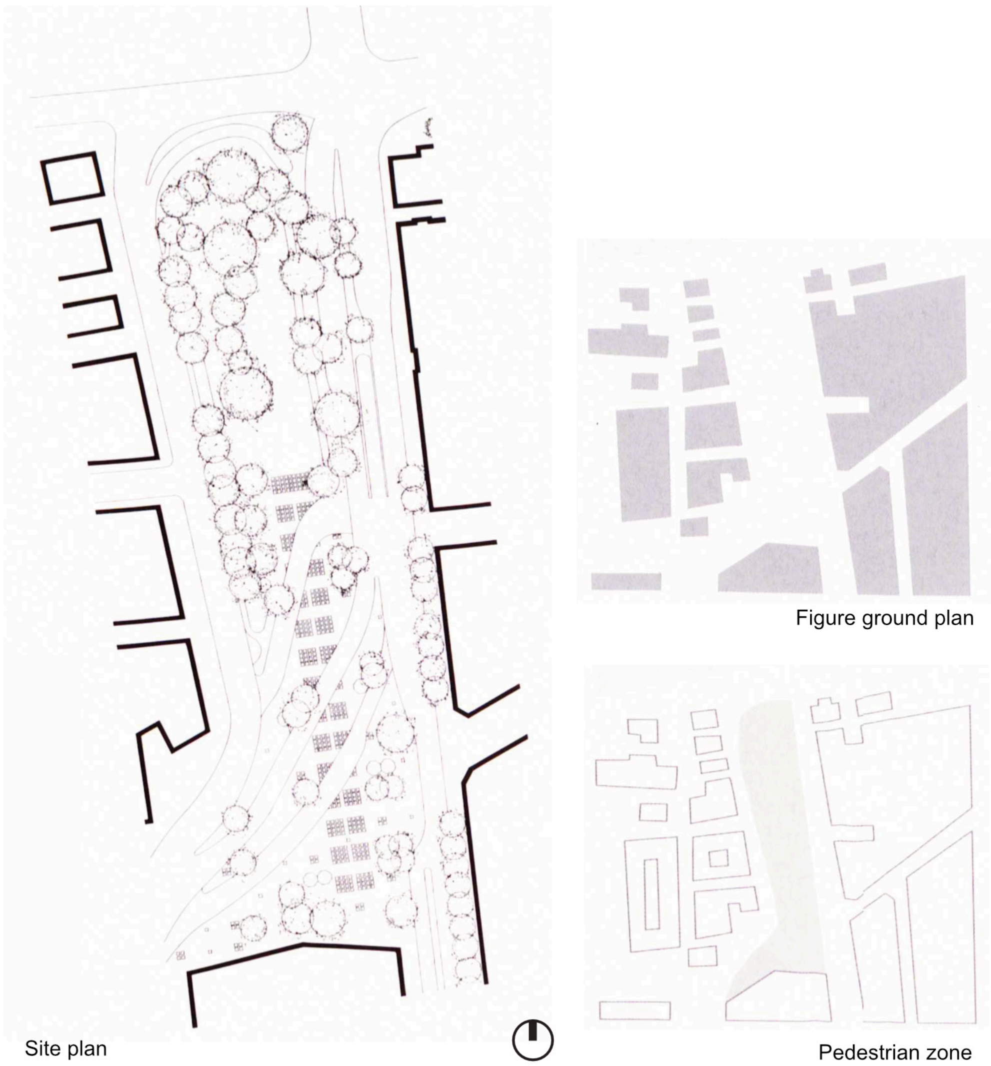


Figure 3. Architectural drawings of the Bismarckplatz
Source: (Gehl and Gemzø', 2000, p. 126)

Trams and buses traverse diagonally the square. The residual slices are wating areas with selling booths and an info point.

Wolfrum's (2015) *Squares. Urban Spaces in Europe*, is a comprehensive collection of urban square typology. The book offers the description of spatial features and architectonical manifestations of European urban squares through architectural drawings of site plans, ground floor plans and sections, and axonometric projections. This way of conveying information and categorising open space is useful both for the creation (design process) and spatial analysis. The authors categorise the compilation of open spaces in a matrix depending on the time of origin, morphological qualities, basic shape and size, functions and programmes, and performative potential.

Time of origin

Divided into five into large time spans: Antiquity, Middle Ages, modern era, 19th century, and since the 20th century.

Morphological qualities

The 15 presented morphological qualities relate to the shape of the square with regard to its buildings and other space-generating elements, as well as the urban context.

Entrée. The square serves as an entrance into the town or urban quarter.

Forecourt The square is located in front of a dominating building, within its spatial sphere of influence – it serves as its forecourt.

Breitenplatz (Camillo Sitte) – Broad-type square. The square is orientated towards its long side, where simultaneously the most important building is situated, dominating the plaza.

Tiefenplatz (Camillo Sitte) – Depth-type square. The square is orientated in a longitudinal direction towards a dominant building located at the far end, in the depth of the space.

Hub. Several routes intersect in the square, which acts as a distributor of pedestrian and/or vehicle traffic flows.

Joint. The square or an essential part of it belongs to two or more spatial systems at the same time; diverse structures or directions interlock on the square.

Interface. Two morphological systems abut on each other in the urban structure. Occupying a peripheral position, the square marks the interface.

City interior. Building fronts, often closed, give the square the appearance of an interior space, even if there are irregular contours. This character sometimes applies to only one part of the plaza or of an ensemble of squares.

Hall. The sense of closure and the compact proportions of the square are enhanced by a regular, for the most part rectangular, shape and the uniform height of the eaves on the building fronts.

Courtyard. Originally the courtyard of a building complex, this open space is used as a public square.

Field. Just as freely arranged objects on a game board create relations between each other, freely distributed buildings stretch out the square between them.

Ornamental square (decorative plaza). Formality of furnishings and planting lend the square its ornamental character.

Garden. *The character of the square is essentially shaped by vegetation.*
Belvedere. Due to its exposed and often elevated position, the square provides overviews and scenic views, mostly in a preferential direction.
Expansiveness. In relation to the extensive floor area, the peripheral heights of buildings in the square appear low or are weakly defined; the square's extent is perceived as expansiveness.

Basic shape and size
The authors use six basic shapes: rectangle, trapezoid, funnel, rounded space, star shape, spatial trajectory. Size is defined in four categories, from small to extra-large, and it is the measured area of the space between buildings. Small up to 5,000 m², medium from 5,000 m² to 15,000 m², large from 15,000 m² to 25,000 m², extra large more than 25,000 m²

Functions and programmes
This category relates to the use of the square and of its buildings. The authors describe five types of functions and programmes:

Trade. The square is a marketplace, or trade and gastronomy in the surrounding buildings determine its appearance.
Traffic. The character of the square is strongly influenced by road traffic.
Residential. A significant proportion of the structures on the square, for example a neighbourhood square, are residential buildings.
Representation. The square as such, or in connection with significant buildings, has a prestigious function.
Public programmes. The public –often cultural – functions of buildings on the square affect the use of and characterize the square.

Performative Potential
This last category relates to "the general spatial dealings with the square, to activities and behaviour
within the square, supported by its architecture". On other words: which type of activities are supported or even encouraged by the built environment. The nine proposed performative potentials are:

Strolling. Without needing a fixed destination, the stroller moves through the square aimlessly
Corso. The shape of the square promotes an up-and-down promenading movement.
Scene. The square, thanks to its architecture, is explicitly laid out for overview, or for seeing and being seen.
Ceremonial. As evidenced by its shape and furnishings, the square is intended for ceremonial procedures.
Relaxation. A cosy atmosphere and a sensation of comfort entice the visitor to linger, without a fixed intention.
Being inside. Just as in a room, in the square one has the feeling of being in an interior. Entrance and exit are decisive acts.

> *Meeting. One drops in, meets acquaintances, loiters for a while, and leaves again – a continuous coming and going.*
> *Gathering. The square is the scene of political and social activities, demonstrations, rallies, protests etc., and gives them significance/meaning.*
> *Void. Predominantly, the square is traversed, and does not incite any particular action or specific behaviour.*

(Wolfrum, 2015, pp.10-11)

Each example is presented through

- Site plan with highlighted square in 1: 5 000
- Ground floor plans and sections 1: 1 250
- An axonometric projection in 1: 1 250

Additionally, some information about the development, urban surroundings and importance of the square is given.

I present two contrasting examples and will only show their site plan and axonometric projection without scale.

Explanada de España, Alicante, ES

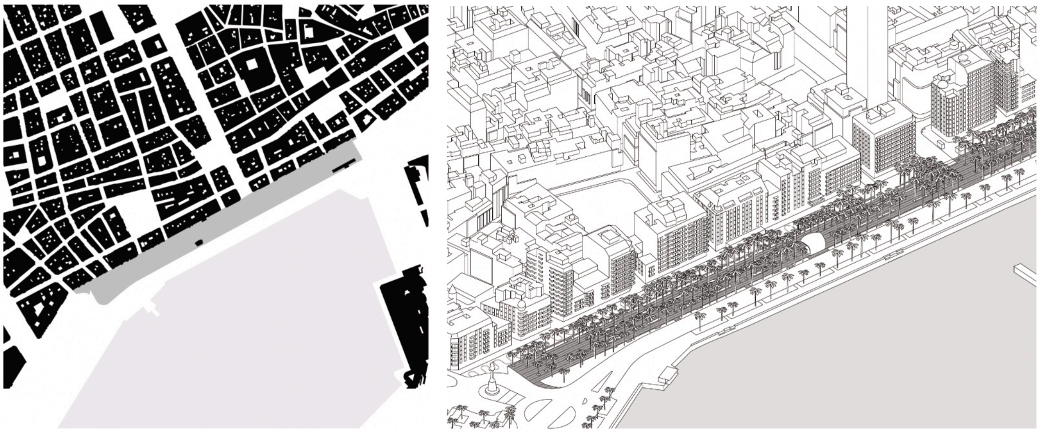


Figure 4. Architectural drawings of the Explanada de España
Source: (Wolfrum, 2015, p. 22-23)

Potsdamer Platz, Berlin, DE

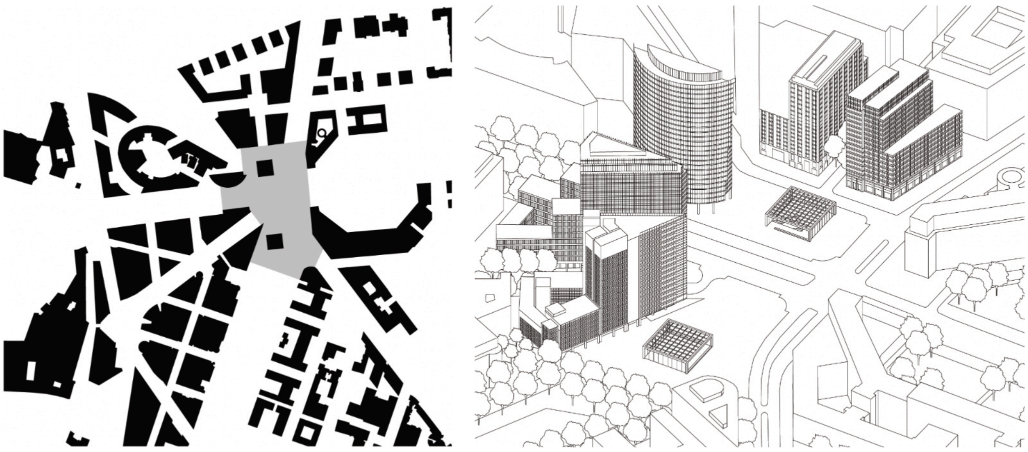


Figure 5. Architectural drawings of the Potsdamer Platz
Source: (Wolfrum, 2015, pp. 52-53)

2.1.2. Configurational approach

Kropf (2017) traces back the origins of this approach to the mathematical and quantitative investigations of architectural and urban form. It focuses on the geometric and topological attributes of the built form. The aim is to understand the interrelationships between different attributes and measures, the ways in which different configurations affect the use of urban environments and buildings, and to predict and improve function and performance.
According to configurational approach, citizens' experiences, perception and behaviour vary according to the setting, i.e., its morphology and environmental properties. The way the elements of the built environment are configured, formed, and transformed is referred to as morphology. Environmental properties can be loudness, exposure to traffic, lighting, crowdedness or temperature, e.g.

Kevin Lynch's approach to analyse the city based on the perception of main urban components –paths, edges, districts, nodes and landmarks– (Lynch, 1960) and Christopher Alexander's analysis of urban grid, which involves graph representation and graph analysis (Alexander, 1968), gives rise to more systematic thinking about spatial design.

The space syntax theory falls in to this approach. It encompasses a range of methods for the socio-spatial analysis of settlements and buildings of all types and sizes, which derive from the pairings of mathematical investigations of spatial relationships based on graphs and the observed behaviours on-site. These can be either movement (e.g., walking or driving) or activity (e.g., sitting or gathering).
The core concepts are based on two fundamental propositions. Firstly, space is intrinsic to human activity and not a background to it. (Karimi, 2012). Space is shaped, designed, in a way that reflects the direct interaction between space and people, which humanises the space we create (Hillier and Hanson, 1984). Secondly, space is fundamentally a configurational entity (Hillier and Hanson, 1984; Hillier, 1996). The built environment is comprised by components of sub-spaces which are used in different ways and play different roles. These components and their pattern of relationships are a configurated. Configuration is thereby how the built form is composed and its different parts relate to each other.

Karimi (2012) explains the fundamental techniques that have been developed, based on the assumption and observations that there is a direct relationship between spatial configuration and urban functions. The representation and modelling techniques model fundamental concepts such as movement, visual perception and human occupation within a model of physical space with simple geometrical attributes, such as lines of sight and movement or visual fields to create a network. In a second step, the modelled network is turned into a pattern of relationships, or a graph representation, which can be analysed quantitatively. The created network is then an interconnected system of spaces and the analysis can help "determine the relative role that each space plays in the configuration of the system, as a whole, or in its parts" (ibid, p. 305). See Figure 6.

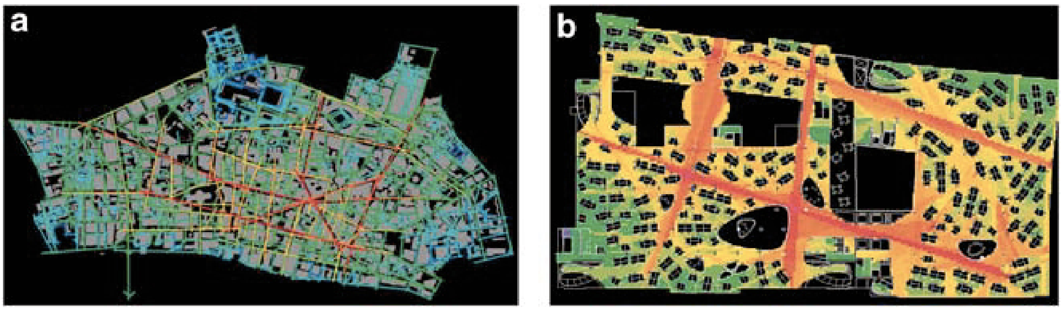


Figure 6. Two methods of spatial modelling: a line-based model of the City of London (a) and a visual field-based model of an office environment (b). Spatial structures of urban and architectural systems are represented by a colour scheme, using a colour scheme that ranges from the most connected (dark red) to least connected (dark blue).
Source: (Karimi, 2012, p. 306)

According to the author, the advantage of the model is that it delivers an uncomplicated model of the spatial network that corresponds directly with the fundamental concepts of movement and navigation in space, and visual perception by representing visibility.

Indeed, research has shown that there is a strong relationship between spatial configuration and how people move through the city, as in the theory of natural movement (Hillier et al, 1993) or who it influences cognition and wayfinding (Conroy-Dalton, 2003), how people feel in a certain context , such as the emotions that are evoked by spatial configuration (Kuliga et al, 2013), and which environmental and spatial parameters are experienced as stressful or relaxing (Halblaub Miranda & Knöll, 2017; Knöll et al, 2015; Knöll et al, 2019). These studies underpinned the syntactical model analysis with empirical on ground data of how people move and perceive the analysed spaces.

2.2. Space, place and activities

2.2.1. Defining the space-place relationship

According to Begum (2017), space refers to a physical location and its substances, and a space becomes a place when it gets assigned with a meaning and social significance by individuals. Space, thereby, receives meaning through different kind of interactions by specific and communal purposes.
Begum argues that space plays a vital role in how we perceive a city or an area; and its meaning and composition is interpreted differently between disciplines. She relies on Lefèbvre's notion of space to argue that space does not exist – rather it is produced, or according to Lefèbvre's theory (Lefèbvre, 1997) – space is perceived, conceived and lived. On the other hand, place is a space with meaning and does not have any boundary. It is said to be that space which is not exchangeable to other space (ibid, pp. 1-2).
According to Dana Pop (2014), space –which is considered to be a homogenous and unorganized entity– has the ability to become a place –a meaningful, organized and well-

defined entity. This shift in quality –the process of turning from space to place— is illustrated in the following approaches.

Space is Movement - Place is Repose

Yi-Fu Tuan's theory, which is spiritually linked to Lefèbvre's subjective space-objective space relationship, relates the concept of place with a feeling of security and stability, namely putting down roots and identifying oneself with a place. This is in essence the act of concretizing values, while space is associated with the freedom of movement (Tuan, 1977).
According to the author, space is linked to movement, while place is linked to reposes, to stops along the way:

> *"What begins as undifferentiated space becomes place as we get to know it better and endow it with value. [...] The ideas 'space' and 'place' require each other for definition. From the security and stability of place we are aware of the openness, freedom, and threat of space, and vice versa. Furthermore, if we think of space as that which allows movement, then place is pause; each pause in movement makes it possible for location to be transformed into place."*

(Ibid, p. 6)

Similarly, Norberg-Schulz (1980) writes about the spirit of the place or genius loci, namely the precise moment when one resonates with a certain space, thus transforming it into a place. On the other hand, Heidegger (1982, as cited by Pop, 2014) defines the role of architecture as being one of factors turning a site into a place and of discovering its potential meanings.

For Tuan, space is given by the ability to move. Movements are often directed toward, or repulsed by, objects and places. Hence, space can be variously experienced as the relative location of objects or places, as the distances and expanses that separate or link places, and - more abstractly - as the area defined by a network of places. According to him, space is what is left behind after delineating all places, but not reaching the level where it opposes the place on a conceptual level. Space itself is structured, organized, based on a network which enables orientation - unlike Lefèbvre's objective space, which is abstract, thus, it cannot exist in a material world without becoming a subjective space, namely a social one.
When discussing place, Pop (op. cit.) cites Tim Cresswell's notion, which is very similar to Tuan's concept, who was actually Cresswell's mentor. According to Cresswell, place is a human necessity: our existence, as a species, depends on the presence of place and places, and it is not independent of human will and existence. This is connected to Tuan's 'topophilia', which characterizes the affectional link between people and places. This relationship, together with the feeling of attachment which it generates, become fundamental for the idea of place - place seen as one's territory and also as a territory to which one belongs to (Ibid, p.279-280).

Space vs. Place

Cresswell (2004) points out that space is a more abstract concept than place. When we speak of space, we tend to think of outer-space or the spaces of geometry. Spaces have areas and volumes. Places have space between them. He relies on Yi-Fu Tuan's theory to emphasize that what begins as undifferentiated space becomes a place when we get to know it better and endow it with value. On the other hand, space as opposed to place is a realm without meaning –as a 'fact of life' which like time, produces the basic coordinates for human life. When humans invest meaning in a portion of space –naming is one of the ways in which space can be given meaning– it becomes a place.

The author discusses how place is used in a myriad of ways; e.g., to show ownership or possession, connection between a person and a location or building, visual aesthetics and social hierarchy. This common use of the word makes it simple as well as complicated to differentiate both terms. This is similar to the differentiation between terms such as 'landscape' or 'territory'.
To more easily illustrate differences, he scrutinizes various examples such as a child's room, an urban garden, a market town, New York City and the Earth to convey that these are all spaces that people have made meaningful and to which people are attached in one way or the other. This is the most straightforward definition of place: a meaningful location. Citing John Agnew (1987, as cited by Cresswell), he highlights three fundamental aspects of place that make it a 'meaningful location':

1. Location
2. Locale
3. Sense of place.

By location, he means that all spaces mentioned above are located and have fixed objective co-ordinates on the Earth. But a ship may also be considered a place when inhabited in case of a long voyage, even though its location is constantly changing. By locale, he means the material setting for social relations – the actual shape of place within which people conduct their lives. By 'sense of place', he means the subjective and emotional attachment people have to place.

Cresswell highlights that place is not merely a thing in the world, but a way of understanding the world. When we look at the world as a world of places, we see different things. We see attachments and connections between people and place. We see worlds of meaning and experience. This leads us to views the world as a rich and complicated interplay of people and the environment. However, looking at the world through this lens of 'place' can also lead to reactionary and exclusionary xenophobia, racism and bigotry. Here 'our place' is threatened and others have to be excluded. He uses this example to emphasize the epistemological and ontological nature of his work.

2.2.2. Activities in public space: amenity quality and performance

Amenity quality encompasses design and environmental properties that invite people to stay and use a space, contributing to its vitality. The performance points towards the type of activities that the said space supports and encourages. Performativity can be understood as the potential that these spaces bare to support both our everyday activities as well as unexpected activities, outdoor activities in public space, and access to them.

Work lead by Jan Gehl, Lars Gemzø, and colleagues at the Public Space Research Centre in Copenhagen portrays a vast array of examples evidencing that design, from the beginning of a project or in later interventions, plays a big role in an open space's vitality and its user's behaviour (Gehl & Gemzø, 2003; Gehl et. al, 2006, Gehl, 2011). Places that are vital are those where people can interact with one another and benefit from social networks. Bosselmann (2008) explores and presents a set of tools for the observation of vitality, liveability and sense of place and pinpoints its origin of study of human use of space within the context of culture in the field of anthropology. The research conducted by both groups is done from the point of view of architectural practitioners and urban designers.

In his book, *Life Between Buildings: Using Public Space*, Gehl (2011; first English translation 1987) examines the relationship between patterns of use, specifically outdoor activities, and the physical properties of the built environment. To this end, the author and research team documented the performance of urban spaces (the activities that took place in them) and analysed which factors influence their use. According to him, outdoor activities in public spaces can be divided into three categories, each of which have very different demands on the physical environment. These are: *necessary activities*, *optional activities*, and *social activities*. To support this idea, the author examines the spatial properties (such as dimensions, spatial configuration and architectural design measures) of traditional medieval public spaces and contrasts these to the success contemporary examples by quantifying the levels of pedestrian flows, levels and length of stationary activity - including human contact and social interaction.
While necessary activities (those that are more or less compulsory such as going to school or work or running errands) are influenced only slightly by external conditions, optional activities mainly take place when favourable external conditions are present. "When outdoor areas are of poor quality, only strictly necessary activities occur" (ibid, p. 9). Optional activities are, e.g., taking a walk to breath fresh air or standing around to enjoy the scenery, nature or weather.
The third category, social activities, are activities that depend on the presence of others. These are e.g., children playing, people meeting, greeting and talking, gathering for communal activities such as listening to a musician or simply to see and hear other people.

The opportunity to see, hear, and meet others can also be shown to be one of the most important attractions in city centres and on pedestrian streets. This is illustrated by an attraction analysis carried out on Strøget, the main pedestrian street in central Copenhagen, Denmark (Gehl, 1988). The analysis is based on two surveys conducted in the same areas and during the same periods under the same weather conditions (ibid, p. 12). The first was carried out in 1968, six years after Strøget was closed to motorised traffic and turned into a pedestrian street, and the second in 1986. The researchers observed pedestrian traffic, pedestrians stopping and what they stopped to look at:

> *"Fewest stops were noted in front of banks, offices, showrooms, and dull exhibits of, for example, cash registers, office furniture, porcelain, or hair curlers. Conversely, a great number of stops were noted in front of shops and exhibits that had a direct relationship to other people and to the surrounding social environment, such as newspaper kiosks, photography exhibits, film stills outside movie theatres, clothing stores, and toy stores.*

Even greater interest was shown in the various human activities that went on in the street space itself. All forms of human activity appeared to be of major interest in this connection […] It was obvious that human activities, being able to see other people in action, constituted the area's main attraction."

(Gehl, 2011, p.21)

2.3. Discussion and conclusions

The theoretical and practical approaches presented in section 2.1.1 analyse and describe the typology and morphology of urban space by examining traditional or famous examples from different parts of the world.

In the first sub-section, three architectural and urban design formal approaches that seek to identify spatial characteristics of successful open spaces were presented. Here, the authors focus on describing and classifying urban open space by examining traditional or famous examples from Europe. These are, according to the authors, all well-functioning places that people like to use and visit. However, they do not offer empirical evidence to sustain whether or how they are used.

Visual relationships play a pivotal role in all three approaches, even if not named this way. Enclosure and artistic elements, as observed by Sitte and Zucker, steer the eye and have an impact on how we perceive a space: how far must I see (or not see) in order to call an area a *space*? Framing, changing and restricting views is, then, the main artistry of open space. Krier integrates architectural elements and takes into account their relationships at eye-level, enriching the previous two formal approaches by taking into account visual permeability between open space and indoor space. By designing visual relationships to reflect our social needs and preferences, we create spaces to gather. This suggests the importance of the built environment in sustaining social practices and vice versa; a dialectical relationship in which both shape each other. While all three authors of the first sub-section deliver more or less versatile and adaptive frameworks to describe and classify the form of different spatial setups, they do not further investigate whether the identified elements and characteristics facilitate an analytical approach of the performance of urban squares that can relate to spatial use, behaviour or perception. This intertwined relationship between behaviour and form is later explored in section 2.1.2.

In a second sub-section, I presented both theoretical and practical approaches. These studies are based on both interdisciplinary theoretical elucidations and applied architectural and urban design classification of modern examples.

According to the theoretical functional approaches, the two types of open space that maintain their relevance and position throughout history are streets and squares. These are undoubtedly types that run throughout human history and cultures, albeit with some variations.

It is interesting that only one group mentions transport facilities as a separate category, although Sandalack & Uribe do see its necessity: "[…] a new category of space is made

necessary by the proliferation of surface parking, empty lots and traffic interchanges" (Sandalack & Alaniz Uribe, p.35). To put it in Lynch's five elements perspective (Lynch, 1960): if pedestrian streets are the pedestrian path and squares their node, transport facilities are the nodes to vehicular paths—ranging from airports to parking lots.
Nevertheless, the authors limit these spaces to the handling and distribution of goods and their function as access point to mobility services is not taken into account. I propose extending this category to passenger mobility in which case, IOS would fall into the category at a meta level.
It is the historical lens as a tool that broadens the understanding of space and enables the integration of functional types such as food production areas, transport facilities; and incidental spaces. The first, being more common and essential to the first settlers in history. The second having its starting point in a moment in history where settlements are widely established and the notion of traveling between them is constituted. The third is a concept that can only be discovered in an era when our settlements have been thoroughly designed and overdeveloped so that we become more easily aware of "non-places".

The use of scale in Stanley's et. al. study is a well-established and helpful tool for urban and regional planning alike. I find it can be useful when describing both the chosen spaces in my study as the context surrounding and leading to them. Which resonates with Sandalack & Alaniz Uribe's premise considering the context in order to deliver a typological framework which can be used in designing the public realm. Their practitioner-oriented framework is very adamant in highlighting the "necessarily pedestrian" experience of open space—a position that has had its ups and downs in modern urban design and planning, as we will see later on.
The authors are aware and point out that places may represent a mix of types, i.e., one space isn't necessarily tied to only one type, and that these are culturally valued for their multi-purpose nature.

I will keep the following five types into account when applying the analytical framework for a typologisation of IOS:

- Streets
- Squares
- Linear systems, green corridor, path
- Incidental space

Both applied functional approaches present particularly characteristic examples that may be representative for other squares, as the authors state. The publications do not set out to provide a comprehensive overview of open space / square typology. Similarly, the examples I have chosen from their works also serve to illustrate the spatial understanding of enclosure and delimitation as presented in each work.

The cases are analysed in a similar sequence in both works. First, the square is located within its historical and urban context. Second, figure ground plans and architectural drawings in greater detail are depicted. They differ when defining the type of space that is being called “square” and how it is being delimited. While Gehl & Gemzø state that the presented examples are a selection of streets and squares (op. cit., p. 7), the categorisation is adapted solely to squares. Although Wolfrum states from the beginning that the analysis is focused on squares, at least one example on a non-square –Explanada de España– is showcased but acknowledged: “[e]ven though this waterfront promenade is not a square in the classic sense, it has to be counted among the most attractive open public spaces” (op. cit., p. 22).

The delimitation of space is handled differently as well, both conceptually and graphic wise. As seen in the examples above, Gehl and Gemzø understand and represent streets as enclosing components. This method is applied throughout all the examples. Wolfrum does this with Explanada de España but the rest of the examples are primally defined by building enclosure and to some extension the functional relationship of the buildings to the square. In the Potsdamer Platz example the borders of what is defined as the square are drawn up to the edge of the surrounding buildings and delimited to the south-west by greenery. The author does acknowledge the spatial fragmentation in the text: “[t]he square's public space has been reduced to the traffic islands and sidewalks between the streets. […] In contrast to the usual concept of an urban square, here the space seems to disappear in all directions (op. cit., p. 52)”.

More than a critique of the approaches presented, I see the possibility of further developing the spatial analysis regarding open spaces' enclosure and delimitation in order to differentiate further types. For this, I adopt typologies and boundary approaches that are consistent with *traffic spaces*, such as vehicular streets which fragment spaces where pedestrians can transit without danger.

Following the differentiations made in the theoretical approaches, and as examples to elaborate the first level of the analytical framework, I would categorise the examples as follows:
Heidelberg's Bismarckplatz and Alicante's Explanada de España would be an open space along a (green) corridor.
Potsdamer Platz, a traffic hub, is redefined as two separated areas with the same function, morphologically defined by both building fronts and segregating traffic infrastructure, i.e., vehicular streets. This approach is based on the “necessarily pedestrian” experience of open space, as Sandalack & Alaniz Uribe propose.
This premise will be investigated on-site through user survey of the perception of such spaces.

In sub-section 2.1.2., a quantitative approach which connects spatial elements to activities on site is introduced. Here, the presented research carried out in the last five decades, introduces to the analysis of spatial compositions as networks –the whole urban fabric—, as opposed to considering discrete open spaces or squares, as done in 2.1.1.

In further conceptualisations of urban space both designers and researchers of different disciplines have differentiated between space and place, as presented in section 2.2.1. According to Pop, places can be and actually are produced; however, the place is not a ready-made, mass-produced product, but rather it is initiated by users, behaving like a process. By relating a place to the everyday experience -linking everyday activity of micro-cultures, through which they identify themselves- to the place, it is being defined. If one were to define a place as the experience of the everyday, then one could also culturally define a place as the manifestation of a certain group in space. This is also supported by Cresswell, who states that places are the outcome of cultural activities.

It is therefore crucial to record and analyse the activities that unfold in open space as it is precisely the presence of other people, their activities, and the resulting stimulation that comprise one of the most important qualities of spaces altogether. The presence of people and the variety of activities are a result of high amenity quality.
The observations carried out in the presented studies consist of, along general lines, mapping the number of pedestrians passing by, the number of people, staying and sitting or staying and carrying out other activities. The latter can be specified according to the functionality and target group being investigated.

Due to the focus on mobility, activities and groups taken into account for the onsite mapping are: people walking, cycling, waiting for public transport or exchanging mode, sitting.
Indicators of possible activities such as outdoor gastronomy seating area, farmers' market stands, are also mapped
The space syntax analysis will concentrate on relating visibility with these activities and the location of spatial elements and mobility services within the selected IOS.

3. Urban mobility in change

This chapter reviews and introduces the reader to how transport and mobility shaped settlements' form and sizes, the current understanding and state of the art regarding the conceptualization of new mobility forms, more specifically mobility stations, and further concepts shaping todays understanding of how to plan for and analyse urban mobility.

The first section of the chapter, I describe some historical aspects regarding the role of mobility in urban development; more specifically how the introduction of motorised vehicles in the beginning of 20th century shaped current urban form and a popular planning concept to counteract through transport-oriented development (TOD).
In the second section, I describe modern concepts and analytical frameworks such as the concept of sustainable urban mobility (SUM) and its implementation tool: SUMP, mobility cultures from geography, and designing mobilities from both a sociological and architectural point of view.
The third section starts with a definition of the term mobility station, followed by an overview of related concepts in guidelines and implemented projects alike through selected examples. I present examples of how mobility stations have been evaluated in academia as well. The latter studies were carried out from a transport planning point of view.
The chapter ends with a summary of the findings in literature research and highlight the attributes and methods that will be taken into account in the empirical analysis. The analytical framework is presented.

This chapter starts with a definition and delimitation of the term mobility and transport, how the term mobility is understood and applied in the framework of this dissertation, as well as the related terms multi-, inter- and monomodality.

Defining mobility: relationships and delimitations

Mobility refers to "the necessity, the ability, and the need […] to change location in order to get to resources" (own translation from Gleich, 1998 in Gather et al., 2008, p. 23).
Gather et al. (2008) dive further into the multifaceted versality of the term and explain the distinction between intellectual, social, and physical mobility as follows:

- *intellectual mobility:* the ability to break away from traditional ways of thinking, change in thinking approaches and patterns, being mentally flexible and open to thinking in alternatives;
- *social mobility:* movement within the social fabric, changing social positions such as ascent and descent between social classes; and
- *physical mobility:* also known as spatial mobility, entails the change of location in physical space.

(Gather et al., 2008, p. 24)

Based on these definitions, this dissertation explores *spatial mobility* in an urban setting. Furthermore, the distinction between mobility and transport within this dissertation can be made as follows: mobility solely describes the possibility of travelling a certain distance in order to meet individual needs for spatial change. Transport means the actual movement from A to B, regardless of the mode of transport used.

Multimodality, intermodality

Chlond (2013, p. 271) refers to multimodality and intermodality as "mobility concepts". The terms can be used with regard to system, person and route properties in passenger transport, as Beckmann et al. (2003) show in the following overview (Table 3). The opposite, i.e., the use of only one means of transport for a chain of routes or a route, is known as monomodality.

Type of modality	Characteristic of the transport system	Characteristic of a person	Characteristic of a trip / trip chain
Multimodality	Offers the possibility to vary modes of transport	Varies modes of transport (has the competence to vary means of transport) in different trips and trip chains	Modes of transport are varied within a trip chain
Intermodality	Offers the possibility to combine transport modes	Combines modes of transport within one trip	Modes of transport are combined within a trip/ change of location
Monomodality	Does not offer options to link or vary/choose modes of transport	Always uses only one mode of transport	Exactly one mode of transport is used on a trip/ change of location

Table 3. Inter- and multimodality as a system, person or route characteristic in passenger transport.
Source: Beckmann et al 2003 (as cited in Chlond 2013, p.: 272), author's translation.

Multimodality thus stands for the basic use of many modes of transport ("multi modi"). Intermodality is a special form of multimodality in which different modes of transport are used during one trip/ a change of location. (Chlond 2013, p. 272).

A person has a multimodal behaviour when she uses different modes of transport within a defined period of time (e.g., a week) for different trips. She is intermodal when she has the ability and possibility to combine two or more modes within a single trip. Intermodal behaviour therefore requires a transfer at an interface, whereas in multimodal behaviour the decision for a mode of transport within a tip is made in advance by weighing alternatives (BBSR/BBR, 2015). Multimodality and intermodality can be represented, as a behaviour, graphically as follows:

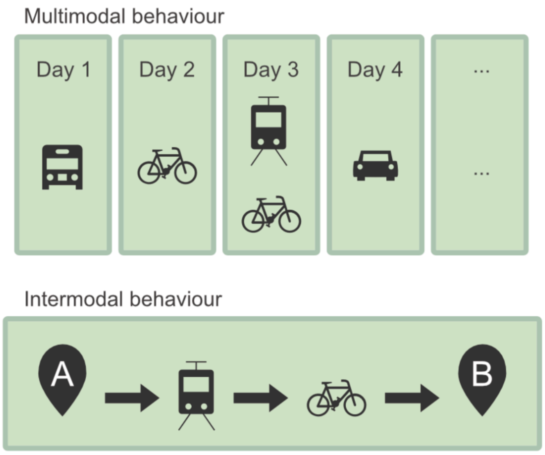


Figure 7. Representation of a multimodal behaviour stretched out through four days and intermodal behaviour within one trip.

In regards to the system, there is a multimodal supply when "there are at least two reasonable transport mode alternatives available for the users' actual mobility needs, while intermodal infrastructure makes it possible to use a combination of different modes within one trip. Similarly, multimodal services enable or facilitate the use of different modes for different trips, while intermodal services enable or facilitate a combination of different modes within one trip." (BMVT, 2016; FGSV, 2017 as cited in Miramontes Villareal, 2018, p. 43-44).
The smallest units in the system of public transport stations usually represent access points to the larger transport system and, thus, multimodality in general (Garde et al. 2014).

3.1. The role of mobility in urban design history: a review

We reviewed the fundamental factors of shape and form of open space in history and their functions and activities in the past chapter. This section deals with the changes the built environment has undergone thanks to changing mobilities.

It all started walking

The very first function and need that open space fulfilled was for inhabitants –human and animal– to be able to go from one place to the other. To this day, it maintains its key function: open spaces connect buildings, residents and services, they enable both movement and the opportunity to meet for exchange; it connects.

Seminal research analysing the role of transport in shaping cities done by Marchetti (1995), introduced the concept of a universal 'travel-time budget' of around one hour on average per person per day. A city's size is thus dependent of how much distance can be covered within one hour. A tool that has been since used by others to see how cities are shaped (Newman & Kenworthy, 1999; 2006).

In his Berlin study, Marchetti traces back the size of medieval walking cities to a radius of around 2.5- to 4-kilometre wide, based on the distance a pedestrian can cover at the average human walking speed of 5 km/h, getting to several destinations within the city in one day. Years later, Newman & Kenworthy (1999) called this the *walking urban fabric*. The authors identify the key characteristics of the walking urban fabric as 1) dense (usually over 100 people per ha or

10 000 per km^2), 2) with mixed-use areas and narrow streets, and 3) they were no more than 3-4 km diameter, or roughly 2 km radius (Newman et al, 2016, p. 433). The later based on both a slower walking speed (3-4 km/h) and comparing cities worldwide.

Thanks to the development and wide introduction of (public) transport, one hour translated into longer distances. With the introduction of the train, and later on tram, cities expanded rapidly at the beginning of the 19th century. Electric trams widened the cities' diameter up to 10-20 km while trains formed outer areas that added up to 20-40 km.

Inside this *transit urban fabric*, trams connected users at a lower speed as trains, but stops were located closer to each other. Newman et. al. state that 250 m distance between each other was the standard of the time. The city's new layer developed along tram corridors, differentiating itself from the importance of trains at a regional level. The corridors were mainly of mixed land use with lower densities that within the nuclear walking city, as activities and housing could now be spread out further and still be reached with ease. This development only occurred in places where a stop could be reached within a five- to ten-minute walk (Newman et. al, 2016, p. 434).

A further expansion is seen in the 1950's with the introduction of the automobile, cities' radii increased to more than 20 km. Along with this technological development, modernist visions began to define urban planning ideas around the world. Below is a brief introduction to the fundamentals of the *functional city* and how it paved the way for the *automobile urban fabric*, followed by the reactions and countermeasures to these changes in the last century.

The functional city or automobile urban fabric

Urban planners and designers of the modern area appeared to gladly shift their way of understanding and shaping the city in order to accommodate the new technology: cars. For the first time, transport is systematically included in future-oriented urban planning in the *Congrès internationaux d'architecture moderne* (CIAM) of 1933 and its resulting manifest from 1943, the Athens Charter (Canzler & Knie, 1998; Newman et al., 2016).

During this gathering, the concept of the *Functional City*, in which living, working recreation are stated as the main functions (land use) and transport the function that combines the land use types, was produced. Modern planners and designers lead the way delivering visions of new, broad and sky-reaching cities. See Brasilia Lúcio Costa's plan for Brasilia in Brazil or Le Corbusier's Chandigarh in India.

The planning of traffic and traffic space was subject to, what some call, "a fatal error": it was carried out under purely functionalist aspects. Architects and planners overlooked the multifunctionality of traffic space and its meaningful historical definition as public open space, where different activities took place and people can gather without a specific purpose.

Gehl (2011) points automobile-based planning as the reason for the displacement of public life in open space in some cases. He claims in several publications, that the introduction of contemporary urban city planning principles, such as functionalism, and the 20th century design ideas based on said functionalism, were central to the lack of vitality in street life.

This is presented in section 2.2, where a shift of activities in open public spaces is identified around the introduction of the automobile in cities. The necessary activities in the public urban space (e.g., visiting the market or daily active mobility) continuously decreased until the 1970s, leaving a small gap of fewer observed activities, until the optional leisure activities, again subdivided into active and passive, increase strongly from this period onwards (cf. Gehl et al., 2006; Gehl, 2011).

What happened during this gap and why did optional activities increase again?

The answer involves new ways of implementing transportation and new policies regarding open space.

Freight logistics replaced and updated their forms of transport in the course of the 20th century, liberating space for new recreation areas and leisure corridors. As a result, the quality of public space in city centres became a design priority (Gehl & Svarre, 2013). Bendiks & Degros (2019) compiled in their book examples of such projects implemented in the last decades. They present projects such as Superkilen in Copenhagen, DK –a former railway site transformed into a linear public park– or La petit ceinture in Paris, FR –a disused railway line opened for neighbourhood activities, among others.

Cities had already started implementing planning strategies to pedestrianize city centres, as one of the examples of reconquering open space at mid-20th century.

(Re-) Pedestrianisation in Germany – a quick review
The implementation of pedestrianised areas had already had started in the 1930's as a way of promoting commerce streets [*Geschäftstraßen*], as seen in the pioneering example of the city Essen, where the city centre was closed for cars in the 1930s (Monheim, 1975). Their emergence contrasts with the above-mentioned critique to the functional city: in order to alleviate increasing traffic pressure and the decline of city centres, Germany started implementing pedestrian zones [*Fußgängerzonen*] influenced by the idea put forward by the functional city that pedestrian routes and automobile routes should follow separate paths (Hilpert, 1978, p. 9).

The second world war did open up the opportunity to leave behind old pedestrian structures (the 'medieval city', as per Marchetti, or Newman & Kenworthy's 'walking urban fabric') and reconstruct inner cities –which had been almost completely destroyed by the war– towards a car-friendly urban development (Kron & Stark, 2006, p. 118). But the rapid growth of motor vehicles in the 1960s, after Germany's economy recovered, spurred traffic congestion in the city centre. This led to the urgent promotion of public transport in the mid-1960s. In order to accelerate the development of urban pedestrian areas and to build a pedestrian network, two prerequisites for urban transport planning were formulated: concentrate the structure of rail-based public transport in the city centre and build a *City Ring* around the city centre (Durth, 1990, p. 30). By the 1970s, pedestrian zones had established themself as an urban design priority and pedestrianisation was combined with public transport planning. After the 1990s, the German pedestrian area developed significantly. The concept, scope and function of the pedestrian area in the city centre was extended to the whole city. In fact, as early as 1979, architect Klaus Uhlig introduced the new concepts of "pedestrian-friendly city" [*Fußgängerfreundliche Stadt*] and "human city" [*Menschliche Stadt*] (Uhlig, 1979, p. 7).

Two of the spaces presented in this dissertation underwent infrastructural changes to better accommodate pedestrians and public transport and reduce car traffic in the 1970s: Frankfurt am Main's Hauptwache and Darmstadt's Luisenplatz.

Public transport: rail-based local transport planning
In the post-war discussion on urban development in Germany, the theme of "urbanity through density" was taken into account in 1960. The rapid rise of private vehicles and the possibility of overcoming greater distances accelerated the separation of housing, employment, commerce, amenities and public services, so the development of new public transport –the establishment of the network system of public transport– were considered important strategies of urban reconstruction, as mentioned before.

The improvement of accessibility into and from the city centre created the necessary conditions for the expansion of the pedestrian zone. In addition to the direct positive effects (traffic relief, inner city revitalisation, commerce's turnover development), the construction of the railways also had longer-term secondary effects: rental value around implemented stations increased (Felz, 1988, p. 205).

This review serves to better understand the origin today's European cities' patchworked urban fabric that support different models and variations of land use and the different types of circulation areas defined both by mode of transport and distinctive mobility networks. We have learned about the spatial characteristics and origins of the so-called the *pedestrian*, *transit* and *automobile urban fabric*; the integration or segmentation of open space that each type of fabric supports, separating active mobility routes from motorised and rail-based routes.

3.2. Rethinking urban mobility

Mobility is an indispensable foundation of our economic, social and cultural activities. Rapid urbanisation, densification, pollution and time lost in traffic demand changes in the way we plan an envision urban mobility. And while it is known that new and improved mobility infrastructure and services must be offered, we confront the spatial limitations within cities. Sustainable urban development —entailing design, planning and policies— aims to prevent a spatially and socially fragmented city, and ideally assures access to a well-interconnected mobility system and a variety of open spaces where urban dwellers and visitors can move and meet freely and with low ecological impact. Cities worldwide are pushing back motorised private transport as the primary mode of transportation in order to promote public transport use and are receiving support from national and international governance to do so. These different measures therefore not only aim to target to strengthen sustainable urban mobility (SUM) but also counterbalance the negative impacts growing motorised traffic may have on people and the environment (e.g., emissions and pollution, traffic accidents, noise, and sealing of natural open spaces, amongst others.).
This section presents the planning concepts sustainable urban mobility (SUM) and its implementation tool: sustainable urban mobility planning (SUMP) and transit-oriented development (TOD) and discusses how they fit in the context of sustainable urban development. The following results are based on a systematic literature review (see pp. A-83).

3.2.1. Sustainable urban mobility

One of the first concepts for sustainable urban mobility and its application was delivered by the OECD. Based on an international project initiated in 1994, Environmentally Sustainable Transport (EST) was further defined as one that throughout its full life-cycle operation, allowing accepted objectives for health and environmental quality to be met, is consistent with ecosystem integrity, and doesn't result in worsening of adverse global phenomena (OECD 2000, p. 35). This revised EST definition - while comprehensive in relation to human and ecosystem health - did not include other important social and economic criteria of sustainable development.

Years later, the OECD's concept was complemented and a sustainable transport system was defined as one that "contributes positively to the economic and social state without prejudicing human health and the environment. Integrating the social, economic and environmental dimensions, it can be defined as that which

- permits the satisfaction of the basic necessities of access and mobility of people, companies and society, of a form compatible with human health and the equilibrium of the ecosystem, promoting intra and inter-generational equality;
- has acceptable costs, functions efficiently, offers the possibility to choose transport modes and supports a dynamic economy and regional development;
- limits emissions and residues in function of the earth's capacity to absorb them, utilises renewable resources at a rate below or equal to their regeneration, utilises non-renewable resources at a rate below or equal to the development of renewable substitutes and reduces land use and sound emissions to the minimum level possible."

(Mourelo, 2002, as cited in Miranda & Silva, 2012).

In her dissertation, Miramontes Villareal (2018) points out that the concept of sustainable mobility is used both as a goal in itself, or a as tool to achieve a higher goal (ibid, p. 17). One of the most relevant implementation tools is sustainable urban mobility planning.

SUMP as an implementation tool

In a planning context sustainable urban mobility is promoted through sustainable urban mobility planning (SUMP). This is a central concept in the European Commission's mobility transition efforts and funding measures. It provides the basis for collaboration across different policy areas, disciplines, and levels of government, and emphasizes collaboration with citizens.

Wefering et al (2014) define SUMP a strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. It builds on existing planning practices and takes due consideration of integration, participation, and evaluation principles.

The authors state that the basic characteristics of a SUMP are that they are long-term vision and clear implementation plans with a participatory approach that balances and integrates the development of all transport modes with consideration of external costs for all transport modes. As such, it must deliver assessments of current and future performance as well as undergo regular monitoring, review and reporting (ibid, p.8).

According to the authors, benefits of this type of planning are:

Improving quality of life. There is strong evidence that sustainable urban mobility planning raises the quality of life in an urban area through attractive public spaces, improved road safety, better health, and less air and noise pollution.

Saving costs – Creating economic benefits. A healthier environment and reduced congestion help to substantially reduce costs to the local community and attract new businesses. In the global and national competition of urban centres, a well organised and sustainable city is also a more attractive city for investors.

Contributing to better health and environment. More sustainable mobility directly translates into better air quality and less noise. Travelling more actively (by walking and *cycling more often) is good for citizens' health. For a city it clearly pays off to invest in less noise and better air quality in the medium to long term. Cities need to play their part in reducing greenhouse gases in the transport sector. Sustainable urban mobility planning is a core element of any climate policy.*

Making mobility seamless and improving access. Sustainable urban mobility planning is an excellent tool to create multi-modal door-to-door transport solutions. Bringing different actors together ensures that particular access needs of citizens and businesses are effectively provided for.

Making more effective use of limited resource. Sustainable urban mobility planning changes the focus from road-based infrastructure to a balanced mix of measures including lower cost mobility management measures. Adopting the polluter-pays principle also introduces an additional revenue stream which can be used to finance alternatives to car use.

Winning public support. Involvement of stakeholders and citizens is a basic principle of a Sustainable Urban Mobility Plan, which reduces the risk of opposition to the implementation of ambitious policies.

Preparing better plans. An integrated and interdisciplinary approach to planning (with different departments bringing in their expertise) helps to put a mobility plan on a broader basis. It ensures that the plan fosters a balanced development of all relevant transport modes, while encouraging a shift towards more sustainable modes.

Fulfilling legal obligations effectively. Cities have to meet many, sometimes competing legal requirements. The legal obligations for air quality improvement and noise abatement are only two examples of a range of national and European regulations. A Sustainable Urban Mobility Plan offers an effective way to respond through one comprehensive strategy.

Using synergies, increasing relevance. A Sustainable Urban Mobility Plan inspires a collaborative planning culture across different policy areas and sectors and between different governance levels within the "functioning city". This cooperative planning culture supports the finding of solutions that reflect the connected nature of urban mobility.

Moving towards a new mobility culture. The outcome of continued sustainable urban mobility planning is a common vision of a new mobility culture, that is agreed by the major political groups and shared by the institutions and citizens of an urban society.

(Ibid, pp. 11-12)

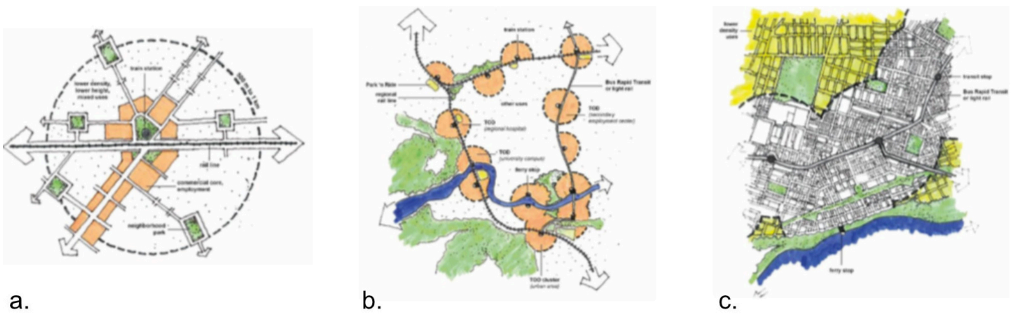
Practical and institutional implications

The institutional framework for sustainable urban mobility in Germany fits within the international framework of the UN sustainable development goals (SDG), which is translated to national and city levels. SDG 11 " Make cities and human settlements inclusive, safe, resilient and sustainable " and in particular target 11.2: "provide access to safe, affordable, accessible and sustainable transport systems for all by 2030 and improve road safety, especially by expanding public transport, with special attention to the needs of people in precarious situations, women, children, people with disabilities and older people" are crucial for sustainable mobility. Here, the indicator is based on the proportion of the population that has convenient access to public transport. The social and economic component of accessibility is taken in to account.

At a national level, the German Sustainability Strategy, the relevant indicator for (urban) mobility is to reduce transport's land use and final energy consumption. The latter should reduce 15-20% by 2030
—based on data from 2005. Furthermore, it strives a reduction in travel time by public transport as well as a drastic reduction of greenhouse gas emissions of 80-95% by 2050 —based on emissions from 1990 (Bundesministerium für Bildung und Forschung, 2018).
These indicators translate to the necessity of spatial conditions that 1) allow easy and close access within a dense and mixed urban structure (Miramontes Villarreal, op. cit.) to an inclusive mobility, making it useful for users with different needs, preferences and possibilities; and 2) allow a reduction of vehicle ownership by offering high-quality public transport supply and infrastructure for cycling and walking that in sum provide more efficient alternatives for mobility than private cars, which require by far more space and energy for every passenger kilometre travelled than any other mode of transport (Newman & Kenworthy, 2015).

3.2.2. Transit-oriented development

Transit-oriented development (TOD) is an urban planning and design strategy to create compact, mixed-use, pedestrian- and bicycle-friendly urban environments. The process focuses on locating amenities, employment, commerce, housing and public services near existing or new public transport nodes served by frequent, high-quality and efficient mobility services. This location aims to support higher usage of public transportation. These districts or corridors should enable people of all ages, backgrounds and incomes abundant efficient and healthy mobility options and thereby access to local and citywide opportunities and resources at the lowest financial and environmental cost and with the highest resilience to disruptive events (Carlton, 2007; Cervero et al., 2002; ITDP, 2013; Salat & Ollivier, 2020; Stojanovski, 2020).



a. b. c.

Figure 8. Main types, characteristics and design of TOD.
Source: Pojani & Stead (2018, p. 4)

The term, coined in the USA in the 1990s by architect and urban planner Peter Calthrope, has generated high interest in Europe over the last decade (Bertolini et al., 2012). It was firstly introduced as the design or development of moderate- or high-density mixed-use urbanisation at strategic points along a regional public transportation system (Calthorpe, 1993). But, as Knowles (2012) and Pojani & Stead (2018) have pointed out, TOD is based on the much older ideas of rail-based urban development that took place in many European cities during the 19th and 20th centuries, as dealt with in the previous section. Nevertheless, it is frequently assumed to be a recent American import and a reaction to the consequences of mass motorisation and sprawl. Albeit, this modern reincarnation of TOD is more focused on urban aesthetics, as Pojani & Stead (op. cit.) and Salat & Ollivier (2020) have pointed out, urban density, mixed land use, high-quality walking environments and access to public transport are nevertheless its core components (Cervero et al, 2002; Stojanovski et al, 2014).

Based on the existent literature, TOD comprises the following components.

Component	Description
Walkability	TOD prioritises pedestrians by striving to improve walkability with short, safe and varied routes. Walking distances are shorter than for motorised vehicles.
Public transport network	High quality public transit accessible by pedestrians. Train station is the focal point, accompanied by a public square.
Non-motorised transport network	Bicycles and scooters with ample and adequate parking facilities within or nearby transit stations and bikeshare rental systems.
Connectivity	Well-connected street network with short distances and multiple routes
Mixed land use	TOD focuses on creating neighbourhoods that are diverse in land use, income and demographics. Retail services including cafes, grocery stores, etc.
High density	To match transit capacity, TOD encompasses optimised density with residences, employment and amenities available within 10-minute walk circle around the train station.
Compact	Emphasis on neighbourhood scale with adequate planning and strategies to evoke a sense of community to avoid the feeling of congestion due to high density and mixed use.

Table 4. Components of TOD based on literature review (ITDP, 2013; Ministry of Housing & Urban Affairs, 2017; Transit Oriented Development Institute).

According to Pojani & Stead (op. cit.), there are three types of TOD, see Figure 8.
The first type, single-node TOD, refers to a single neighbourhood based around a rail station. The district may be in an urban or suburban location and is developed in a circular patter around the station with an optimal radius of 0.5 km, which is internationally regarded as the easily walkable distance to a station (fig. 8a).
The second, the multi-node TOD is characterised by a regional network of nodes around heavy railway stations in an urban or suburban location. Here, the existing nodes are complementary

and may be specialized by land use or services (e.g., higher education or health care node, etc.). The spatial distribution of this type is a comprehensive network of nodes that serve adjacent areas and develop in circular or semi-circular patterns (fig. 8b).
Lastly, the corridor TOD is a linear or ribbon-like development based on a rail transit or bus rapid transit stops in an urban location (fig. 8c).

Sustainable development

Li and Lai (2009) have presented a synthesis of the existing definitions of TOD with respect to sustainable development:

References	Definitions and impacts	Sustainable Development		
		Ec	En.	So.
Salvesen (1996)	Development within a specified geographical area around a transit station with a variety of land uses and a multiplicity of landowners.	X		X
Bernick and Cervero (1997)	A compact, mixed-use community, centred around a transit station that, by design, invites residents, workers, and shoppers to drive their cars less and ride mass transit more.	X	X	
Boarnet and Crane (1998)	The practice of developing or intensifying residential land use near rail stations.	X		
Boarnet and Compin (1999)	TOD is consistent with the mixed-use, pedestrian-friendly character.	X		
Maryland Department of Transportation (2000)	A place of relatively higher density that includes a mixture of residential, employment, shopping and civic uses and types located within an easy walk of a bus or rail transit centre.	X	X	
Bae (2002)	A means of reducing automobile dependence, promoting more compact residential development and fostering mixed land uses.	X	X	
Belzer and Aulter (2002)	TOD focuses on desired functional outcomes. Three main outcomes or goals of TOD: location efficiency, choice, and value capture/financial return.	X		X
California Department of Transportation (2002)	Higher density development, located within an easy walk of a major transit stop, with a mix of residential, employment and shopping opportunities without excluding the automobile.	X	X	
Still (2002)	Mixed-use community that encourages people to live near transit services and to decrease their dependence on driving.	X	X	
Cervero et al. (2004)	TOD is a tool for promoting smart growth, leveraging economic development, and catering for shifting housing market demands and lifestyle preferences.	X	X	X
Lund et al. (2004)	The design and mixed-use features of TOD may reduce both work and non-work automobile trips.	X	X	

Ec.: economic efficiency; En.: environmental protection; So.: social equality.
X, representative for TOD definitions relative to one perspective of sustainable development.

Table 5. Definitions and possible impacts of TOD from a sustainable development perspective
Source: Li & Lai (2009, p. 73; references as cited by authors.); with author's alterations.

3.3. New mobilities and mobility stations

In Germany, the BBSR/BBR [Federal Office for Research on Building, Urban Affairs and Spatial Development/Federal Ministry of Transport, Building and Urban Development] pushes this idea forward with the concept *Neue Mobilitätsformen* [new forms of mobility], the use of which should contribute to reduce CO2 emissions in the transport sector (BBSR/BBR, 2015). Next to services such as car sharing, public bike sharing and remote bus terminals, mobility stations — in German *Mobilitätsstationen*— are a new form of mobility identified by the authors.
The authors of the report point out the need for new or modified infrastructures that have to be embedded in the respective urban environment in order to accommodate new forms of mobility and make them attractive and accessible to its users.

This section presents the state of the art of mobility stations and similar concepts that integrate various mobility services, its definitions and descriptions, implementations and some examples of existing stations found through literature research. This is done in order to define the infrastructural and spatial requirements and presumptions made in literature.
It therefore seeks to answers the questions:
What exactly are mobility stations –and the related terms mobile station, mobility hub and mobility point–, what are their distinctive characteristics and what mobility services do the offer?
How do mobility stations support sustainable planning concepts such as SUM and TOD?

The following results are based on a systematic literature review of scientific articles, university master thesis and doctoral dissertation, past systematic literature reviews and reports published (also in university repositories) in (or translated to) English between 2010 and 2020. Open access peer reviewed literature from Europe was prioritized.
The searched terms were mobility stations, mobile stations, mobility points, mobility hubs, and intermodal exchange stations. 27 items were listed based on the abstracts, 13 were relevant. Further literature was searched to supplement information, especially when further describing the implemented examples.

3.3.1. Concepts, guidelines and implemented examples

The following section elaborates on descriptions of concepts, guidelines and implemented examples of stations that promote intermodality.
The terms urban transport interchanges, City-HUB have no examples because the literature that uses these terms deal with and discuss models and conceptual frameworks. Nevertheless, they will be taken into account in the discussion.

Mobility station *[Mobilitätsstation]*

Origin: Germany

According to the BBSR/BBR (2015, p. 6) the central feature of a mobility station is the above-average integration of different means of transport in the respective local context, coupled with a marketing message in favour of ecomobility. Generally, this message is supported by appropriate design measures at the station. The station is designed in such a way that exchanging between the modes of transport is enabled in a simple manner through the spatial concentration.

In general, it is advised in the different concepts and calls for action, that mobility stations must be located near public transport stations whenever possible in order to provide seamless connections between different modes.

The following is a selection of four German examples:

mobil.punkt, Bremen

hvv switchh Punkte, Hamburg

Münchener Freiheit, Munich

Mobilitätsstationen ESWE, Wiesbaden

mobil.punkt, Bremen

The BBSR/BBR (2015, p. 22) identifies the first example of facilities regarded as mobility stations in Germany as the *mobil.punkt*, in the City of Bremen, Germany. The city implemented two stations in 2003 and they have since then been expanding.

These consist of car sharing stations as well as bike parking facilities in public space, which are easily accessible by bus, train, bicycle or on foot and are clearly marked with a stele[6].

> *"Beyond the spatial concentration of various transport modes at the mobil.punkte, public transport subscribers in Bremen also receive preferential rates for carsharing (BSAG, 2018 [as cited in Miramontes Villareal, 2018]), and there is an integrated marketing and information for these two mobility services."*

(Miramontes Villareal, 2018, p. 44).

Figure 9. Mobility stations in Bremen: the mobil.punkt station with its characteristic blue stele, car sharing and bicycle parking area next to a bus stop and near a tram station.
Source: City of Bremen – Senat für für Klimaschutz, Umwelt, Mobilität, Stadtentwicklung und Wohnungsbau

Figure 10. mobil.punkt without public transport.
Source: Architekturbüro Ulrich Ruwe (http://www.architektruwe.de/7.html)

[6] https://mobilpunkt-bremen.de/mobil-punkte/ (accessed on 13.11.2020)

hvv switchh Punkte, Hamburg

A further well-known example is Hamburg's *hvv switchh Punkte*, which were first implemented in 2013 in station the Berliner Tor.

In general, the stations are planned next to public transport stops as a designated area where supplementary mobility offers are available, such as reserved parking spaces for car sharing and rental cars, bike parking facilities including a bike garage, a bike sharing docking station, a taxi stand, a charging point, and a customer service centre, as in the Berliner Tor (Table 14). The *switchh* stations are distinguished by a stele and green-coloured parking spaces reserved for car sharing vehicles, which make these facilities highly visible.

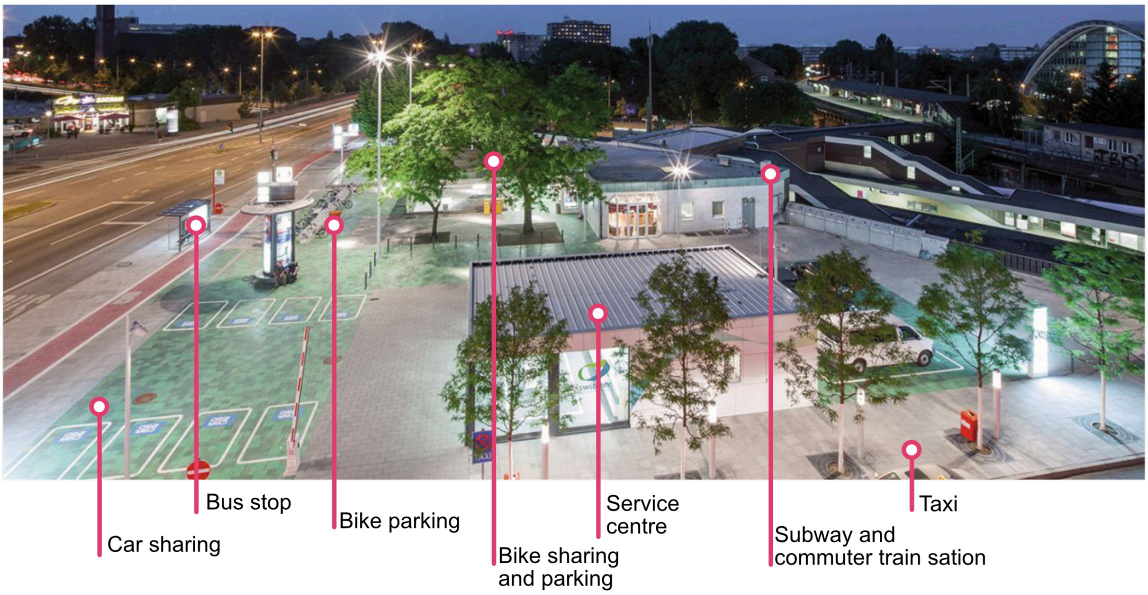


Figure 11. hvv switchh point at the public transport station "Berliner Tor"
Source: METTEN Stein+Design GmbH & Co. KG. (https://www.metten.de); with author's additions

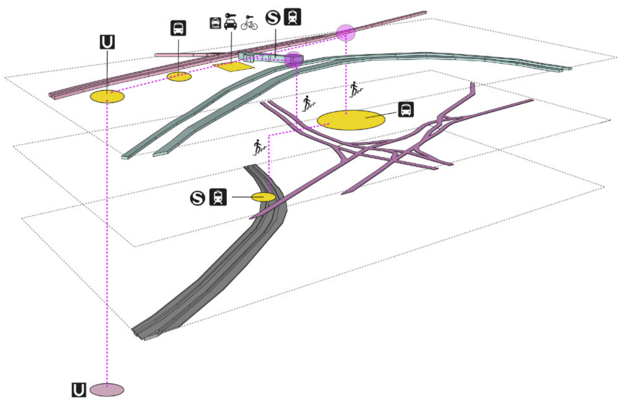


Figure 12. Spatial distribution of the different services at different levels.
Source: Cakmak, E., Nasser, K., Vegerenko, O. (2018)

Figure 13. hvv switchh point with car sharing in front of the subway station.
Source: Hamburger Hochbahn AG

Münchener Freiheit, Munich

A year later, in 2014, the mobility station *Münchner Freiheit* was implemented. This example is a pilot project by the City of Munich and the public transport operator in the city (MVG) to connect public transport and new shared mobility services. The project's goal is to provide diverse mobility services suitable for every trip purpose, so that owning a car becomes unnecessary (MVG, 2015; Miramontes et al., 2017). It bundles the services of the subway, bus, tram, taxi, bicycle parking facilities, car parking.

The services are situated along the street and on each side. There is a bigger concentration to the east side, where there are parking bays (waiting areas) for taxis, the bus and tram station with a roof as a connecting element, and the ca sharing parking spots to the north. There are designated cycle lanes on both sides. Its course is adapted to the position of the other services and grants easy access to a parking area near each one of them.

The station has its name thanks to the square located to the north, and at a lower level, where there is an outdoor seating area from a café and the main entrance to the subway station. The square host a Christmas market in winter.

As in the previous examples, there is an information pillar (stele).

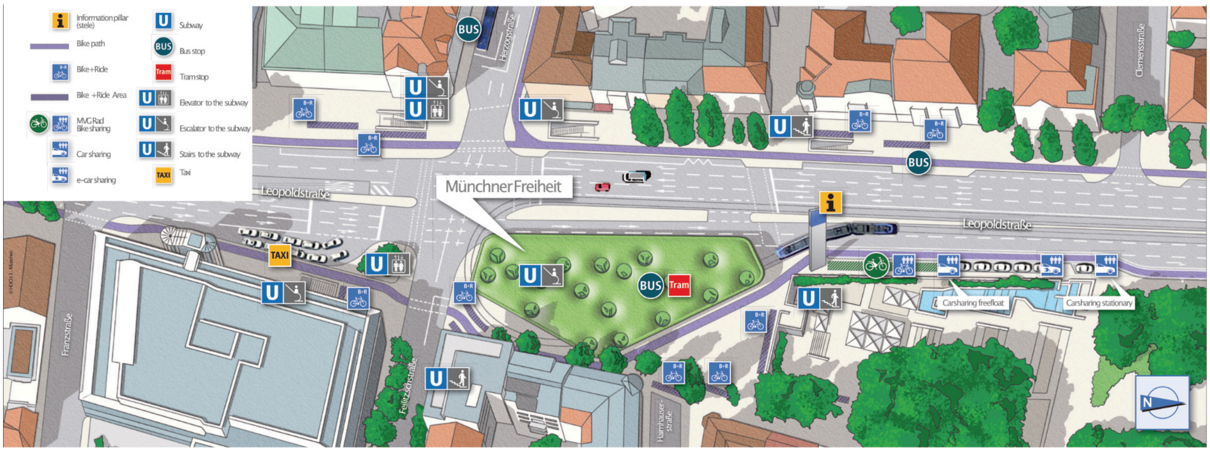


Figure 14. The mobility station at Münchner Freiheit and its surroundings.
Source: MVG (2015); with author's alterations

Mobilitätsstationen ESWE, Wiesbaden

Together with the city of Wiesbaden, the local public transport organisation ESWE designated in 2018 the first ten bus stops as mobility stations. With this new vision for the stations, ESWE and the city aim to improve public transport by offering more options for people to come in and move around the city, and see take a step towards digitalisation of public transport. The first is achieved by bundling city, regional and night bus lines (thereby increasing frequency) in selected stations, offering ESWE bicycle rental system "meinRad", a municipal Park+Ride facility, ticket sales and an electronic dynamic passenger information system. Some stations serve train stations, where a connection to commuter and regional trains is offered. The second through the development of an application that allows users to book and combine all the services.

Additionally, the city strives to make improvements in cycle lanes that lead towards the stations, designated bus lanes to avoid traffic jams, and increasing capacity in Park+Ride facilities where possible[7].

The city of Wiesbaden only has a bus-based public transport system.

In this case, the designation serves as a framework to identify needed adjustments in the infrastructure and how the services interlock.

One example, the Luisenplatz, is analysed on part II of the dissertation.

[7] http://www.wiesbadenaktuell.de/startseite/news-detail-view/article/mehr-als-park-ride-wichtige-wiesbadener-bushaltestellen-werden-zu-mobilitaetsstationen.html (accessed on 24.04.2020)

Mobile Station

Origin: Germany

This is a concept presented by the Zukunftsnetz Mobilität NRW[8].
In their handbook, mobile stations are the spatial bundling of different sustainable mobility services (Figure 15) and an element that serve as "visible connection points and interfaces of ecomobility with systemic integration of several modes of transport in direct spatial connection" (Netzwerk Verkehrssicheres NRW, 2014, as cited in Zukunftsnetz Mobilität NRW, 2015, p. 1-3).
The authors set four basic tasks a mobile station should aim for in their handbook. Next to (1) linking mobility services –the basis of the station–, it should (2) be part of a communication and marketing strategy, (3) offer information and services, and (4) be a meeting point or recreation area.
This is the first mention in the presented examples of the importance that the space has as something other than a station. "An appropriate compromise between prominence and blending into the surroundings should ensure urban integration" (ibid, p. 10). Still, the design suggestions are limited to proposals for possible information elements (stele) at mobility stations and single stations (Figure 16).

The authors suggest that because of their innovative concept, the stations have the potential to take on strategic and transport policy tasks. For example, a mobile station can reflect an innovative approach to the promotion of public transport, but also be established as a model location for e-mobility. Depending on the specific type of location (inner city district, main station of a large city, station of a small town, commercial area, etc.), the public transport system forms the backbone of a mobility stations (Zukunftsnetz Mobilität NRW, 2015, p.8).

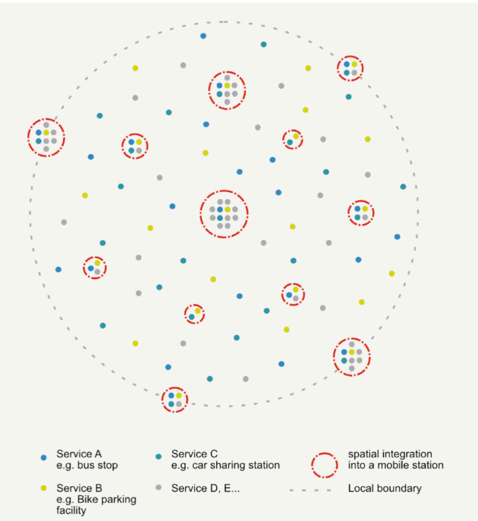


Figure 15. Spatial interaction of mobility stations and single stations.
Source: NRW (2915); with author's alterations

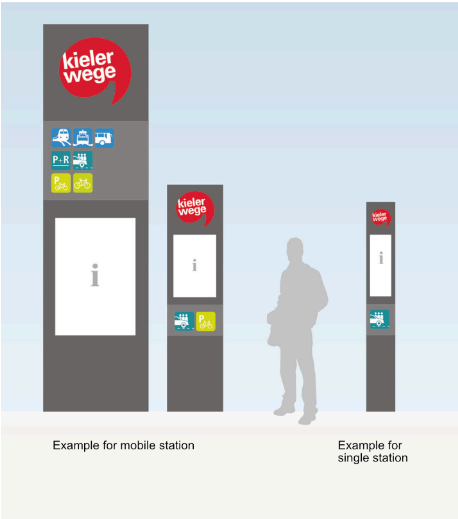


Figure 16. Proposal for possible information elements (stele) at mobility stations and single stations.
Source: NRW (2915); with author's alterations

[8] A municipal support network funded by the Ministry of Transport of the State of North Rhine-Westphalia, partners and transport associations. It supports and advices municipalities in establishing a mobility management system. Accordingly, it doesn't implement stations; it analyses existing approaches and makes recommendations.

Mobility point

Origin: Austria

tim-Standorte, Graz

tim-Standorte are centralised mobility hotspots in Graz that offer (e-)car sharing and public charging points for private electric cars, rental cars, tim e-taxis, bicycle parking facilities, and bike sharing. They are easily accessible by public transport or bicycle.
The concept is modular. A station can have just one or several of the components mentioned before. The corporate design includes, additionally to the information stele, the vehicles have the logo, see below.

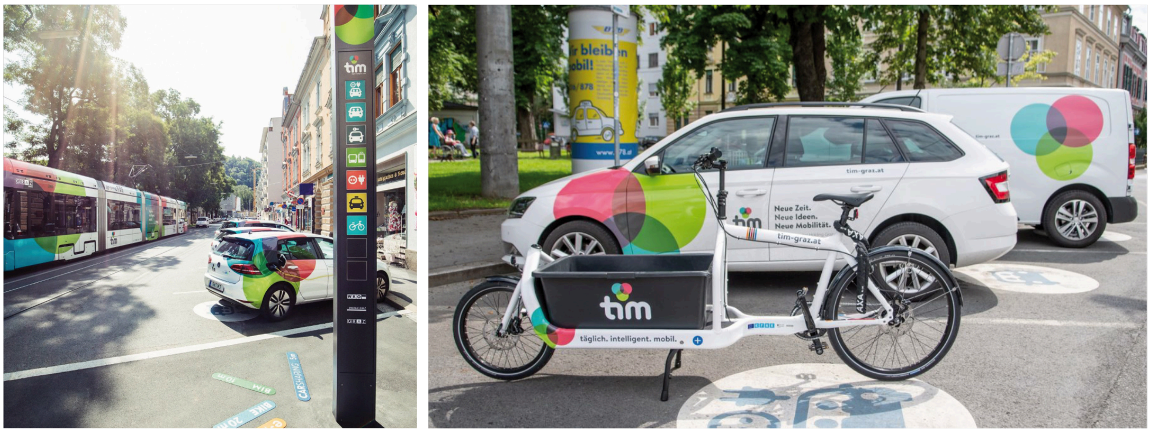


Figure 17. A tim-Standot near public transport and a station with different types of sharing vehicles.
Source: © achtzigzehn/Hinterleitner (https://www.holding-graz.at)

MO.Point

Similar to the German concepts of mobility stations, a mobility point is focused and sharing services

> *"MO.Point plans and operates low-emission vehicle pools and additional services [...]. Residents and neighbors can rent various environmentally friendly vehicles, such as e-bikes, e-cargo bikes, e-scooters or electric cars, and use additional accessories, right on their doorstep. The vehicles can be booked easily and flexibly via an app or website."*[9]

The exclusive feature of this concept is that it isn't dependent on public transport nor public investment. Private developers can choose to plan a MO.Point within their premises.

[9] https://www.mopoint.at/about-mopoint/?lang=en (accessed on 24.04.2020)

Mobility hub

Origin: Canada (North America) and Europe

Despite not being the sole proponent of the concept, the Canadian authorities engaged in this example, did elaborate both a concept and a development plan and guidelines, defining what a mobility hub is and how it should work and be designed. It is an exercises in Smart Growth and Transit Oriented Development policy in North America by which "[...] integrating economic growth targets and environmental protection measures with land-use planning [...]" (Keenan, 2013, p.10).

The development plan has its starting point at identifying areas that can by densified, in order to counteract sprawl, and thereby need a mobility hub. "Mobility Hubs are particular nodes in the transit network that connect multiple modes and lines of transit. The term "Hub" refers to their surrounding area, not just the transit station or junction itself." (Keenan, 2012, p.11). The term hub refers to an area encompassed in, at least, a one-kilometre radius (see Figure 18). It looks at *the primary zone* in a 250 m radius or 2,5 min walk, the *secondary zone* in a 500 m radius or 5 min walk, the *tertiary zone* in an 800 m radius or 10 min walk, and the *catchment area* of up to 6km or a 10.15 min drive.

In the proposed plan, two categories are presented: gateway hubs of local importance, anchor hubs of regional importance. Gateway Hubs are defined as important points in the network where at least two lines or modes of transit meet (or are planned to meet). In addition, this list includes points in the network that are close to a particularly interesting or popular site, or nodes that have great potential for development (Metrolinx, 2008, pg. 85, as cited in ibid, p.11).

In their guidelines, mobility hubs are defined as places "[...] where transportation modes, including rapid transit, local transit, specialized transit, cycling and accessible pedestrian networks come together seamlessly. Mobility hubs are locations for major destinations such as offices, hospitals, educational facilities and government services. They offer amenities to travellers such as heated waiting areas, traveller information centres, cafés or restaurants, and services like day cares, grocery stores or post offices." (Metrolinx, 2011, p.2)

The guidelines are structured around three goals: (1) ensuring *seamless mobility* for all modes (walking, cycling, public transit, private vehicles through parking), (2) *placemaking* through a mixed-use environment and attractive public realm, and (3) *successful implementation* of the guidelines themselves, which include a number of planning tools and suggestions.

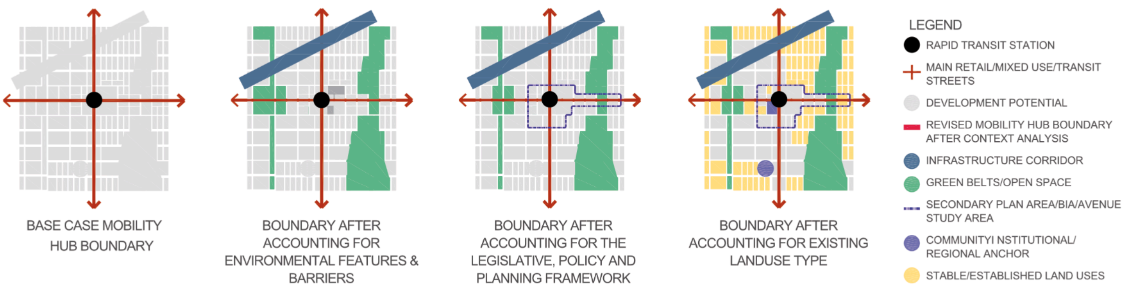


Figure 18. Considerations for Defining the Mobility Hub Planning Area.
Source: Metrolinx, 2011, p. 10

3.3.2. Mobility stations and sustainability

Conceptual model: Exchange nodes / intermodal hubs

Amoroso et al. (2012) name (but do not thoroughly describe) "a place where transportation networks are organized to facilitate intermodality" as *exchange nodes* or *intermodal hubs* (among others) throughout their paper. Independent of the term used, the authors offer a function-based model of what exchange nodes should integrate: transport, urban and service functions (Figure 19). An exchange node can therefore be "an element that 'creates urbanity' and […] the interface between the transport (and people) networks and urban territory (ibid, p. 962).

The authors see the potential contribution to sustainable mobility by promoting multimodal mobility and therefore decreasing the use of private transport means, which has had significant repercussions on environmental sustainability.

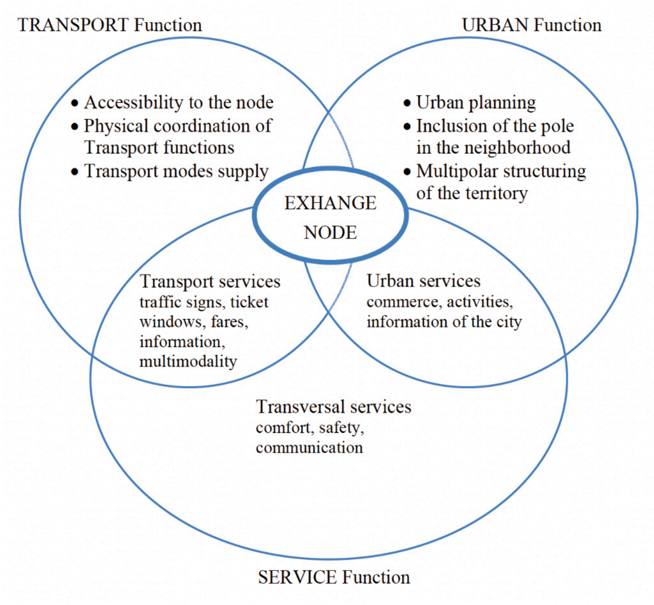


Figure 19. Three functions of an exchange node.
source: (Amoroso et al., 2012, p. 963)

Within the urban function, the node serves both at a local (e.g., neighbourhood) and a global level (e.g., regional territory). This notion of the interconnection between a node and its network is illustrated through the "spatial translation of intermodality" which is expressed in terms of spatial pathways. "Each [one] of the main transport modes (private car, collective urban transport, taxis, trains, pedestrians) has a spatial location, which may suffer of conflict zones in its performance" (ibid, p. 960).

The researchers state that it is, therefore, essential to study the pathways of the different categories of involved users. As an example, they refer to pedestrian movement, which is characterised by unpredictable behaviour and multiple generator points such as bus stops, subways stairs, entrances to buildings and so on.

CITY-Hub project

Monzón et al. (2016) present their study about efficient urban interchanges, where they interviewed practitioners in 26 selected interchanges in 9 European countries. The approach is based on understanding key factors for increasing public and sustainable transport trips through improving intermodality. For this, different perspectives are included: social, urban, administrative and governmental, and technological. Efficient use of space is considered essential within the urban component.

The model, City-HUB, emerged from the need of planning interchanges as "key element of the transport system which provides clear added value for travellers" (ibid, p.1132). One way of doing so is by integrating further services so users can expand their trip-planning by adding "multi-activity patterns" (ibid, p.1126)
In order to make it attractive for users and achieve efficiency, the authors conclude that *urban transport interchanges* must both be a 'transport node' and a 'place' (see Figure 20). This is achieved by integrating services and creating a pleasant space within a safe and secure framework. The authors afford interchanges with a social role and state that they therefore support transport sustainability.

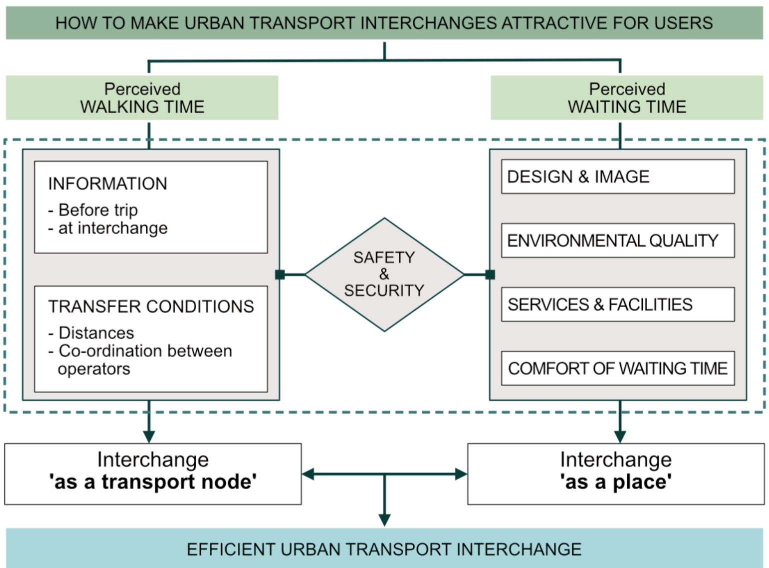


Figure 20. Key factors identified to make urban transport interchanges attractive for users
Source: based on Hernandez and Monzón, 2015, as cited in Monzón et. al. (2016, p. 1132)

Assessments of mobility stations in Germany

The first example of an assessment of implemented mobility stations in Germany is based on an online survey conducted among users and non-users of Offenburg's mobility stations *Einfach mobil* to evaluate users' perception and acceptance of the stations and their potential to change mobility behaviours (Heller, 2016). The second evaluates, through a similar online survey of users and non-users, perceptions, awareness, and effects on travel behaviour, car ownership, and CO2 emissions in Würzburg's *Mobilstationen* (Pfertner, 2017). The third study assesses success factors and contributions to sustainable urban mobility in *Münchener Freiheit*, Munich. This was achieved through a comprehensive evaluation consisting of stakeholder interviews, user survey, non-user survey, focus groups and analysis of operational data (Miramontes et al., 2017).

The three studies were then compared and grouped into three categories: awareness, acceptance, and potential effects on mobility behaviour (Miramontes et al., 2019). In the following section, I will present the here highlighted results and a related work.

Both evaluated stations, which weren't presented before, share similar organisation and services as *mobil.punkt* in Bremen or *tim-Standorte* in Graz.

Components Offenburg

- Car sharing
- Bike sharing
- Facilities for private bike parking
- Electric vehicles
- Electric car sharing and charging facilities
- In station "Messe": three pedelecs, coach bus services
- Proximity to public transport

Heller (2016)

Components Würzburg

- Car sharing
- Bike sharing
- Proximity to tram stop
- Facilities for private bike parking

(Pfertner, 2017)

The following are the results provided by the comparative study.

Awareness. The authors state that visibility in public space, generated through information pillars (steles), coloured parking spots, etc., are essential in gain users' attention.
From these measures, the stele seemed to be the best measure to raise awareness from a higher share of users passing by (Table 6).

Acceptance. Mobility stations seem to be well accepted in all three cities amongst their users.
In Offenburg, 59% of users would like to have more mobility stations, 28% do not know and 15% do not want more mobility stations.
In Würzburg, 73% would like to have more and the rest is against more mobility stations (the option "I don't know" was not given to respondents in Würzburg).
In Munich, 68% of users would like to have more mobility stations, 28% don't know and 4% do not want more mobility stations.
(Ibid, pp. 804-805)

	Offenburg	Würzburg	Munich
Sources of awareness	Users aware through this source (%)		
Passing by	41	56	53
Information Pillar	n.a.	52	20
Advertisement	18	42	24
Media	35	13	5
Friends	23	11	14
Smartphone	0	22	24
Others	32	32	6

Table 6. Percentage of users that became aware of mobility stations.
Source: (Miramontes et. al., 2017, p. 804)

Effects on mobility behaviour. Here, uses agreed with the proposed statements related to the influence the mobility station has had on their mobility behaviour (see Table 7).

City	Offenburg	Würzburg	Munich
	Users that agree* to the statement (%)		
I became customer of [shared mobility service] because the Mobility Stations made me aware of the offer	26	59	12,3
Since I use the Mobility Station(s) I use [carsharing service] more often	36	74	29,1
Since I use the Mobility Station(s) I use public transport mode often	14	23	23,9
Since I use the Mobility Station(s) I use [bikesharing service] more often	9	12	56,1
Thanks to the Mobility Station(s) I can always be sure to have an appropriate transport mode available	67	73	78,6
New mobility offers like the Mobility Stations contribute to making the own car unnecessary	86	83	76,9
	*sum of "completely agree" and "agree"		

Table 7. Effects of mobility stations on mobility behaviour and attitudes
Source: (ibid, p. 805)

The authors highlight the impact that mobility stations had in Würzburg. The supply of car sharing vehicles increased significantly, since 9 stations were set up at once. The increased supply was met with increased use of this service: 59% of the surveyed users became aware and actively use the service because of the stations. 74% agreed that the use the services more often since they starting using the stations. These are contrasting numbers to Offenburg and Munich.

At a high degree, users agreed mobility stations allow them to use the mode of transport they need; and even to a higher degree that the services offered in mobility stations can contribute to making car ownership unnecessary.

Shared mobility services should generally complement public transport instead of replacing it. Thus, it is an important finding that there are also respondents that indicate that they have increased their public transport use with the implementation of the stations.

In her dissertation, Miramontes Villareal formulated a framework for the evaluation of three mobility stations presented above with regards to whether they do contribute to the goal of sustainable urban mobility. The assessment method proposes two criteria and six sub criteria, based on previous evaluations and literature review.

Criteria	Sub-criteria
Fulfilment of needs	Access to opportunities
	Access to mobility options
Consumption of resources	Space consumption
	Energy consumption
	Time consumption
	Money consumption

Table 8. Criteria and sub-criteria assessed by Miramontes Villareal, 2018.
Source: ibid, p. 258

She concludes that, it is not possible to derive definitive conclusions about the contributions mobility stations make to sustainable urban mobility with the results of the corresponding evaluations, but can rather points towards the *potential contributions* to SUM.

She ventures to do so since the assessment of the six criteria indicate that mobility stations *can* positively influence SUM by providing and facilitating access to opportunities and mobility services, and by reducing users' resource consumption by providing alternatives to private cars and further faster mobility options than public transport depending on the purpose of a trip (ibid, p. 269).

In order to potentialize these possible contributions she provides further arguments that need to be taken into account when assessing through the delivered framework of criteria. I summarise:

Fulfilment of needs. Mobility stations bear great potential when it comes to offering diverse opportunities to users, both mobility services as well as other services and amenities. By offering further options, unnecessary trips could be avoided and thereby the associated consumption of resources, e.g.

Furthermore, mobility stations cover needs prompted by diverse purposes (reason for traveling). "Since mobility is considered to be a need in itself, access to mobility options also contributes to satisfy the need of mobility 'for the sake of mobility'" (ibid, p. 270).

Consumption of resources. This is tied to the changes in mobility behaviours: "[t]he results indicate that mobility stations in general can contribute to reducing car ownership, especially when carsharing services are available. This in turn, can be translated to a reduction of total vehicle kilometers traveled among users, and thus, in a reduction in space and energy consumption in the long term."

It also opens up the possibilities for users to choose the most efficient and comfortable travel mode or a combination of various modes for the purposes of their trips. The author points out that "efficiency and comfort" may subjective, they may be in conflict for one mode, and that there is no one mode that can supply both for all trips, it is situational.

> *"Under the right circumstances, mobility stations can reduce both car ownership and car usage, thus reducing the consumption of space and energy for mobility. In addition, other aspects affecting the consumption of these resources such as an increase in vehicle occupancy, vehicle energy efficiency, and carsharing turnover, can be positively influenced by mobility stations".*

(Ibid, p. 271)

And while she does see the possible positive effects, she warns about the risk of having the opposite effect: disadvantaging public transport and active mode by supporting the use of the less space and energy efficient modes for certain trips. I.e., "[…] public transport users and cyclists could replace their usual modes for a given trip and travel alone in a carsharing vehicle" (ibid, p. 271).

3.3.3. Summary

Based on the definitions and examples presented above, mobility/mobile stations, mobility point/hub are transport nodes where various mobility services are spatially bundled. These aim to enable multi- and intermodality and integrate public transport at different degrees. While some concepts consider the spatial proximity and access to public transport as an optional component, the majority either emphasise on the importance of the integration of public transport as the backbone of a mobility station or implemented near/within a public transport station. mobil.punkt, hvv switch stations, tim-Standorte and MO.point focus primarily on sharing services. Still, all but one (MO.point) are –at different degrees– near a public transport station.

The presented examples have as a commonality they are all inside the city, mostly city centre or nearby. Mobility stations, mobile stations and mobility points are visually distinguishable thanks to the stele and further corporate design elements such as colourful pavement or painted vehicles.

Some models work with an integrating smartphone application that may offer multimodal trip planning and mobility packages that work with tariffs other have smart cards to access the services.

Table 9 presents a summary of the physical services found in mobility stations.

One major difference between the concepts that originated in Europe compared to the mobility hub concept that originated in North America, is that these integrate more actively the land use component. This might be due to the fact that the integration of land use and transport is already established (or better established) in Europe than in North America because of the differences in the historical development of the urban fabric.

Mobility service	Description
Public transport	Access to public transport is the backbone of a mobility station. Part of the urban public transport system are: commuter train, subway, tram and bus, among others. For stations that aim to serve at regional level, regional trains and buses can be taken into account.
Cabs and taxis (ride hailing)	As part of the public transport systems, collective cabs offer an on-demand service in stations that aren't operated around the clock. Both collective cabs and taxis can be particularly helpful to ensures accessibility to areas with poor public transport accessibility, even for people without a driver's license.
Ride sharing and ride pooling (Uber, *Mitfahrgelegenheiten*, etc.)	Ride sharing and ride pooling are on-demand services that respectively work on a door-to-door basis or with fixed pick-up points. Mobility stations can provide the latter and be the connection to other modes of transport.
Car sharing	This on-demand service refers to both free-floating and station-based carsharing services. Since sharing concepts are seen as an important complement to public transport, mobility stations (or its immediate surroundings) can provide return and parking opportunities for this service.
Bike sharing	Bikes sharing systems offer fast first- and last-mile connections to (and from) mobility stations as well as direct connections between stations and destinations. They usually can be rented and returned in a variety of points in open space. Just as with car sharing, mobility stations can provide return and parking opportunities.
Cargo bikes	Cargo bike sharing systems are emerging in many cities. They can add benefits for users that need to transport goods or children by reducing the need for a car.
Bike parking	Private bikes are an important access mode to the stations and need high-quality parking facilities. Nice-to-have extra service: bicycle repair stations
Charging point / facility	Charging points for electric vehicles, both cars or bikes. Can be for sharing or private vehicles.
Private car parking	Next to Park+Ride options, short-term parking may be a useful service for ride sharing/pooling users.

Table 9. Components and services of mobility stations and their description according to literature review.

We find several studies about the type of services, how mobility stations should be marketed or branded, but little to nothing about the urban context in which they are, should or could be embedded in. The majority of the found examples seem to be a mere place were to pick up or leave a car / bicycle and take the next available public transport option.

Becoming a place for recreation or leisure is tied to attracting different services such as commerce, administrative, health services and public services, amongst others. This *amenity quality approach* contrasts with the spatial understanding of the European examples, where only few of them offer spaces for users to rest, meet or to carry out other activities. Other than the necessary equipment for information and wayfinding (stele, signs, information office), mobility stations must also be equipped with elements that allow users to be stay and use the space in other manners.

In all three concepts –i.e. Metrolinx's guidelines, Monzón et. al. and Amoroso et. al.– urban space is considered an elemental component of intermodal stations, regardless of their name and location (inner-city, suburban, etc.). I would like to highlight the inclusion of the network of paths to travel to and within the node (railways, streets, sidewalks, cycle lanes, etc.), and the radial zoning of the hub (see Figure 18) as to understand the urban space taken by the station through and beyond the catchment area.
This extends the understanding of the mobility station to the networks that feed it. In order to have a *node*, paths carrying the services and different modes must be able to meet without interfering with each other and with continuity. Equally, a *place* can be only created if objects and services that give meaning to it are placed in this space, which is sufficiently connected to the rest of the network (the city) through the above-mentioned paths.

The presented evaluations make apparent that, although the term sustainability is based on three pillars –socially responsible, ecologically compatible and economically viable–, most of the strategies appointed to sustainable mobility are often targeting the ecological pillar[10]. All three base mobility stations' greatest contribution to reducing the use of cars and therefore of pollution. The two other articles, rather than providing any solid evidence of the stations' contribution to sustainability in any other way, put forward an understanding of creating places where people can carry out other activities while changing modes or just be in, which in turn should rise attractiveness and have some social value.

3.4. Discussion and conclusions

Urban dwellers and visitors are, and historically have been, highly mobile. City form, urban lifestyle, and mobility have influenced each other since their beginnings. As animal traction and motorised vehicles further developed and became common, space was reorganized, and the customs, activities and ways of living in the city changed. Thanks to innovation, policies, activism, and historical events such as wars, urban form and our ways of moving have varied

[10] I suspect that this is a disciplinary focus rather than the actual intention of the studies.

back and forth between spaces that encourage or discourage active mobility, public transport and private motorised traffic.
Both planning concepts (TOD and SUM) share similar objectives: to reduce trips in private motorised vehicles (especially solo-driving), and to promote ecomobility by increasing use and trips in public transport or active mobility. While SUM and SUMP concentrate on the dynamics of the mobility system itself –such as policies, life cycle and functionality, amongst others–, TOD is based on clear spatial requirements and consequences –such as planning around public transport, regulating land use and offering pedestrian and cycling networks.

Mobility stations, as a *new form of mobility,* are envisioned as a way of reducing CO2 emissions in the transport sector (see 0 in page 47) in order to contribute to a more sustainable urban development. In this sense, the presented evaluations elaborate on the effects that (some type of) mobility stations have on the mobility behaviours of three groups of citizens in three different cities. Users' awareness and acceptance of the mobility stations contributed to a change in users' perception of (unnecessary) private car ownership. But the risk of having a different effect, public transport users and active mobility user/practitioner could shift towards car sharing. This points towards broader potential contributions to SUM: preference or balanced provision off certain modes –such as public transport and active mobility–, by increasing their offer, instead of just focusing on car sharing options. Nothing new, but a real necessity.

In the BBSR/BBR report, the provision of car sharing parking spaces is seen as a core element of mobility stations. These are tied to higher spatial requirement than other modes, e.g., bike sharing. The prioritisation of car sharing as a core element proves to be an obstacle to implement more mobility stations, as the authors themselves corroborate (BBSR/BBR, 2015, p. 23).
Although car sharing is a good measure to discourage car ownership or allow users to refrain from using a private car –as seen in some evaluations–, it does require them to have a (valid) driving licence. This automatically excludes certain age groups and users with impairments that do not allow them to have a driving licence. Accordingly, I plead, in favour of *accessibility or all*, that the majority of stations should prioritize access to public transport and sharing concepts that cater a larger user group other than able-bodied and wealthy enough[11].

Under this light, a consequent implication for mobility stations is that the urban context and networks supporting access to, from and into public transport must be taken into account.

[11] Driving licences in Germany have a cost of around 2000 € or more

Part II: Empirical analysis

4. IOS in the Rhine-Main Region

The following chapter presents the study area and the transport association operating within it, the selection process of the case studies, open spaces and chosen parameters. The chapter ends by formulating the more specific and deepened sub-questions according to scale, as presented in chapter 1 and the devised analytical framework. The results will be presented in chapter 5.

4.1. The study area within the Rhine-Main Region and its mobility

4.1.1. The study area

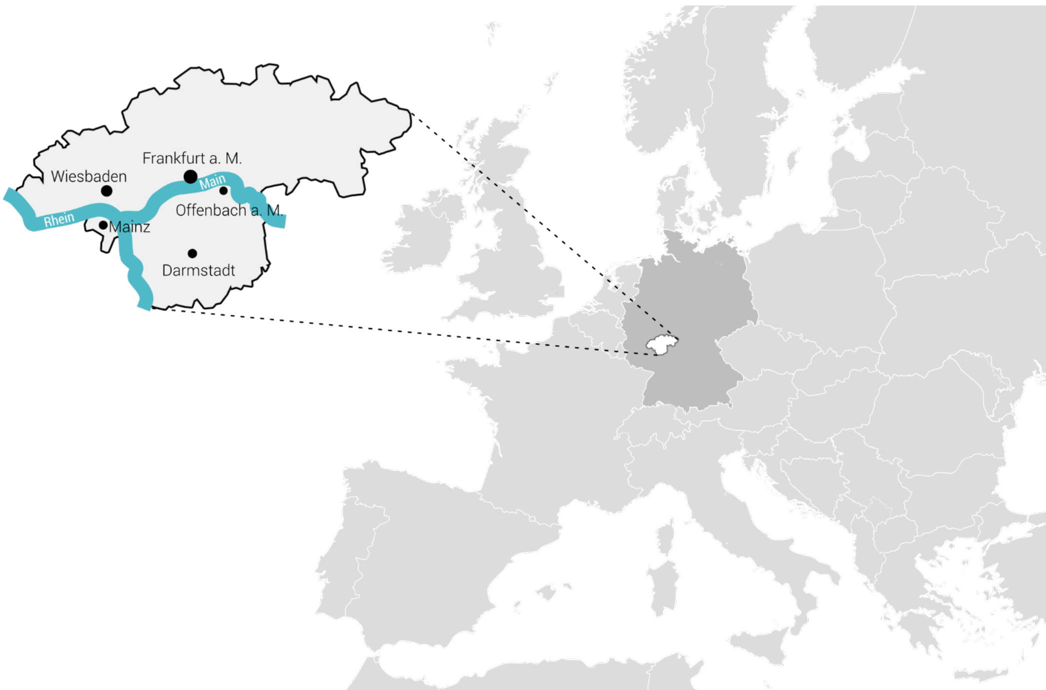


Figure 21. Location of the study area and its 5 large cities along the main rivers.
Source: Own based on TUBS, CC0, via Wikimedia Commons.

The study area is part of the Rhein-Main Metropolitan Region, located in the central-western portion of Germany. It stretches over three German states: Hesse, Rhineland-Palatinate, and Bavaria. The total population of the Metropolitan region is about 5,8 million people[12].
It comprehends the narrower defined "Frankfurt Rhine-Main Metropolitan Area" –which includes the independent cities of Frankfurt and Offenbach am Main and their directly neighbouring districts–, and the independent cities and districts that are shareholders in ivm

[12] https://service.region-frankfurt.de/ia/metropolregion/bevoelkerung/atlas.html (accessed on 15.07.2021)

GmbH, an associated practice partner of the LOEWE research cluster. These are the independent cities of Darmstadt and the two state capitals: Mainz and Wiesbaden and the neighbouring districts of Darmstadt-Dieburg and Rheingau-Taunus-Kreis. The metropolitan area has dense urbanisation of around 2.4 million people.[13]

The independent cities Frankfurt am Main, Darmstadt, and Offenbach am Main, and the state capitals Wiesbaden and Mainz have over 100.000 inhabitants. The International Statistical Institute defines these as large cities ("*grandes villes*") (IIS, 1887, p. 212).
I chose to study stations in these large cities since it is more probable that they offer a higher number of mobility services based on their size alone.
Table 10 shows the number of inhabitants in each city, their density in inhabitant/km^2 and the urban area in km^2.

City	Inhabitants	per km^2	Area in km^2
Frankfurt am Main	753 056	3 033	248.31
Mainz	217 118	2 222	97.73
Darmstadt	159 207	1 304	122.07
Offenbach am Main	128 744	2 869	44.88
Wiesbaden	278 342	1 365	203.87

Table 10. Overview of the cities with over 100.000 inhabitants and density in inhabitants per km^2 [14]

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4.1.2. The transport association: RMV

The Rhein-Main-Verkehrsverbund (RMV or Rhine-Main Regional Transport Association) is one of Germany's most prominent transport associations. The association coordinates and organises regional rail and bus transport services across an area of around 14,000 square kilometres[15], a responsibility that has been assigned to the network by law.

The RMV is constituted by 15 regional authorities and 11 municipal authorities. The members and the state of Hesse are shareholders. Due to the State of Hesse's legal framework, the association plays a twofold role: the RMV is a contractor of services on the one hand and serves as an intermediary between policy-makers and service providers.[16]

The association also gives local public transport organisations (*Lokalen Nahverkehrsorganisationen*, LNO in short) a common roof. LNOs are essential partners on-site and are responsible for local transport in the districts, independent towns and particular status

[13] https://service.region-frankfurt.de/ia/regionalverband/bevoelkerung/atlas.html (accessed on 15.07.2021
[14] https://www.statistikportal.de/de/produkte/gemeindeverzeichnis (accessed on 22.04.20)
[15] https://www.rmv.de/c/en/information-on-rmv/rmv (accessed on 17.08.2020)
[16] https://www.rmv.de/c/en/information-on-rmv/rmv/structure (accessed on 17.08.2020)

towns (cities with more than 50,000 residents). They plan the line routes and finance and commission buses, trams and metros."[17]
Users may either be aware of the LNO or may perceive and use the network as a whole, thanks to its unifying task.

The LNO in each city is

- Frankfurt am Main: RMV
- Darmstadt: Darmstadt-Dieburger Nahverkehrsorganisation (DADINA)
- Mainz: MVG / Mainzer Mobilität
- Offenbach am Main: NiO - Nahverkehr in Offenbach GmbH
- Wiesbaden: ESWE Verkehr

It is important to note that Mainz, the capital of Rhineland-Palatinate, is not a member of the RMV, but it is associated via the Mainz-Wiesbaden Transport Association.
In Mainz, Mainzer Mobilität, a subsidiary of Mainzer Stadtwerke AG, is in charge of the local transport, a public task. It organises and operates the local tram and bus lines for the city. It is in charge of organising regional transportation and the tasks to be regulated beyond the city, such as the fare system.[18]

Put together, the RMV and the LNOs provide the following on site[19] services:

1. Regional and municipal buses
2. Trams (*Straßenbahn*)
3. Metro/Subway (*U-Bahn*)
4. Commuter trains (*S-Bahn*)
5. Regional trains (*Regional Bahn*)
6. Collective cabs (*Anruf Sammeltaxi, AST*)
7. Mobility information offices, stop displays or postings, and ticket vending machines.

For simplicity, I wall call these *services offered by the RMV*.

4.1.3. Daily mobility

Due to its high density, proximity between municipalities, and connectivity, people often commute between the different cities of the region. The reasons to do so are varied, including but not only: get to places of work or learning, to access services and businesses, or to partake in leisure activities, and to head back home.

[17] https://www.rmv.de/c/en/rmv-on-site (accessed on 17.08.2020)
[18] https://www.rmv.de/c/de/rmv-vor-ort/staedte/mainz/ (accessed on 06.09.2021)
[19] As opposed to digital or telephone services such as the hotlines for information or lost and found services, smartphone applications to plan trips or buy tickets, etc.

In 2019, each city had the following number of in-commuters:

Frankfurt am Main	387 518
Darmstadt	72 603
Offenbach am Main	33 098
Wiesbaden	77 721
Mainz	70 677

These are the total amount of commutes across the district borders within the metropolitan region, including inner regional commutes. The numbers reflect only employees subject to social security contributions as of 30.06.2019 [20], thus only representing employees' commute by both private and public transport.

The association gives an idea of the number of passengers that travel within the region, regardless of employment status or, in its defect, the reason for commuting: "RMV transports a total of 788 million passengers a year. It, therefore, carries around 2.5 million passengers per workday and hence is a key contributor to the development of the Rhine/Main area as a pulsating metropolitan region."[21]

4.2. Analysed modes, services, and its infrastructure

4.2.1. Selection process

The selection and integration of different services and their supporting infrastructure was developed in two phases. First, a preliminary analysis was carried out in which the possible IOS were listed according to a minimum number of available services. Second, an extended list of offered services was created after on-site visits. This list is used to include or exclude the presented IOS.

Preliminary list

The services taken into account for the preliminary analysis were the services offered by the RMV, as listed in 4.1.2 (without regional trains), as well as taxis, shared services (car and bike sharing), and parking infrastructure for private mobility (car and bike). Although collective cabs are an RMV service (service nr. 6 in 4.1.2), they usually drive to and stop at any public transport station, making it difficult to map their availability so that they won't be taken into account.

These are the ten selected services and infrastructure that were used in the first step of the analysis:

1. Bus
2. Tram
3. Subway

[20] Source: Genesis Online Regional via https://service.region-frankfurt.de/ia/metropolregion/verkehr/atlas.html)

[21] https://www.rmv.de/c/en/information-on-rmv/rmv (accessed on 17.08.2020)

4. Commuter train
5. Mobility info point
6. Taxi
7. Bike sharing
8. Car sharing
9. Bicycle parking facility
10. Parking / P+R

An overview of the availability in each chosen city can be found in Table 12, the first list used in the analysis.

Other services and infrastructure were taken into account after visiting the sites. As presented in section 0, electric transportation plays a significant role in mobility stations, next to shared mobility. These services and infrastructure were found on-site and added to the list.

The final list of analysed modes and services

The following modes, infrastructure and services were as inclusion parameters:

1. Bus
2. Tram
3. Subway
4. Commuter train
5. Taxi
6. Cycling infrastructure (separate lane or cycling street)
7. Car lanes (and car-free areas)
8. Bike sharing station
9. Car sharing station
10. Bicycle parking facility
11. Parking / P+R
12. E-car charging station
13. Mobility information office and ticket vending ("Mobility info")

4.2.2. Spatiality: the required infrastructure and services

The following spatial translation adopts a heuristic approach, extending the components and mobility services listed in Table 9 informed by on-site visits and expanded to their spatial translation. Although technically part of the empirical analysis, it fits thematically to this section. And while regional trains are not part of the study, they are listed in this table because they share infrastructure with the commuter train within the RMV region.

As discussed in section 3.4, I find this notion to be related to the premise of defining IOS spatially not only by buildings (enclosure) but also by segregating traffic infrastructure, such as motorized traffic roads.

	Modes			Infrastructure and services				
	Active	Electric or hybrid	Motorised (fuel combustion)	for movement				for access/stationary
Private	Walking		—	Sidewalks, plazas, parks, …open space in general	Traffic light	Information (analogor digital) in formof signs, guidancesystems for different imparements, acess, etc.	Bookingsystem/ ticketing(analogor digital)	[Safe] pedestrian crossings, areas to stand
	Wheelchair	Electric-powered wheelchair	—					
	Skateboard*	E-Skateboard	—					
	Scooter	E-Scooter	—	Bike lane /street / sidewalks				Parking
	Bicycle	Pedelec / E-Bike	—					
		Moped	Motorcycle	Street				Parking+E-Charging station (+loadingarea)
		Electric car or truck	Motor vehicle (private car or commercial truck/vehicle, etc.)					
Shared	—	E-Scooter	—	Bike lane /street / sidewalks				(Floating) Station + parking
	Bike sharing		—					
	—	Car sharing		Street				Stop /waitingarea
	—	Ride sharing☆						
Public	—	Taxi						
	—	Ride pooling★	Collective cab					
	—	E-Bus	Bus	Steet (**Ownlane**)				Station /stop
	—	Tram	—	Rail on street (**Own lane**)				
	—	Subway	—	**Own** (long-distance) railroad				(Train) station
	—	Commuter train	—					
	—	Train						

* driving in public space / streets is punishable in Germany

★Ride pooling in the region is an add-on / complimentary serviceoffered by LNOs.It isn't a door-to-door service, as opposed to taxis or Uber. The system decides at which virtual stop you can get on or off. In the RMV region: HeinerLiner in Darmstadt (started in 2021), MainzRIDERinMainz (started in September 2020).

☆ Ride sharing is an on-demand service that can be door-to-door (e.g., Uber in Frankfurt) or start and end in agreed-upon locations (e.g., BlaBlaCarnation and Europe-wide). In Germany, the term can also mean "Fahrgemeinschaften" and be applied to non-commercial purposes, e.g., carpooling/ridesharing to the office or school.

Table 11. Components and services found on-site in the RMV region. Modes are arranged by type (active, hybrid/electric versions, motorised), system (private, shared or public), and its (shared) supporting infrastructure and services in a multi-level diagram.

Table 11 presents the services arranged by system (private-shared-public) while differentiating between three mobility types: active, motorised, and hybrid mobility in order to identify the supporting infrastructure with its spatial extent. This allocation of modes to their carrying infrastructures gives an overview of the type of (open) space that has to be taken into account in the analysis. The table lists mobility systems and types, and their spatial translation, both from a local and an international perspective.

These allocations reveal urban planning implications that can be translated into urban design approaches and terms. For example, when the infrastructure listed in the column "for movement" and limited by the element "traffic light" doesn't have distinctive design features that differentiate them nor segregates modes from one another, it's called "shared space".

It is also made clear, that in order to allow (even promote) multi- and intermodality, it is essential to pay attention to information systems on all levels. This is the one service feature that every transport system and types and infrastructure have in common and is crucial to facilitate accessibility. This is an aspect that was highlighted in the evaluated mobility stations presented in section 3.3.2.

4.3. Case studies selection

4.3.1. Selection process

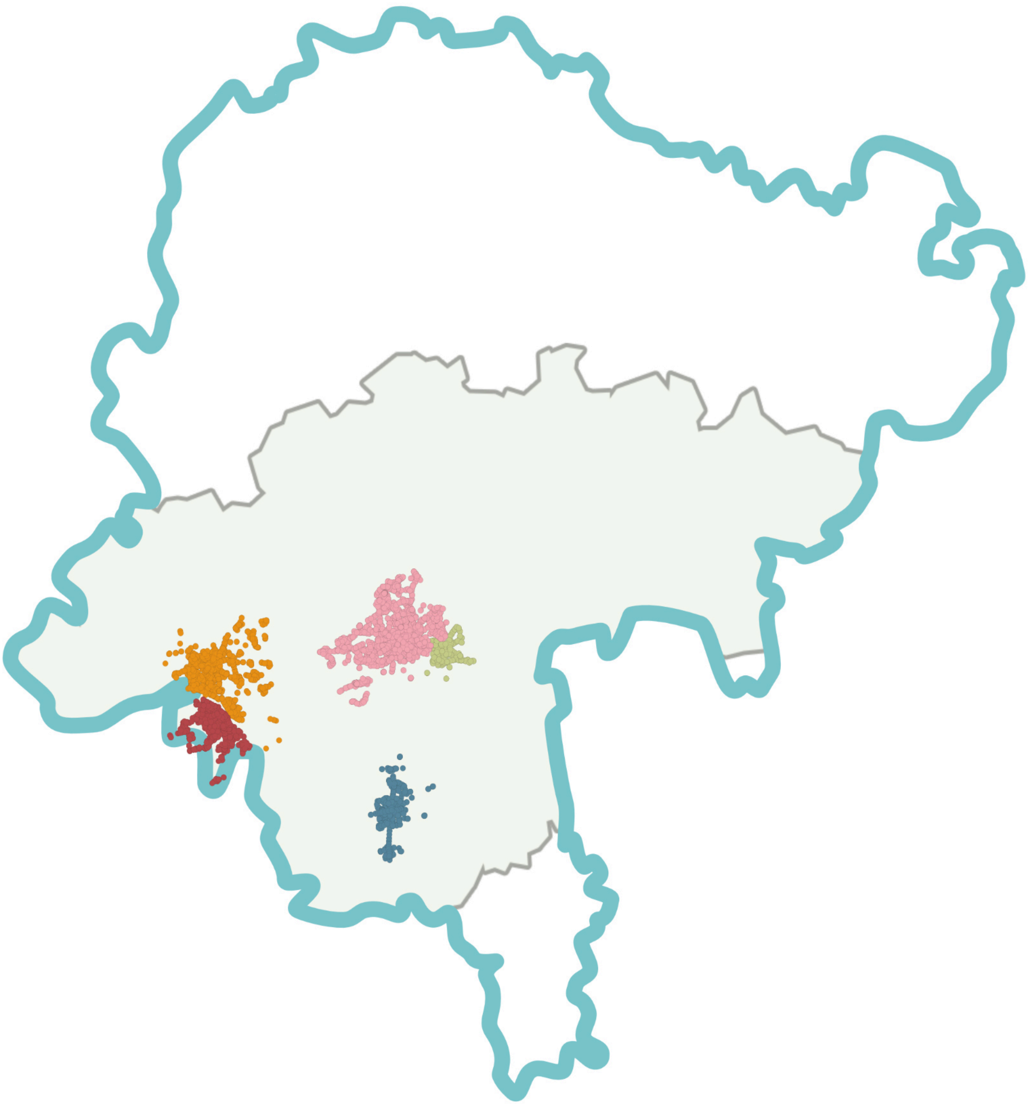


Figure 22. All the public transport stations of the five selected cities. Red: Mainz, yellow: Wiesbaden, pink: Frankfurt am Main, green: Offenbach, blue: Darmstadt. The aquamarine outline is the RMV area.
Source: © OpenStreetMap contributors visualized in QGIS, status 2019

All of the five large cities of the region meet the requirement of availability of a multimodal system with varying degrees of diversity (see Table 12). I have differentiated between the services offered city-wide and in the inner-city area in order to have an understanding of which services can be expected in the regional IOS.

City	Public transport						Sharing		Parking infrastructure		Total number of services
	RMV										
	Bus	Tram	Subway	Commuter train	"Mobility info" office/point	Taxi	Bike sharing	Car sharing	Bicycle parking facility	Parking lot or P+R	
Frankfurt am Main											
Citywide	x	x	x	x	x	x	x	x	x	x	10
Inner city	x	x	x	x	x	x	x	x	x	x	10
Mainz											
Citywide	x	x	-	x	x	x	x	x	x	x	9
Inner city	x	x	-	-	x	x	x	x	x	x	8
Darmstadt											
Citywide	x	x	-	x	x	x	x	x	x	x	9
Inner city	x	x	-	-	x	x	x	x	x	x	8
Offenbacham Main											
Citywide	x	-	-	x	x	x	x	x	x	x	8
Inner city	x	-	-	x	x	x	x	x	x	x	8
Wiesbaden											
Citywide	x	-	-	x	x	x	x	x	x	x	8
Inner city	x	-	-	-	x	x	x	x	x	x	7

Table 12. Overview of the availability of mobility services at a city-wide level and inner-city level. Marked with a green x means that this service is provided, a red - means that it isn't

The preliminary selection of stations was made based on the availability of the ten items listed above. The first screening was done by reviewing OpenStreetMap (OSM) data retrieved and visualised on QGIS in combination with information about each station retrieved from the websites of each local public organisation to confirm or complete in case it is necessary. All the stations with two or more public transport modes and a minimum of an additional mobility service were listed. 33 possible IOS were identified from this desktop research (Table 13).

The second step consisted of a parallel on-site mapping and desktop research of:

- mobility services according to the 13-item list presented on page 70, and
- observations of the use and multifunctionality of space.

Table 14 presents the 14 stations that were chosen and the availability of services and infrastructure according to the 13-item list.

Table 15 presents a preliminary listing of the multifunctionality of space, differentiating between temporary and continuous uses and amenities of each place. Performative potential and multifunctionality were determined in each station by the activities and uses mapped on-site, and complimentary desktop research.

		Bus	Tram	U-Bahn	S-Bahn	"Mobility info"	Taxi	Bikesharing	Carsharing	Bycicle parking	P / P+R	Number of services
	Frankfurt am Main	x	x	x	x	x	x	x	x	x	x	10
1	Festhalle/Messe	x	x	x			x	x	x			6
2	Willy-Brandt-Platz	x	x	x			(x)	(x)				5
3	Hauptwache			x	x	x	x	x				5
4	Konstablerwache	x	x	x				x	x			5
5	Zoo	x	x	x			x	x				5
6	Alte Oper	x		x			x	x			x	5
7	Bockenheimerwarte	x	x	x			x	x	x	x		4
8	Taunusanlage	x			x		(x)	(x)				4
9	Habsburger/Wittelsbacher	x	x					x		x	(x)	4
10	Eschenheimer Tor	x		x				x	x			4
	Darmstadt	x	x	-	-	x	x	x	x	x	x	8
11	Luisenplatz	x	x			(x)	x	x		x	(x)	7
12	Schloss	x	x				x	(x)		x		5
13	Rhein-/Neckarstraße	x	x					x	(x)			4
14	Pallaswiesenstraße	x	x				x				x	4
15	Landskornstraße	x	x					x			x	4
16	Schulstraße	x	x							(x)		3
17	Willy-Brandt-Platz	x	x						(x)			3
18	Roßdörferplatz	x	x					x				3
	Mainz	x	x	-	-	x	x	x	x	x	x	8
19	Schillerplatz	x	x					(x)		x	x	5
20	Münsterplatz	x	x					x		x	x	5
21	Neubrunnen/Römerpassage	x					x	(x)		x	(x)	5
22	Bismarckplatz	x	x					x	x		x	5
23	Höfchen/Listmann	x					x	x	(x)			4
24	Lessingstrasse	x	x					x	x			4
25	Goethestrasse	x	x					x				3
	Offenbach am Main	x	-	-	x	x	x	x	x	x	x	8
26	Marktplatz	x			x	(x)		x	e-mobil		x	5
	Wiesbaden	x	-	-	-	x	x	x	x	x	x	7
27	Luisenplatz	x				x	x	x		x		5
28	Sedanplatz	x					x	x	x	x		5
29	Loreleiring	x					x	x		x	x	5
30	Platz der Deutschen Einheit	x				(x)	x	(x)		x		4
31	Dernsches Gelände (/Rathhaus/Schloßplatz)	x				(x)		x		x		3
32	Elsässer Platz	x					x	x				3
33	Dürerplatz	x				x		x				3

Table 13. List of the 33 inner-city stations with two or more public transport modes and a minimum of one additional mobility service offered.

	City	Bus	Tram	Subway	Commuter train	Taxi	Private car	Cycle lane	Bikesharing	Carsharing	Bicycle parking	P/ P+R	Charging station	Mobility info	TOTAL
	Frankfurt am Maininner city	x	x	x	x	x	x	x	x	x	x	x	x	x	13
1	Hauptwache	(n)		x	x	x	x	x	x		x	x	(x)	x	**10 (2)**
2	Zoo	x	x	x		x	x	x	x		x	x	x		**10**
3	Willy-Brandt-Platz	(n)	x	x		x	x	x	x		x	x	(x)		**9 (1)**
4	Alte Oper	x		x		x	x	x	x			x	(x)		**7 (1)**
	Darmstadt inner city	x	x	-	-	x	x	x	x	x	x	x	x	x	11
5	Luisenplatz	x	x			x	x	x	x		x	x	(x)	x	**9 (1)**
6	Schloss	x	x			x			(x)		x	(x)			**4 (2)**
	Mainz inner city	x	x	-	x	x	x	x	x	x	x	x	x	x	11
7	Münsterplatz	x	x				x	x	x		x	x			**7**
8	Lessingstrasse	x	x				x	x	x	(x)			(x)		**5 (2)**
9	Höfchen/Listmann	x				x	x		x	(x)		x			**5 (1)**
10	Schillerplatz	x	x				x		(x)	(x)	x	(x)	(x)		**4 (4)**
11	Neubrunnen/Römerpassage	x				x	x	x	(x)		(x)	(x)	(x)		**4 (4)**
	Offenbacham Maininner city	x	-	-	x	x	x	x	x	x	x	x	x	x	11
12	Marktplatz	x			x	x	x	x	x	x	x	x	x	(x)	**10 (1)**
	Wiesbadeninner city	x	-	-	-	x	x	x	x	x	x	x	x	x	10
13	Luisenplatz	x				x	x	x	x		x	x	(x)	x	**8 (1)**
14	Dernsches Gelände (/Rathhaus/Schloßplatz)	x				x	x		x		x	x	(x)	(x)	**6 (2)**

Table 14. The 14 stations chosen for further analysis. The (x) means the service is nearby, in a radius of less than 250m. The (n) stands "Nachtbus", a bus service that is only offered during night hours.

		Fixed	Mobile
	Frankfurt am Main		
1	Hauptwache	Greenery, seating, fountain	Outdoor gastronomy area
2	Zoo	Greenery, seating, fountain	Outdoor gastronomy area
3	Willy-Brandt-Platz	Greenery, seating, fountain	
4	Alte Oper	Greenery, seating, fountain	Outdoor gastronomy area
	Darmstadt		
5	Luisenplatz	Greenery, seating, fountain, monument	Outdoor gastronomy area
6	Schloss	Fountain	Outdoor gastronomy area, farmer´s market
	Mainz		
7	Münsterplatz	Seating, public toilettes	-
8	Lessingstrasse	Greenery and seating. Empty kiosk (Trinkhalle)	-
9	Höfchen/Listmann	Greenery	-
10	Schillerplatz	Greenery, seating, fountain	Outdoor gastronomy area
11	Neubrunnen/ Römerpassage	Fountain (monument)	Outdoor gastronomy area
	Offenbach am Main		
12	Marktplatz	-	-
	Wiesbaden		
13	Luisenplatz	Greenery, seating, monuments	-
14	Dernsches Gelände	Greenery and seating	Farmer´s market

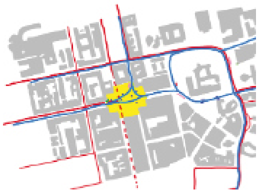
Table 15. List of fixed and mobile furniture and amenities that indicate uses that are given to the open space in which the station and mobility services are embedded.

4.3.2. Preliminary clustering of IOS types and inclusion parameters

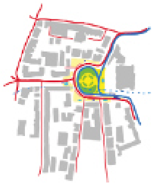
I proceeded to organise the possible IOS by groups with the help of schematic drawings done on-site (see figure 23). These show the open space's extent or enclosure type (i.e., morphology) space and its position in the urban fabric as well as the course of motorised traffic in and around it (i.e., traffic flow). All illustrations have the same scale.

The figure also includes first annotations about the immediate surroundings, whether modern or historic or a specific use, and impressions of the possible interesting characteristics after the first on-site visits.

Enclosed OS

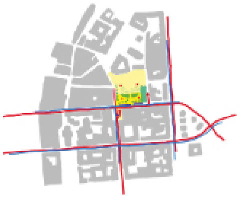


Darmstadt Luisenplatz
Historic + modern
Multimodal users, iconic



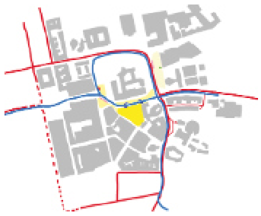
Frankfurt am Main Zoo
Historic + modern
Multimodal user can relax, local

OS in pocket position

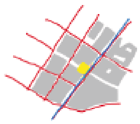


Wiesbaden Derndsches Gelände
Historic + modern
Central, commercial area; convinient for car

Wiesbaden Luisenplatz
Historic
Convinient for car, info point, calm

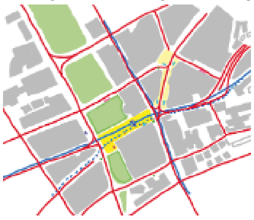


Darmstadt Schloss
Historic + modern
Central, commercial area

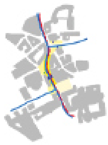


Mainz Neubrunnenpl./Römerpass.
Historic
Cyclists have own space

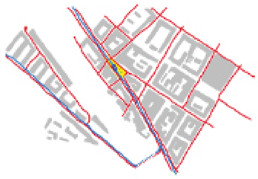
OS along a street segment or green corridor



Frankfurt am Main Willy-Brandt-Platz
Business center
Landmark park and forecourt.

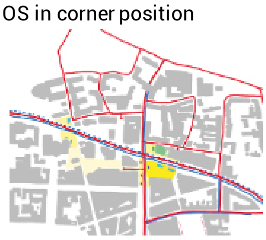


Mainz Höffchen-Listmann
Historic
Commercial passages

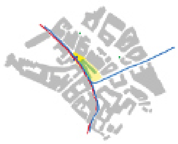


Mainz Lessingstrasse
Historic
Cyclist and pedestrians on linear park, local

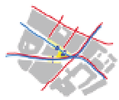
OS in corner position



Offenbach am Main Marktplatz
Modern
Commercial area, heavy traffic

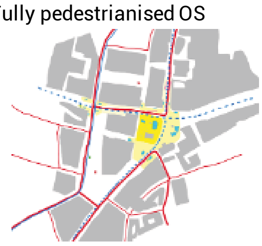


Mainz Schillerplatz
Historic
Garden with igh amenity quality

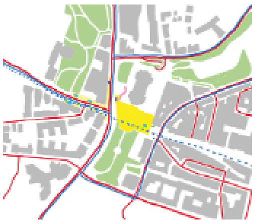


Mainz Münsterplatz
Historic + modern
Heavy traffic, hub, cohesive design

Fully pedestrianised OS



Frankfurt am Main Hauptwache
Historic + modern
Commercial ground floor and underground



Frankfurt am Main Alte Oper
Historic + modern
High amenity quality, iconic, heavy traffic

Figure 23. Schematic drawings of the course of motorised traffic (blue lines public transport and red lines for private vehicles) and the highlighted open spaces (yellow) organised by their position within the immediate urban fabric.

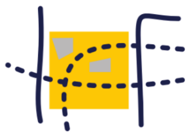
The five groups that resulted from this clustering are defined as follows:

Enclosed OS
The surrounding buildings shape the ground form.
Traffic runs through and/or under the space.

OS in pocket position
The open space is in front or a forecourt to an important historic building.
Traffic runs next to the space.

OS along a street segment / green corridor
The elongated open space marks a linear spatial trajectory.
Traffic runs through and/or under the space.

OS in corner position
The open space has one closed side (buildings).
Traffic runs along two flanks.



Fully pedestrianised OS
The open space has an extensive floor area with no clear enclosure at eye level.
Traffic runs under or around to the space, allowing a completely pedestrianised area.

Table 16. Types of IOS depending on spatial definition and traffic flow.

At least one open space of each type presented in figure 23 was chosen for further analysis.

Inclusion and exclusion parameters in the final round

The final stations were selected by the highest number of services on-site (potential intermodality), and potential for multifunctionality (number of amenities and usages). A minimum of one station will be presented for each city and type as presented above, as well as location withing the city and land use, to show the variety of solutions depending on the built environment and services offered. Some IOS explore all three levels of the sub-questions; some have little to offer at level C due to their lack of activities or diversity of use.

4.3.3. Selected IOS and their services

City	Bus	Tram	Subway	Commuter train	Taxi	Bike sharing	Car sharing	Bicycle parking	P/ P+R	Charging station	Mobility info	TOTAL
Frankfurt am Main	x	x	x	x	x	x	x	x	x	x	x	11
Hauptwache	(n)		x	x	x	x		x	x	(x)	x	**7 (1)**
Zoo	x	x	x		x	x		x	x	x		**8**
Willy-Brandt-Platz	(n)	x	x		x	x		x	x	(x)		**6 (1)**
Darmstadt	x	x	-	-	x	x	x	x	x	x	x	9
Luisenplatz	x	x			x	x		x	x	(x)	x	**7 (1)**
Mainz	x	x	-	x	x	x	x	x	x	x	x	9
Münsterplatz	x	x				x		x	x			**5**
Lessingstrasse	x	x				x	(x)		x	(x)		**4 (2)**
Offenbach am Main	x	-	-	x	x	x	x	x	x	x	x	9
Marktplatz	x			x	x	x	x	x	x	x	(x)	**8 (1)**
Wiesbaden	x	-	-	-	x	x	x	x	x	x	x	8
Luisenplatz	x				x	x		x	x	(x)	x	**6 (1)**

Table 17. List of the 8 selected stations and the services offered in them. The (x) means the service is nearby, in a radius of less than 250m. The (n) stands "Nachtbus", *a bus service that is only offered during night hours.*

Frankfurt am Main:

1. Hauptwache,
2. Willy-Brandt-Platz,
3. Zoo

Mainz:

4. Münsterplatz,
5. Lessingstraße

Darmstadt:

6. Luisenplatz

Offenbach am Main:

7. Marktplatz

Wiesbaden:

8. Luisenplatz

4.4. Detailed research questions

In the preliminary analysis to choose the stations, a typification was attempted, and relevant urban design characteristics were identified, translating into more specific sub questions of the research questions.

As presented in chapter one, the three main research questions are:

A. How is the location and integration of IOS within the city?
B. How are IOS spatially configurated, and how is their morphology?
C. Which spatial characteristics support which activities (performative potential) and are tied to high amenity quality?

Based on the preliminary analyses, the research questions were further formulated to cover urban design characteristics that were deemed relevant.

The research questions are structured around three blocks and according to scale:

A. **Location and integration**

In a radius of 500 m (catchment area of the station):

A.1. Where are IOS integrated within the urban fabric, and what is the fabric's composition (granularity, typologies)?
A.2. How are the city's motorised transport networks (public transport and private motorised traffic) integrated and located?
A.3. What type of land use is dominant?

B. **Morphology and configuration**

In a radius of 250 m (immediate urban context):

How do urban open spaces where mobility takes place look like? Specifically,

B.1. How much open space is there, and what is its typology and morphology?
B.2. How is space allocation for pedestrians and cyclists?
B.3. How do the different modalities and infrastructure relate to the built environment (spatial configuration, composition and visibility)?

C. **Activities and amenity quality**

Within the IOS:

How does the spatial configuration relate to (possible) activities? Specifically,

C.1. what elements and infrastructure, besides the ones dedicated to mobility services, that support amenity quality and leisure activities can be found??
C.2. What is the performative potential of the IOS? What can the user do in the space other than access transportation throughout the year?

4.5. Material basis, data sets and methods

This section lists the data sets and mapping methods that were used, organised by sub questions.

A.1. Ground floor plan with the highlighted area by author. Map base from schwarzplan.eu, from 2019

A.2. Mapping of the networks. Maps with OpenStreetMap data, retrieved and visualised in QGIS and supplemented by RMV network maps and site visits. Data from 2019 and 2020.

A.3. Land use maps based on the *Flächennutzungsplan* as assigned by German law, retrieved from Geoportal Hessen and Geoportal Rheinland-Pfalz. Data from 2019 and 2020.

B.1. Plan with building floor coverage area, and public and private open space with map base from schwarzplan.eu, coverage areas were drawn and quantified in ArchiCAD. Assessment of public or private open space was crosschecked with online maps (OpenStreetMap, GoogleMaps, Geoportal Hessen, Geoportal Rheinland-Pfalz. and planAs) with revisions on site. Data from 2019 and 2020.
The typo-morphology is assigned as presented in section 2.3.

B.2. Maps showing spatial allocation for different users. Map bases, i.e., CAD data, are from the respective city planning and cadastral office. Areas were drawn and quantified in ArchiCAD. Cycle lanes were retrieved from online maps (OpenStreetMap, GoogleMaps, Geoportal Hessen, Geoportal Rheinland-Pfalz. and planAs) and an Orthophoto from the city of Wiesbaden as well as cross-checked with own on-site mapping and previous students' mappings at a stand from 2019, early 2020. Some CAD data had mapped cycle infrastructure. Nevertheless, it was cross-checked with the sources mentioned above—available data from 2019 to 2021.

B.3. On-site mapping of the different mobility services paired with online information from each service provider. Data from 2019 and 2020.
Spatial composition and visibility are explored through a Visibility Graph Analysis (VGA), which calculates the visual integration of the space (Turner, 2001). The urban space was reduced to a grid system of a 2-meter mesh in order to construct the visual relations and the open space's relation to its surroundings. Although Cutini (2003) suggests a 1-meter mesh, the 2-meter dense mesh proved to allow sufficient representation of every urban element and narrow street in the vicinity since their streets are wide enough. Trees were not taken into account.

C.1. On-site mapping based on elements presented in section 2.3. Site visits recurrently from 2019 to 2021.

C.2. List of the activities that take place on the open space through site visits and complementary desktop research. Data from 2019 and 2020.

5. Case studies

Chapter five gives a brief introduction to each city and its particularities and presents the results according to the research questions.
The maps for each station, arranged by sub-question, can be accessed in the appendix to maintain reading flow.

5.1. Frankfurt am Main

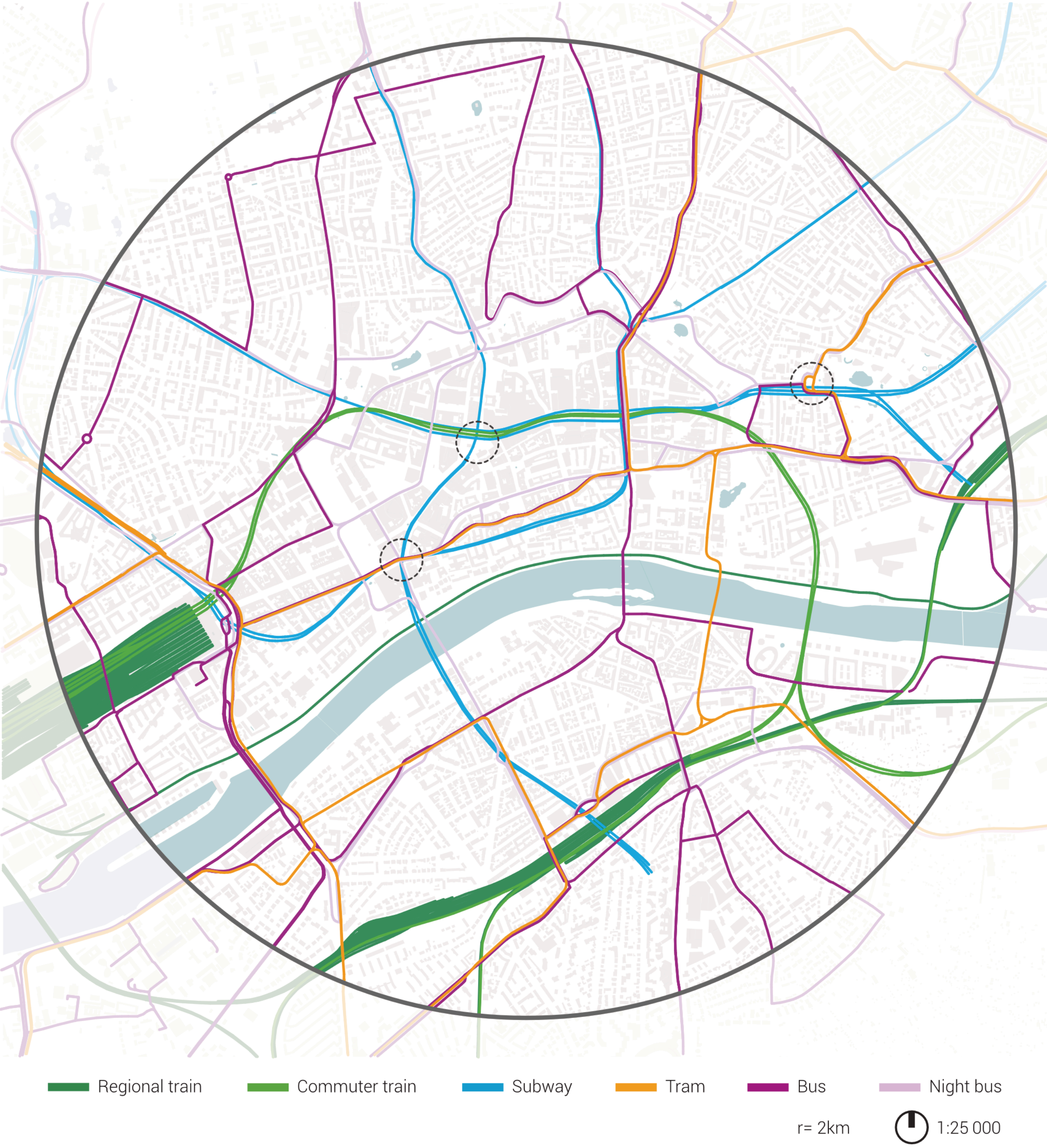


Figure 24. Frankfurt's public transport lines at a city-wide radius and the three chosen IOS marked with a dotted circle.

The city of Frankfurt am Main has a population of 753 056 inhabitants in an area of 248.31km^2, which translates to a density of 3 033 inhabitants per km^2 [22]. It is the city with the highest number of inhabitants, biggest area, and the most densely inhabited one in the study.
The centre of the 2km radius is the Römerberg, the Town Hall Square and the centre of the old town since the High Middle Ages.

Particularities

During the day, bus lines go through the city centre only along one north-south axis to the east, between the Konrad-Adenauer-Straße and the Alte Brücke. This makes every other public transport, i.e., rail-bound, dominant in the area. An exception is done in the evenings, when night bus lines (in light purple) replace the rail-bound services and offer merged and simplified routes.

[22] https://www.statistikportal.de/de/produkte/gemeindeverzeichnis (accessed on 22.04.20)

5.1.1. Hauptwache

A. Location and integration

Figure 25. Figure ground plan of the Hauptwache and its surroundings with highlighted open space in yellow.
Source: © OpenStreetMap contributors with author's additions

Located in the historical city centre, the square *An der Hauptwache* marks the beginning for the commercial area and pedestrian shopping street Zeil, which stretches until the Konstablerwache. The square and Zeil are framed by secondary roads that cross the city centre from west to east. There are mainly residential streets in the direct vicinity completing the mesh inside this frame. The northern streets are part of the city ring. A secondary road flanks the west side of the pedestrian area. (p. A-4)
The station is served by commuter train and subway lines. There are 4 other transport stations in a 500 m radius, all of them at an average of ca. 400 m away (p. A-5).

In a radius of 500 m, the building typology is very varied. The old city centre, with its small-scale buildings in a fine granularity (*Historische Altstadtbebauung*), is situated mainly to the south and north-west side. Next to the plaza, the buildings are bigger, showing higher coarseness and broader streets. This is due to their use: department stores and further big retail options.

The dominant land use immediate to the plaza is commercial with some residential buildings, the majority of which have commerce on the ground floor. There are some public buildings towards the south: churches, administrative buildings and museums (p. A-6).

B. Morphology and configuration

Area: around 15 900 m^2

The Hauptwache is a square with a freely arranged building (the Hauptwache or main guardroom), one prominent and various smaller entrances to the underground levels. It is mainly surrounded by pedestrian paths and streets and adjacent plazas. It can be categorized as a *city interior* square when one only looks at the shape of the square within the framing buildings. But its extensive floor area (see Figure 25) makes it difficult to grasp the enclosure of the space as at eye level, making it fall into the category *expansiveness*.

45.6% of the area in a 250 m radius is developed, leaving 50.8% of the area for open space from which only 3.6% is private (p. A-7).

The public open space is allocated as fallowed:

Pedestrian sidewalks are at the periphery of the square and run alongside the roads available to motorised traffic. Shared areas (salmon) are open for pedestrians, motorised traffic and cyclists, and have no structural separation, i.e., there are no higher or lower areas, the street is flat.

A road used to run through the square. After closing the road for motorised traffic, the former road area was flattened to the ground level and it open for cyclist traffic (magenta). Nevertheless, pedestrians have priority (p. A-8, A-9).

Overall, dedicated areas for pedestrians, whether to walk or stay, shared or not, are about 81.7% of the total open public space area. 2.3 % of the area is dedicated to marked cycle lanes and a total amount of about 16% is for streets and ground level parking area.

Open space - public	89 478.2 m^2	45.6%
Open space - private	6 969.1 m^2	3.5%
Building floor area	99 902.2 m^2	50.9%

Pedestrians	63 022.1 m^2	70.4%
Shared area	10 050.9 m^2	11.2%
Cyclist	2 051.0 m^2	2.3%
Street	14 354.2 m^2	16.0%

Table 18. Left: area coverage of open space (public and private separate) and building floors in m^2 within r= 250 m. Right: subdivision of the area coverage of the open space –Hauptwache, Frankfurt am Main

The Hauptwache has almost all of the mobility services offered in the city centre, in a radius of 250 m, only missing tram and access to car sharing. The mobility services found on site are: commuter train and subway underground station, bicycle parking and bike sharing point, taxi stops, and a mobility info point. Car parking and charging station are located further away but there are several car parks within the analysed radius. The services are mostly arranged on the periphery of the square, leaving the ground floor free for different uses (p. A-10). This is possible thanks to the fact that the access to public transport is underground, as schematically shown in Figure 26, and motorised traffic is kept out.

The centre of the square has a high visual integration (p. A-11). The area with very high visual integration is currently occupied by outdoor seating for gastronomy and bike sharing to the south. To the north east, the area of high visual integration is dedicated to trees with seating options and performing area (musicians, etc.).

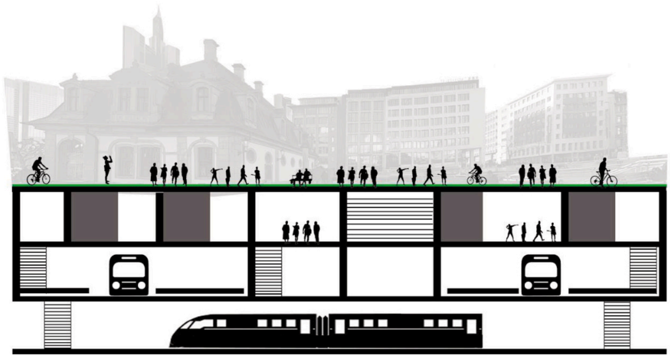


Figure 26. Schematic section through the underground levels.
Source: (Gopal, V. Mitra, S., Xiao, G., 2019)

C. Activities and amenity quality

The Hauptwache offers several outdoor gastronomy areas and plenty of seating for the public without having to consume in any shop. There is greenery, a fountain and a monument. The surrounding facades are in their majority permeable since the main use is retail. The church and the Hauptwache are historic buildings that were reconstructed after the second world war.

Due to its centrality and expansiveness, the square is stage to several recurring events such as the cider market in late summer[23] and the Christmas market[24] in winter. It also hosts several protests every year.

[23] https://www.frankfurt-tourismus.de/Entdecken-und-Erleben/Veranstaltungen/Volksfeste-Festivals-und-Maerkte/ABGESAGT-Frankfurter-Apfelweinfestival (accessed on 8.07.2021)
[24] https://www.frankfurt-tourismus.de/Media/Veranstaltungen/Frankfurter-Weihnachtsmarkt2#/eventDate/8e1946ab-77b8-4dfb-8ebe-f35b8d880fd8 (accessed on 8.07.2021)

5.1.2. Willy-Brandt-Platz

A. Location and integration

Figure 27. Figure ground plan of the Willy-Brandt-Platz and its surroundings with highlighted open space in yellow.
Source: © OpenStreetMap contributors with author's additions

The Willy-Brandt-Platz is a central OS located along the wall park, the former city wall fortification (*Wallanlage*), between the Main Station and the historical city centre. It was formerly named Theatre square because it was the forecourt of the municipal theatre. Today, the building to the south is the municipal theatre company as well. The area of the Wallanlage that limits with the square is called Gallusanlage. It is part of the so-called Financial District (*Bankenviertel*).

> *"Many banks, insurance companies and other financial institutions raised their headquarters in the zone located west from the city centre, and gradually created an unofficial urban district without clearly defined and still extending borders." (Camprag, 2014 :149)*

It is in between broad 3-4 lane secondary streets located to the west, and east and south behind the municipal theatre. West and east are part of the city ring. The latter is a prolongation

of the bridge that connects the Old Town to the southern districts of the city (*Untermainbrücke*). The Willy-Brand-Platz is freed of cars thanks to the underground-led secondary street (p. A-14). The tram crosses the square from east to west, while the subway passes it underground (p. A-15). There are 3 other stations in a 500 m radius.
The main land use surrounding the square is commercial and business oriented, the immediate buildings are the Frankfurt Opera to the south and the Eurotower to the north.

B. Morphology and configuration

Area: around 11 500 m^2
The building typology in a 250 m radius is characterised by the high-rises and skyscrapers from the financial district, which extend towards the north-west (see Figure 28). These buildings have a coarse granularity due to its big floor cover area. To the east, on the other hand, is the Old Town with its finely granulated "*Historische Altstadtbebauung*". To the west, mainly mixed-use buildings with residential use in the upper floors and commercial use on the ground floor ("*Innenstadtbebauung*").

Figure 28. High-rise cluster of the Financial District (Bankenviertel) – borders of the area according to Camprag, 2014.
Source: https://planas.frankfurt.de 07.09.2021; with author's additions

The Willy-Brandt-Platz is situated within the *Wallanlage*, the former city fortification and now park area, and right next to the river. It is the last broad space along the green corridor before ending at the river bank. 56% of the space is open public space and around 40% of building floor area. The remaining 4% is private open space.
Although its name suggests that it is a square, the enclosure and flow of PT mark a linear spatial trajectory, making it an OS along -in this particular case- both a street segment and a green corridor.

Pedestrians have a consistent network of sidewalks that connect each block from east to west. In the *Wallanlage*, pedestrian paths are within the green area (p. A-18). Cyclists have several dedicated bike lanes, mainly marked with paint on the floor (p.A-19).
Overall, dedicated areas for pedestrians, whether to walk or stay, shared or not, are about 17.3% of the total open public space area. Around 2.8 % of the area is dedicated to marked cycle lanes, almost 20% is green area, and a total amount of about 60% is for streets and ground level parking area.
The square used to be the forecourt of the theatre and has an elongated shape. The delimitation to the north is the park and two long benches that mark a cut (p. A-22). The mobility services found on site are: tram and night bus station, bicycle parking and bike sharing point, taxi stops, and underground parking. Almost all the offered services are arranged within these two fronts: tram station, entrance to the underground, bike sharing and parking. These are all rather bundled to the west side, where the visual integration es medium. Further services are found to the sides of the theatre.

Open space - public	109 689.8 m²	55.9%
Open space - private	6 861.4 m²	3.5%
Building floor area	79 798.3 m²	40.6%

Pedestrians	18 280.2 m²	16.7%
Shared area	671.6 m²	0.6%
Cyclist	3 062.9 m²	2.8%
Green	21 811.7 m²	19.9%
Street	65 863.4 m²	60.0%

Table 19. Left: area coverage of open space (public and private separate) and building floors in m² within r= 250 m. Right: subdivision of the area coverage of the open space –Willy-Brandt-Platz, Frankfurt am Main

C. Activities and amenity quality

The space offers seating and access to greenery and a playground. The green area limiting the square to the north, Gallusanlage (and the whole Wallanlage), is a cultural heritage landmark. There is also an iconic modern landmark in it: the Euro sign in front of the Eurotower, and a Jugendstil fountain to the south west.
There is a linear bench that serves as a divisor to the green area. The activity that takes place to the north and south side is mainly seating. In several visits I found employees from the surrounding office buildings having their lunch break. It has also hosted protests.
No other activities could be recorded on site or found online.

5.1.3. Zoo

A. Location and integration

Figure 29. Figure ground plan of the Zoo and its surroundings with highlighted open space in yellow.
Source: © OpenStreetMap contributors with author's additions

The intermodal station Zoo is located on the eastern edge of the city centre, in a straight extension of the main shopping street *Zeil*, on the square Alfred-Brehm-Platz in the Ostend district. The square is the entrance to the Zoological Garden.
The immediate surrounding of the square is mainly residential. This is clear by the perimeter block surrounding the area (*Blockrandbebauung*) (p. A-26). The streets are residential streets (p. A-24). Roads encase the square from 3 sides, the tram surrounds it. There are 5 further stations in a 500 m radius.

B. Morphology and configuration

Area: around 7 000 m^2
The open space division around Zoo is: 45% public space, 27% private and 28% building floor area.
The main open space is enclosed within the surrounding buildings and has a regular trapezoidal shape (Figure 29) which is contrasts with the remaining lingering area for users: an oval park, which is the Alfred-Brehm-Platz This is due to the road and tram dividing the space.

The mobility services found on site are: underground, tram and bus stations, bicycle parking and bike sharing point, car parking and charging station, and taxi stop.
The public space offers a wide and well-connected sidewalk network (p. A-28). The space in front of the entrance to the zoo is one level, shared by pedestrians, cyclist and the tram. The centre offers seating around the fountain.
Overall, dedicated areas for pedestrians, whether to walk or stay, shared or not, are about 48% of the total open public space area. Around 0.8 % of the area is dedicated to marked cycle lanes, almost 41.7% is green area (taking into account the zoo area), and a total amount of about 9.6% is for streets and ground level parking area.

Open space - public	88 157.6 m²	44.9%
Open space - private	53 327.5 m²	27.2%
Building floor area	54 864.4 m²	27.9%

Pedestrians	40 646.6 m²	46.1%
Shared area	1 641.3 m²	1.9%
Cyclist	684.3 m²	0.8%
Green	5 387.5 m²	6.1%
Zoo	31 327.0 m²	35.5%
Street	8 471.0 m²	9.6%

Table 20. Left: area coverage of open space (public and private separate) and building floors in m^2 within r= 250 m. Right: subdivision of the area coverage of the open space –Zoo, Frankfurt am Main

This leaves the peripheric areas, both from the centre part and the remaining corners in front of buildings, as the spaces where the mobility services are located (p. A-30). and have less visual integration as the centre. Nevertheless, the square has in general a medium-high visual integration in general. This makes it relatively easy to spot the different services from afar. According to the VGA (p. A-31) the southern area has a higher visual integration, which is where the majority of the amenities are situated at the outer periphery

C. Activities and amenity quality

There are several outdoor gastronomy areas to the south and west side of the outer periphery. In the core of the square, a fountain and several benches allow residents and zoo visitors to linger and kids to play. It is well protected from traffic.
The west side of the square is the meeting point for zoo guided tours[25] and protests have taken place on it as well.

[25] https://www.zoo-frankfurt.de/zoobesuch-planen/was-ist-los-im-zoo/event/abendfuehrung-61 (accessed on 8.07.2021)

5.2. Mainz

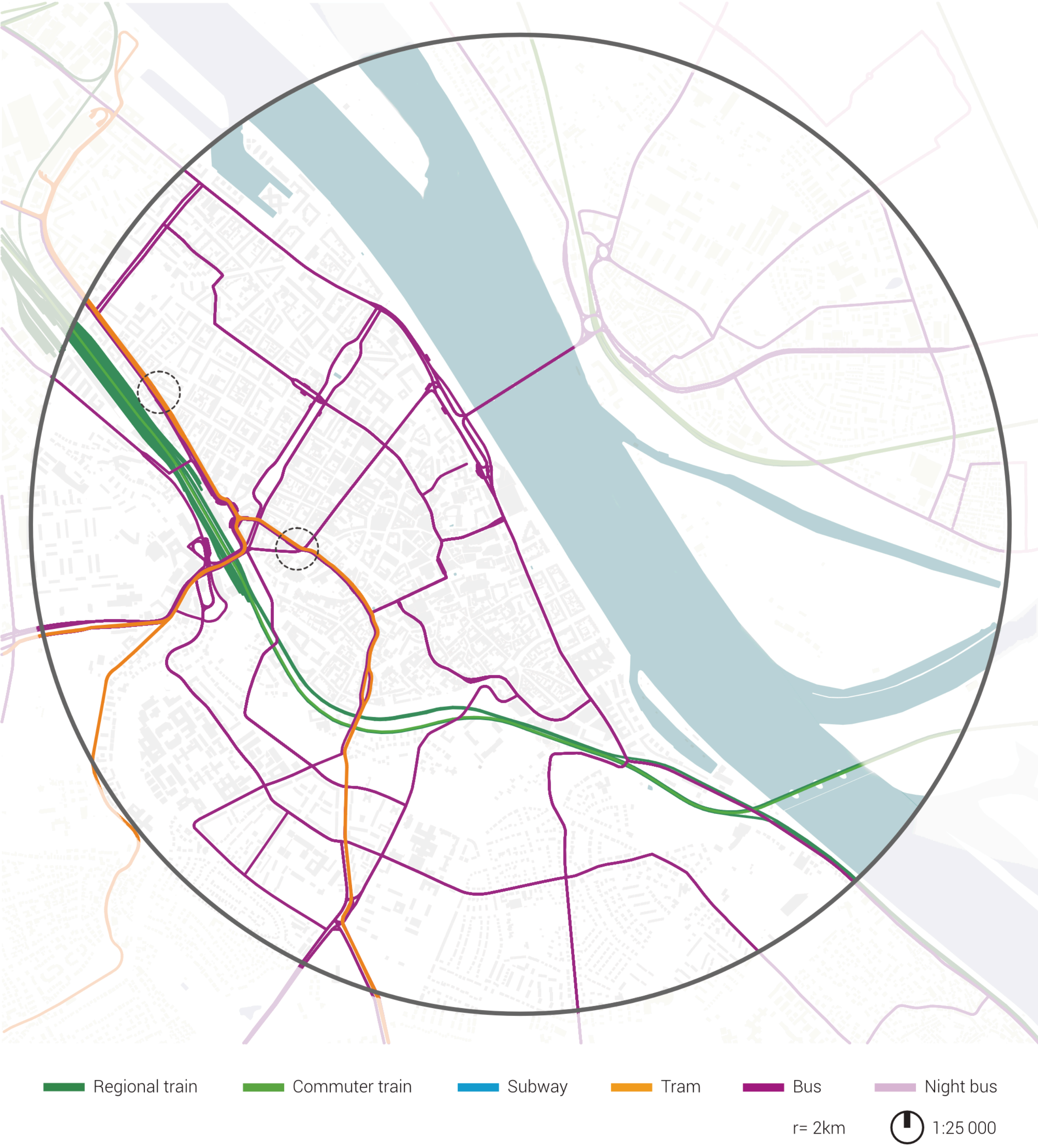


Figure 30. Mainz's public transport lines at a city-wide radius and the two chosen IOS marked with a dotted circle.

The State Capital Mainz has a population of 217 118 inhabitants in an area of 97.73 km^2, which translates to a density of 2 222 inhabitants per km^2 [26].
The centre of the 2 km radius is the Jockel-Fuchs Platz, the Town Hall Square in the east side of the old city centre, next to the river. The city extends from the river towards the west and is divided into 15 districts. Because of this position, parts of the local districts Neustadt, Oberstadt, and Hartenberg-Münchenfeld are not included in the area, but parts of Mainz-Kastel and Mainz-Kostheim can be seen on the other side of the river. The rest of the city area can't be seen in the chosen 2km radius.

Particularities

The tram lines in Mainz are radially arranged, and are combined public transports routs —i.e., tram alongside buses– that have their starting point in the main station. One towards north-west, one towards south-west and one towards south-east towards the peripheric districts. Trams serve a small part of the city centre. The rest of the city is mainly served by buses.
Mainzer Mobilität operates the city's own bike sharing system: meinRad. With 800 bikes and 112 stations (numbers from 2016) throughout the city, it forms one of the densest rental bike systems in Germany[27]. The station network is continuously being expanded.
The bicycle rental stations are integrated into the existing public transport network. The area served covers almost the entire state capital. All tram and suburban railway stations, as well as numerous stops in the city, are equipped with bicycle rental stations. The rental bike system is perceived as the third pillar of MVG's service alongside the bus and the tram. The bikes were specially developed and designed to maintain the design language of the city's buses and trams.

[26] https://www.statistikportal.de/de/produkte/gemeindeverzeichnis (accessed on 22.04.2020)
[27] https://www.vcd.org/themen/multimodalitaet/beispiele/mvgmeinrad-mainz/ (accessed on 06.09.2021)

5.2.1. Münsterplatz

A. Location and integration

Figure 31. Figure ground plan of the Münsterplatz and its surroundings with highlighted open space in yellow.
Source: © OpenStreetMap contributors with author's additions

Münsterplatz is located on the Bahnhofstraße, between the Main Station and the historical city centre. Because of its location and history, it is considered the most important entrance to the old town of Mainz.
The Bahnhofstraße is car free and only passable for the tram and bus thanks to the traffic routing that leads the secondary road, Binger Straße/Große Bleiche, that flanks the southern side of the square, towards north-west. The area is enclosed by a primary street to the west as well. To the east, the old city centre, the street network is dedicated to shared areas, where pedestrians have priority (p. A-34).

Münsterplatz is the first station after the main station in the tram/bus route that radiates towards the south-east. There are 6 further stations in a 500 m radius (p. A-35).

The immediate surrounding of the square is characterised by a perimeter block development in a bilateral grid. Further to the east, towards the city centre, the perimetry block is oriented in a

variety of directions, typical for old cities. In general, the granularity of buildings in Mainz is very fine.
The main land use near the station is residential with the majority of buildings having commerce in the ground floor. There are some public facilities, such as the postal services right next to the square.

B. Morphology and configuration

Area: around 2 750 m²

This area has a 38% of developed land, a 47% of public open space and a remaining 15% and private open space, mainly the courtyards of the perimetry blocks. The ground floor figure suggests it has the morphological quality of a city interior with irregular contours, but it has actually been reduced to the "traffic island" to the south. I have added the adjacent sidewalks, as highlighted in yellow in Figure 31, since they are the main part of the station. It is thereby a composite open space: a street with a square.

Streets in Mainz are narrower, which is fitting to the above-mentioned fine granularity of buildings. The city has a dense network of sidewalks along the streets. There is a segregated shared area, which is where tram and buses transit and is part of the station area. I have named it *segregated shared area* because (*free range*) pedestrian traffic is expected but still there is an infrastructural differentiation from one side: sidewalks are higher than the rail road. The southern area is lowered to the railroad level.
There are only two squares in the 250 m radius: the Münsterplatz and the Romano-Guardini-Platz to the south-east.
The only designated cycle lane runs along the Binger Straße/Große Bleiche, which comes from the main station.
Overall, dedicated areas for pedestrians, whether to walk or stay, shared or not, are about 40.8% of the total open public space area. Around 1.9 % of the area is dedicated to marked cycle lanes. There is no green area, and a total amount of about 57.3% is for streets and ground level parking area.

Open space - public	92 255.8 m²	47.0%
Open space - private	28 829.8 m²	14.7%
Building floor area	75 263.9 m²	38.3%

Pedestrians	3 4831.5 m²	37.8%
Shared area	2 838.6 m²	3.1%
Cyclist	1 760.7 m²	1.9%
Green	0.0 m²	0.0%
Street	5 2825.1 m²	57.3%

Table 21. Left: area coverage of open space (public and private separate) and building floors in m² within r= 250 m. Right: subdivision of the area coverage of the open space –Münsterplatz, Mainz

Although it is one of the smallest open spaces in the study, this station allows users to change between up to 4 different modes in a radius of less than 200 m. The mobility services found on site are: tram and bus station, bicycle parking and bike sharing point, and different types of car parking in the area.

There is a medium to medium-high visual integration (VI) in the analysed areas, increasing towards the square corner. But the highest VI at the street, the intersection Binger Straße/Große Bleiche/Schillerstraße.

C. Activities and amenity quality

The square to the south, is an area where visitors can linger or wait for and exchange public transport modes (Bahnhofstraße) has scattered seating and 5 roofed waiting areas, which organize space between waiting area towards the street, and transit area towards the building fronts. Big information steles, as used in mobility stations, inform passengers which bus/tram will be arriving were. The east corner of the square offers seating and a roofed waiting area along with public toilet.

5.2.2. Lessingstraße

A. Location and integration

Figure 32. Figure ground plan of the Lessingstraße and its surroundings with highlighted open space in yellow.
Source: © OpenStreetMap contributors with author's additions

Situated in the corner between the Keiser-Wilhelm-Ring, a direct connection to the central station to the south east, and the Boppstraße, the Lesseingstraße station is a characteristic "residual area" where the streets meet at an acute angle. The majority of the streets within the neighbourhood are *Spiel-/ Wohnstraßen*, marked as "other" in p. A-44. The surrounding building typologies are perimeter block development (*Blockrandbebauung*) and buildings are narrow and have big courtyards.

The Lessingstraße is located in the *Neustadt*, the most populous and densely populated district, so the main land use is residential. The train lines divide Neustadt from the adjacent neighbourhood, which is only accessible by two underpasses in this area.

B. Morphology and configuration

Area: around 1 500 m^2

Open public space accounts for 55% of the area at a 250 m radius, 17% is private open space and 28% is developed land.

The immediate streets surrounding the space are roads for motorised traffic with elevated sidewalks for pedestrians. The *Spiel-/ Wohnstraßen* streets to the north and south-west of the station are laid out as mixed traffic areas and are subjected to a special design: pedestrian and motor vehicle traffic are not clearly separated ("shared area" in pp. A-48 – A.49) and must take each other into consideration. The road space has a drawback ("shared area segregated" in pp. A-48 – A.49) and in the area of pedestrian crossings, it is raised to the sidewalk level. Consequently, motor vehicles lose their priority and have to adapt their speed to the given circumstances.

Overall, dedicated areas for pedestrians, whether to walk or stay, shared or not, are about 25% of the total open space area. Around 1 % of the area is dedicated to marked cycle lanes, around 2% is green area, a total amount of about 38% is for streets and ground level parking area, and around 33.5% for the train track area to the west.

Open space - public	108 535.7 m^2	55.3%
Open space - private	33 355.0 m^2	17.0%
Building floor area	54 458.9 m^2	27.7%

Pedestrians	1 6710.2 m^2	15.4%
Shared area	10 035.3 m^2	9.2%
Cyclist	1 090.7 m^2	1.0%
Green	2 230.4 m^2	2.1%
Street	42 045.2 m^2	38.7%
Train tracks	36 423.9 m^2	33.60%

Table 22. Left: area coverage of open space (public and private separate) and building floors in m^2 within r= 250 m. Right: subdivision of the area coverage of the open space –Lessingstraße, Mainz

As mentioned before, the *square* is a residual area. It is delimited by streets from all three sides, which can make it seem a simple traffic island at first glance. But at a closer look, it turns out to be a varied space: the linear park that stretches from north-west to south-east has both green and a shared pedestrian and cycle area. It is also where the bike sharing stations are located. Buses and trams run on both sides of the park. The tram and bus area are segregated by a drawdown. To the north-east, the residual triangular area offers space to linger. Its insular position is of easy access for active mobility users. Cyclist have two dedicated routes: along the linear park or the

There are 3 car sharing stations in a 250 m radius and sufficient parking space for cars and bicycles a like. There is an electric car charging station two blocks further. These services aren't visually integrated when standing in the station. The visual integration in the station and small square itself is medium to medium-high.

C. Activities and amenity quality

The area has sufficient greenery thanks to the linear park. There is seating under the roofed waiting areas. Users are safe from motorised traffic.

There is a currently empty kiosk (*Trinkhalle*) on the small square.

5.3. Darmstadt

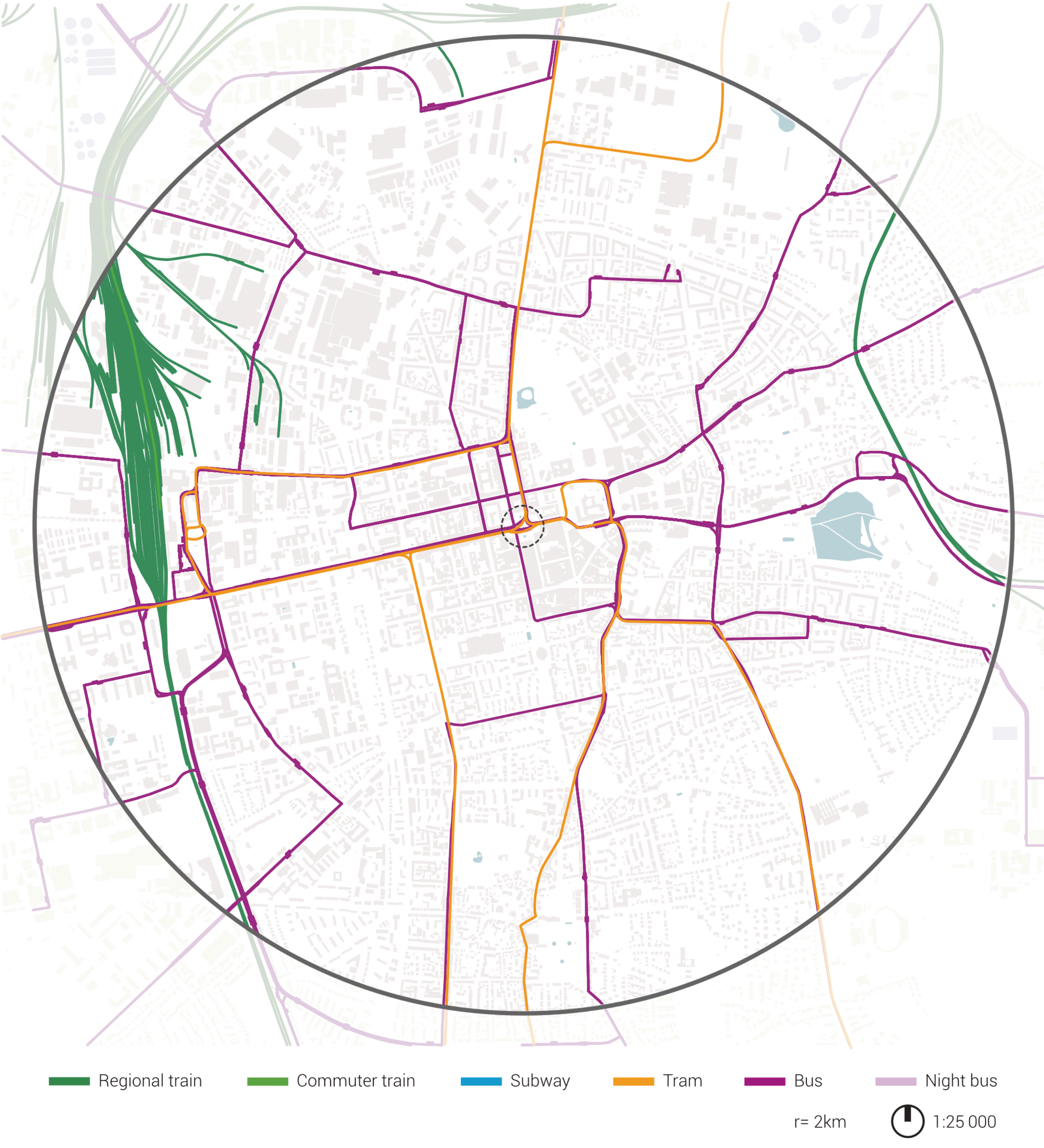


Figure 33. Darmstadt's public transport lines at a city-wide radius and the chosen IOS marked with a dotted circle.

The city of Darmstadt has a population of 159 207 inhabitants in an area of 122.07 km^2, which translates to a density of 1 304 inhabitants per km^2 [28]. This is the least dense city in the study. The centre of the 2km radius is the Luisenplatz, the city's main public square and city centre. It is also the square in front of the Town Hall.

Particularities

The city's public transport is constituted by trams and buses. Regional buses run through the city centre and not only the train stations, connecting smaller municipalities in the outskirts directly to the city centre. The north-east side of the city is only served by buses.
Commuter and regional trains arrive only on the fringe of the city

[28] https://www.statistikportal.de/de/produkte/gemeindeverzeichnis (accessed on 22.04.2020)

5.3.1. Luisenplatz

A. Location and integration

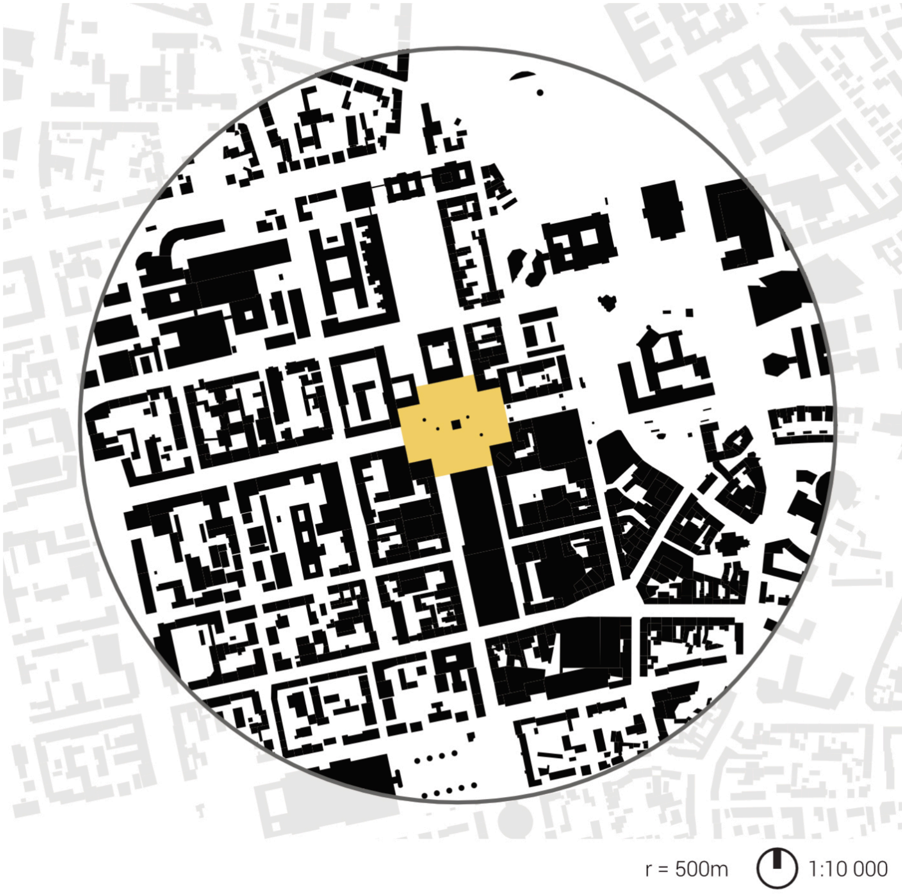


Figure 34. Figure ground plan of the Luisenplatz and its surroundings with highlighted open space in yellow.
Source: © OpenStreetMap contributors with author's additions

The Luisenplatz lays within the primary roads that form the city ring, almost fully depicted in p. A-54. The important square is free of car traffic thanks to the *city tunnel*, which connects the ring from north to south and gives access to underground parking. The streets within the city ring grid are residential streets.

The square is surrounded by various amenities, services and residency, and is a junction where the majority of the tram and bus lines meet. Eight of the nine lines of the Darmstadt tram meet here.
There are nine further public transport stations around the Luisenplatz.

Land use around the square is highly varied. To the north there are mainly public facilities, to the south-east a majority of commercial buildings with some residence, and mainly residential buildings to the south-west.

B. Morphology and configuration

Area: around 14 200 m^2

The square has a cruciform layout which is framed by the perimeter block development surrounding it. It has the morphological qualities of a hub and is a city interior. The blocks and buildings towards the commercial area are broader and coarse grain. The building floor area is around 45.5%, while open public space is around 40% and private open space 14.5% of the area.

Due to the commercial land use to the south-east, those streets are part of the pedestrian zone (*Fußgängerzone*) and exclusively for pedestrians. To the north and west, sidewalks run along the street sides and every junction offers a safe pedestrian crossing. The square is crossed by the tram tracks, which are also the area for the buses to run on. There is no infrastructural segregation, the whole area is at one level (p. A-58). There are cycle lanes to the north and west. To access the square, cyclist must either share space with pedestrians ("cycle/pedestrian") or with pedestrians and public transport vehicles ("shared area"). On the pedestrian zone, cyclist must get off the bike (p. A-59).

Overall, dedicated areas for pedestrians, whether to walk or stay, shared or not, are about 74% of the total open public space area. 0.8 % of the area is dedicated to marked cycle lanes, around 6.4% is green area, and a total amount of about 18.8% is for streets and ground level parking area.

Open space - public	78 064.4 m²	39.8%
Open space - private	28 884.2 m²	14.7%
Building floor area	89 400.9 m²	45.5%

Pedestrians	48 851.4 m²	62.6%
Shared area	8 921.6 m²	11.4%
Cyclist	620.1 m²	0.8%
Green	4 999.3 m²	6.4%
Street	14 672.0 m²	18.8%

Table 23. Left: area coverage of open space (public and private separate) and building floors in m² within r= 250 m. Right: subdivision of the area coverage of the open space –Luisenplatz, Darmstadt

The mobility services offered are: tram and bus stops, bicycle parking and bike sharing stations, taxis, access to the underground parking, and a mobility info point. All of them, except the underground parking access, are at medium to high visual integration location.

C. Activities and amenity quality

The Luisenplatz has scarce greenery in form of tree rows on the side pockets of the square. The south and west pockets have big outdoor gastronomy areas. There is a big fountain, both to the north and south side of the square. There are several seating options, mainly to the south side, the north-east pocket, and in the centre. The fountains are used as seating areas as well. The roofed waiting areas with seating are transparent in order to see the public transport coming.

All the buildings to the west, south and east have services, retail or gastronomy accessible to the public and with permeable facades on the ground floor. The building to the north, the *Kollegiengebäude*, is the only historic building standing. It is a municipal office building and a cultural monument.

The square is the venue of several events, some recurring and seasonal, others spontaneous. It hosts, among others, the international citizens festival[29] in spring, parts of the wine festival[30] in autumn, and some stands from the Christmas market in winter[31]. It also hosts cultural events like small concerts or theatrical presentations, and information stands from various different groups. Protests also take place in the square. The viewing platform from the *Ludwigsmonument,* the monument in the centre of the square, can be visited in special dates during summer. Latter were experienced during site visits.

[29] https://transition-darmstadt.de/Veranstaltung/internationales-buergerfest/ (accessed on 8.07.2021)
[30] https://www.darmstadt-tourismus.de/veranstaltungen/darmstaedter-weinfest.html (accessed on 3.12.2021)
[31] https://www.darmstadt-citymarketing.de/veranstaltungen/darmstaedter-weihnachtsmarkt.html (accessed on 8.07.2021)

5.4. Offenbach am Main

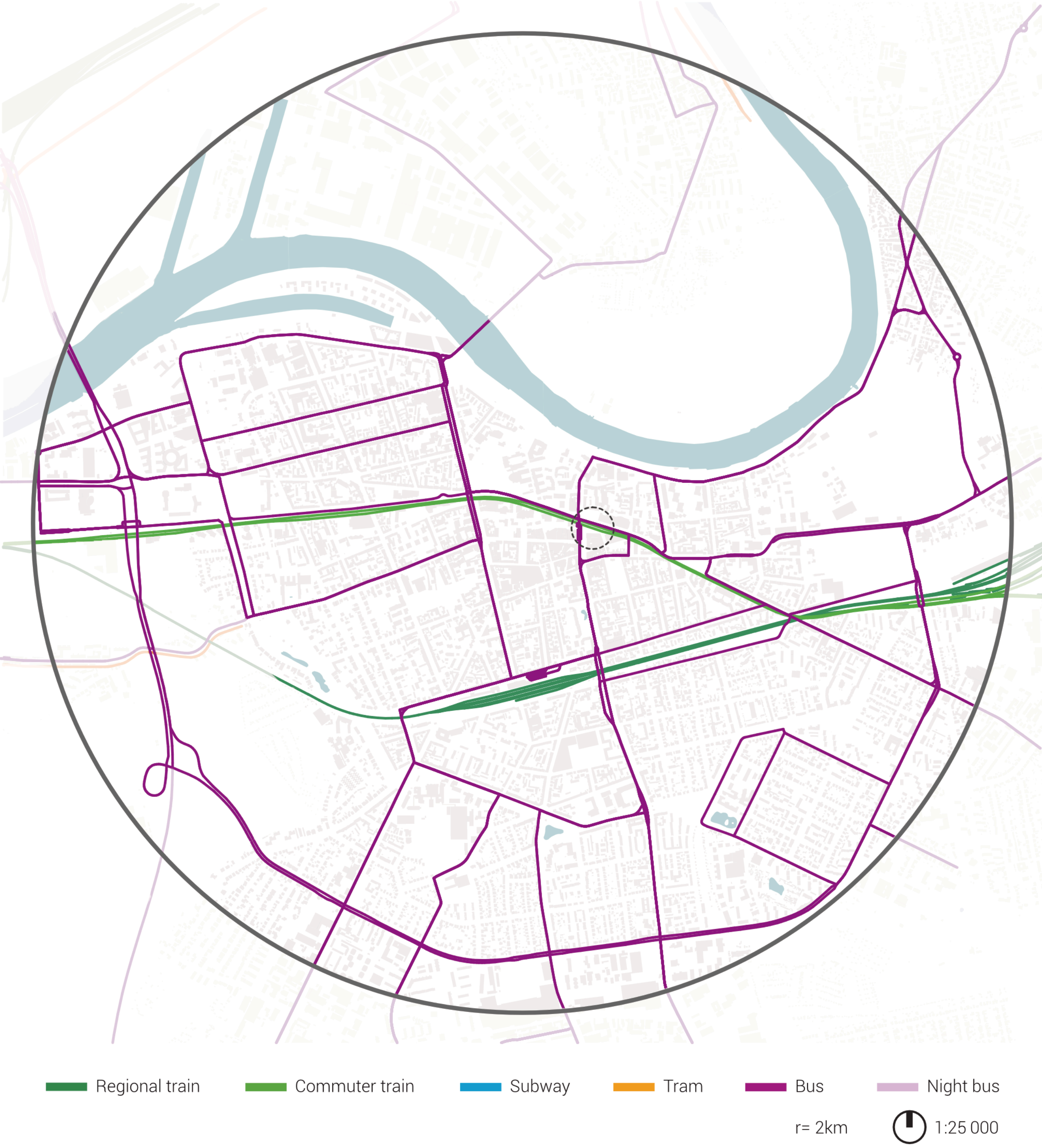


Figure 35. Offenbach's public transport lines at a city-wide radius and the chosen IOS marked with a dotted circle.

The city of Offenbach am Main has a population of 128 744 inhabitants in an area of 44.88 km^2, which translates to a density of 2 869 inhabitants per km^2 [32]. It is the smallest city both in area and inhabitants, but the second densest in the study.
The centre of the 2km radius is the *Stadthof,* the square in front of Town Hall.

Particularities

Offenbach's inner-city is mainly served by buses, and 4 commuter train lines that run through one east-west railroad beneath the main street.

[32] https://www.statistikportal.de/de/produkte/gemeindeverzeichnis (accessed 22.04.2020)

5.4.1. Marktplatz

A. Location and integration

Figure 36. Figure ground plan of the Marktplatz and its surroundings with highlighted open space in yellow.
Source: © OpenStreetMap contributors with author's additions

The Marktplatz is in the heart of the city centre. Located on the corner between of a broad 3-4 lane secondary street and a 3-lane tertiary street, it is also the centre for the majority of commuters or shoppers from the fringe area. The Marktplatz is an underground station, currently classified as a railway station category 4 which is served by commuter trains. The bus stops on the surface are actually called Martkplatz/Frankfurter Straße and Martkplatz/Berliner Straße and are the only transfer option to get to further areas of the city which aren't served by the commuter trains.
There are further 6 bus stops around the square in a 500 m radius.

The building typologies are varied. Large buildings surround the plaza. These stand in contrast with the perimeter block development of the old city centre towards the south.
The usages surrounding the station are varied, but the direct vicinity tis dedicated to commerce and public administrative facilities. Residence buildings usually have ground floor commerce. This extends towards the south as well.

B. Morphology and configuration

Area: around 3 600 m^2 the southern square; 4 000 m^2 both areas.

The open space area around the square is 43% of the area in a 250 m. radius. About 12% is private open space and building floor area take up to 45% of the space.

The ground floor figure suggests it has the morphological quality of a field. The edges of the area aren't determined by buildings, but by the surrounding broad streets that dissect the available open space in this major junction, leaving two islands. To the south, an island enclosed on two sides by coarse-grain buildings—of which it seems to be the forecourt. A second "slice" is left on the north side of the street, which is also connected underground through the commuter train station.

The broad streets have accordingly broad sidewalks, which have dedicated pedestrian crossings from north to south more consistently than from west to east. There is a high number of squares and pedestrian streets around the square. There is only one cycle lane along the road in front of the Marktplatz. Overall, dedicated areas for pedestrians, whether to walk or stay, shared or not, are about 83.3% of the total open public space area. 1.8 % of the area is dedicated to marked cycle lanes, less than 1% is green area, and a total amount of about 13.9% is for streets and ground level parking area.

Open space - public	84 534.7 m^2	43.1%
Open space - private	23 106.9 m^2	11.8%
Building floor area	88 708.0 m^2	45.2%

Pedestrians	67 806.8 m^2	80.2%
Shared area	2 648.1 m^2	3.1%
Cyclist	1 552.3 m^2	1.8%
Green	799.2 m^2	0.9%
Street	11 728.2 m^2	13.9%

Table 24. Left: area coverage of open space (public and private separate) and building floors in m^2 within r= 250 m. Right: subdivision of the area coverage of the open space –Marktplatz, Offenbach am Main.

The mobility services found on site are: commuter train station, bus stops, bicycle parking and bike sharing point, taxi stop, and a mobility info point. On the other side of the road, there is a e-car sharing and e-bike sharing point with the respective charging point. There are several access stairs to the underground parking on the square to the west.

The area with highest visual integration to the south is where the bus stops are, while the square of the commuter train station has a medium VI. The northern area with high VI, which can be accessed by pedestrians, is dedicated to a charging station and sharing stations for both electric autos and e-bikes.

C. Activities and amenity quality

The space is simply structure and equipped: roofs waiting areas for the bus stops to the west, a segregate bike lane with "spacing green" separate pedestrian area from the broad street, the underground station entrance is partially roofed, and there is a public toilet near the station stairs. There are no special activities or characteristics point towards a place with high amenity quality. The space lacks of seating, other than the options from the bus stops. The northern area for the sharing services has trees rows and is in front of a cultural heritage building. It has hosted protests.

5.5. Wiesbaden

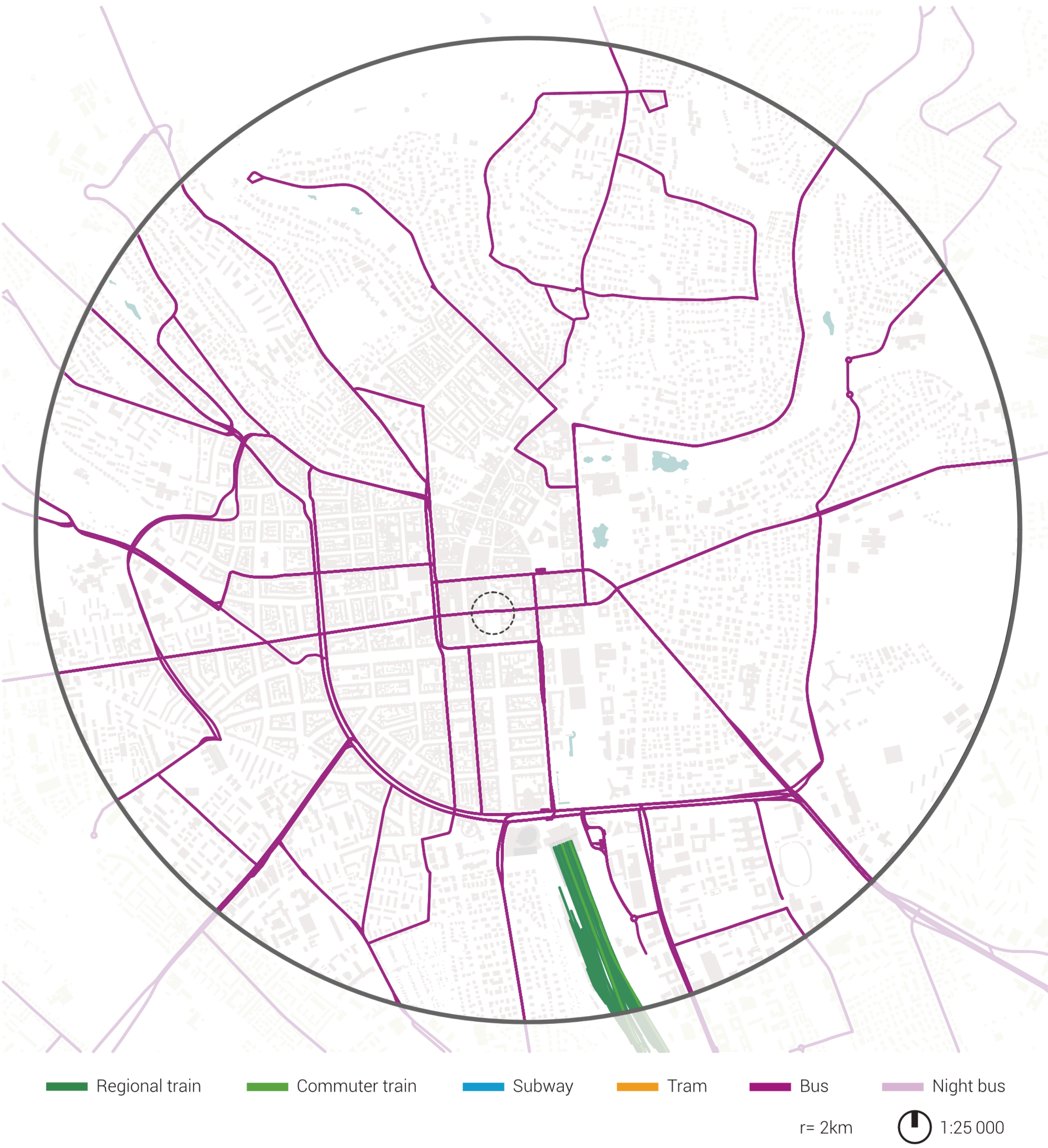


Figure 37. Wiesbaden's public transport lines at a city-wide radius and the chosen IOS marked with a dotted circle.

The city of Wiesbaden has a population of 278 342 inhabitants in an area of 203 87 km², which translates to a density of 1 365 inhabitants per km² [33]. It is second to Frankfurt am Main with regards to number of inhabitants and area, but penultimate with regards to density.
The centre of the 2km radius is the Schloßplatz, the Town Hall Square and the centre of the historic old tow.

Particularities

Wiesbaden is the only city in the study that has one public transport service running through it: buses. Commuter trains arrive to the main train station. The city held a local referendum for the creation of a tram line connecting Wiesbaden with Mainz and the peripheries. Citizens voted against the construction in November 2020.
Mainz' meinRad also services Wiesbaden. The fleet in the city is operated by the LNO ESWE and these bicycles are orange and have the ESWE logo.

[33] https://www.statistikportal.de/de/produkte/gemeindeverzeichnis (accessed on 22.04.2020)

5.5.1. Luisenplatz

A. Location and integration

Figure 38. Figure ground plan of the Luisenplatz and its surroundings with highlighted open space in yellow.
Source: © OpenStreetMap contributors with author's additions

The Luisenplatz is located at the southern end of the mainly pedestrianized city centre. The area is bordered by secondary streets. Only three inner streets are open to motorised traffic. One of those runs in front of the square, which is the street where the buses drive on (p. A-74). The bus network is dense with various lines running at maximum distance of two blocks from each other; these changes outside of the 500 m radius, the network loosens (see Figure 37) There are nine further stations in a 500 m radius (p. A-75).

The area has a very mixed land use with several big retail areas towards the north and south-west, and smaller commerce near the square. The high amount of residential land has a high amount of ground level commerce. There are several public facilities adjacent to the square and around the perimeter. These range from religious buildings, to education, and administration (p. A-76).

B. Morphology and configuration

Area: around 8 600 m²

The square is the forecourt for the church to the north. It is clearly delimited by the perimeter block developments to the east and west and by the road street to the south.

Buildings account for a ca. 51% of the space, while public open space for ca. 35% and private open space ca. 14% (p. A-77).

Thanks to the diversion of heavy traffic by the surrounding streets, a network of pedestrian streets can be found. Nevertheless, every street has sufficient sidewalk area with dedicated pedestrian crossing on each intersection of the mayor roads to the periphery. Pedestrian crossings are a scarce good inside the quadrant. Merely the outer edges of the square are shared areas, open to pedestrians, cyclists, and cars to a certain degree (p. A-78).

Cyclist have dedicated bike lanes at a medium degree at both sides of the car lanes. In Wiesbaden, cycle lanes share space with the bus lanes (p. A-79).

Overall, dedicated areas for pedestrians, whether to walk or stay, shared or not, are about 50.7% of the total open public space area. 2.3 % of the area is dedicated to marked cycle lanes, around 4.3% is green area, and a total amount of about 42.7% is for streets and ground level parking area.

Open space - public	66 963.0 m²	34.1%
Open space - private	28 625.8 m²	14.6%
Building floor area	100 760.7 m²	51.3%

Pedestrians	29 901.2 m²	44.7%
Shared area	4 056.4 m²	6.1%
Cyclist	1 532.1 m²	2.3%
Green	2 876.3 m²	4.3%
Street	28 597.0 m²	42.7%

Table 25. Left: area coverage of open space (public and private separate) and building floors in m² within r= 250 m. Right: subdivision of the area coverage of the open space –Luisenplatz, Wiesbaden

The mobility services found on site are: bus stops, mobility info point, bicycle parking and bike sharing point –including cargo bikes–, taxi stop, and access to underground parking directly next to the bus stop. There is a charging point in the 250 m radius (p. A-80).

The VI within the square is medium, increasing towards the northern and southern flank, respectively. The most part of mobility services are in this small area between the bus stops and the front sidewalk of the church (p. A-81).

C. Activities and amenity quality

The square is framed by classicist buildings which are part of the historical pentagon (*Historisches Fünfeck*)[34], an ensemble with historic preservation status. The forecourt is framed by two double tree rows running along both sides towards the buildings. It has a landscaped green area towards the south and houses a monument in the centre and one to the south-east. There is also an outdoor gastronomy area to this flank.

[34] https://www.wiesbaden.de/leben-in-wiesbaden/stadtteile/suedost/geschichte.php (accessed on 4.12.2021)

There is enough seating, both under the big roofs at the wating area or in the square. (See p. A-82)

The square is decorated with Christmas lights in winter[35], usually accompanied by a musical event[36], and at present an ice-skating ring[37]. It is also the starting point for architecture guided tours [38]

[35] https://www.wiesbaden.de/microsite/weihnachten/010/content/sternschnuppenmarkt-2020.php (accessed on 8.07.2021)

[36] https://wiesbaden-lebt.de/illumination-fuer-den-luisenplatz (accessed on 3.12.2021)

[37] https://wiesbaden-lebt.de/luisenplatz-on-ice-ist-eroeffnet (accessed on 3.12.2021)

[38] https://wiesbaden-lebt.de/lust-auf-architektur-entdeckungstour (accessed on 8.07.2021)

6. Summary of results

This chapter is a summary and descriptive comparison of the results presented in chapter 5. The results are presented according to the three sets of research questions and divided into the sub questions. The answers to each sub question are also presented in tables when deemed helpful.

A. Location and integration

The first set of questions aimed to determine the location and integration of IOS within the city and analyse its catchment areas, i.e., a 500 m radius.

A.1. Where are IOS integrated within the urban fabric, and what is the fabric's composition (granularity, typologies)?

From the eight selected IOS, three are located in the (historic) city centre (5.1.1; 5.3.1; 5.4.1), further three at the border of the city centre (5.1.2; 5.2.1; 5.5.1), and two outside the city centre (5.1.3; 5.2.2).
The granularity and typologies surrounding the IOS are varied. Each city itself, has a different urban fabric and the different city areas vary as well. The IOS in the city centres are withing a mix urban fabric: historic structures and perimeter blocks with fine granularity along narrower streets, and newer, coarser buildings along broader streets. The two IOS at the boarder of the city centre are within contrasting surroundings. 5.1.2. is within a coarse granularity with high-rise buildings while 5.2.1 and 5.5.1 are embedded in perimeter block structures, each with different block and building sizes; the later has bigger blocks. The two IOS outside of the city centre are exclusively within a perimeter block structure with fine granularity, 5.3.1 having bigger blocks and some discontinuity in the formation of the perimeter and infills in the blocks.

Table 26 presents an overview of the results of sub question A.1.

	Location within the city	Fabric composition, i.e., granularity and typology
5.1.1. Hauptwache, Frankfurt am Main	City centre.	Mix of older multi-story residential and commercial buildings at a fine granularity on narrower streets and newer commercial buildings with high coarseness on broader streets. Two solitaire historic buildings on the OS.
5.1.2. Willy-Brandt-Platz, Frankfurt am Main	Border of the historical city centre, along the former city wall fortification.	Coarse granularity and high-rise buildings around the OS, finer granularity further away.
5.1.3. Zoo, Frankfurt am Main	Outside of the city centre.	Perimeter block, fine grain multi-story residential buildings with commercial use on ground floors.
5.2.1. Münsterplatz, Mainz	Entrance to the old city centre and therefore border of the city centre.	Perimeter block, fine grain multi-story residential buildings with commercial use on ground floors.
5.2.2. Lessingstrasse, Mainz	Outside of the city centre.	Perimeter block, very fine grain multi-story residential buildings with some commercial use on ground floors.
5.3.1. Luisenplatz, Darmstadt	City centre.	Mix of older perimeter block multi-story residential and commercial buildings at a fine granularity on narrower streets and newer commercial buildings with high coarseness on broader streets.
5.4.1 Marktplatz, Offenbach am Main	City centre.	Mix of newer commercial and administrative buildings with high coarseness on broader streets and perimeter block development of the old city centre towards the south with fine granularity and narrower streets.
5.5.1. Luisenplatz, Wiesbaden	Border of the city centre.	Perimeter blocks with both fine and coarse granularity due to several commercial and public facilities. The square is a forecourt to a church.

Table 26. Location of the IOS within the city and its urban fabric at a 500 m radius of the OS. Overview of answers to question A.1.

A.2. How are the city's motorised transport networks (public transport and private motorised traffic) integrated and located?

The integration of the IOS into the cities' networks is diverse according to their different locations. The private motorised traffic (PMT) networks vary significantly between cities, nevertheless all eight IOS are fairly easily accessible by private motorised traffic. Although two are pedestrianised, access by private car or motorcycle, e.g., is possible at a small distance. Five OS are pedestrianised or freed of private motorised traffic: 5.1.1, 5.1.2, 5.2.1, 5.2.2, 5.3.1. Darmstadt and Frankfurt am Main have implemented underground tunnels for private motorised traffic, allowing the OS to be free of cars (5.1.2 and 5.3.1). In both cases, the tunnel is part of major traffic arteries. In cases where the tunnel wasn't implemented, roads were closed to cars and allocated either to active and hybrid modes (5.1.1) or reserved only for public and shared systems (5.2.1, 5.2.2). In all five cases, the OS are part of a pedestrianised network in one way or another.
The other three areas around the IOS (5.1.3, 5.4.1 and 5.5.1) are designed in a way, that all three mobility systems -i.e., private, shared and public- share the street network. These cut pedestrian and cycle pathways, often subdividing the IOS into smaller areas, as it is the case with 5.1.3 and 5.4.1 Both 5.4.1 and 5.5.1 are adjacent to pedestrianised areas. In the later, the street is much smaller and only used by residents, since the major artery is further south.
A further measure to avoid segmentation of space for active mobility users, is to prioritise them in the street design and definition. This option is only seen in the city of Mainz, where the network surrounding the IOS also presents *Spiel-/ Wohnstraßen*.

The six IOS located both in the city centre and its border are major public transport connection points, both at a local and a regional level. The PT stations are closer to each other and in higher numbers in dense bus line networks, such as Wiesbaden and Darmstadt, where the average number of stations in a 500 m radius is 9. In areas with a less dense bus line network in combination with rail-bound public transport services, there is an average number of 6 stations (5.1.3, 5.2.1, 5.2.2, 5.5.1). In areas with a predominant rail-bound public transport network (5.1.1 and 5.1.2), it is 3,5 stations.

Table 27 presents an overview of the results of sub question A.2.

	Integration	
	private motorised traffic network	public transport network
5.1.1. Hauptwache, Frankfurt am Main	OS is the starting point of a fully pedestrianised area thanks to a road closure, framed by secondary roads and adjacent to the city ring to the north.	Served by underground commuter trains and subway lines, central at local and regional level. 4 further stations.
5.1.2. Willy-Brandt-Platz, Frankfurt am Main	Framed by the city ring and broad 3-4 lane secondary streets, the station is freed of cars thanks to the underground-led secondary street.	Subway and tram station. 3 further stations.
5.1.3. Zoo, Frankfurt am Main	Encased by residential streets on three sides, the fourth side is the entrance to the Zoo and thereby pedestrianised.	Subway, tram and bus. The tram surrounds the square, the bus boarders the southern part. 5 further stations.
5.2.1. Münsterplatz, Mainz	Car free, encased within primary, secondary and tertiary roads, traversed by residential streets. Only passable for the tram and bus thanks to the traffic routing that leads the secondary road	First station after the main station in the tram/bus route that radiates towards the south-east. 6 further stations.
5.2.2. Lessingstrasse, Mainz	Enclosed by a secondary street and residential streets, surrounded by shared streets (*Spiel-/ Wohnstraßen*).	Tram and bus lines projected outwards from the main stations along a linear park. 6 further stations.
5.3.1. Luisenplatz, Darmstadt	Pedestrianised square, within the city ring (primary roads), which crosses it underground. Fully pedestrianised areas to the east and residential streets to the west.	Junction for tram and bus lines, central at local and regional level. 9 further stations.
5.4.1 Marktplatz, Offenbach am Main	On the corner between of a broad 3-4 lane secondary street and a 3-lane tertiary street. A serving open space (sharing services) is located to the north, on the other side of the secondary street.	Underground station for commuter trains and bus stops on the surface, central at local and regional level since it acts as the main station. 6 further stations.
5.5.1. Luisenplatz, Wiesbaden	Southern end of the mainly pedestrianized city centre bordered by secondary streets. Three residential streets are open to motorised traffic, used by buses.	The bus network is dense with various lines running at a maximum distance of two blocks from each other. Further 9 stations.

Table 27. Integration of the IOS within the city networks at a 500 m radius of the IOS. Overview of answers to question A.2.

A.3. What type of land use is dominant?

The six IOS located both in the city centre and its boarder are within a mix land use, near to commerce and public services. The IOS outside the city centres are located mainly in residential areas.

What emerges from the results reported here is that, as expected, IOS are mainly found closer to the city centres and their commercial areas. The two outliers, 5.1.3 and 5.2.2, are within residential areas with ground commerce, the first with the Zoo as a major attraction point.

Table 28 presents an overview of the results of sub question A.3.

	Land use
5.1.1. Hauptwache, Frankfurt am Main	Mixed land use, mainly commercial and some public facilities.
5.1.2. Willy-Brandt-Platz, Frankfurt am Main	Mixed land use, mainly commercial. Forecourt to an important cultural building (public facility).
5.1.3. Zoo, Frankfurt am Main	Residential area with some commerce on ground floor and several public facilities. Forecourt to an important cultural building (public facility) and green area.
5.2.1. Münsterplatz, Mainz	Mixed land use with several public facilities.
5.2.2. Lessingstrasse, Mainz	Residential area with some commerce and public facilities. Green area along the linear park.
5.3.1. Luisenplatz, Darmstadt	Mixed land use with mainly public facilities to the north
5.4.1 Marktplatz, Offenbach am Main	Mixed land use with mainly commerce and public administrative facilities in the direct vicinity.
5.5.1. Luisenplatz, Wiesbaden	Mixed land use with several multi-story big retail areas, smaller commerce at ground level and several public facilities.

Table 28. Land use at a 500 m radius of the IOS. Overview of answers to question A.3.

B. Morphology and configuration

The second set of questions aim to find out how IOS look like, by analysing the spatial configuration and morphology of the IOS themselves and its immediate urban context within a 250 m radius.

B.1. How much open space is there, and what is its typology and morphology?

The presented IOS range from the smallest being around 1 500 m^2 to the biggest having an area of around 15 900 m^2. Marktplatz, Offenbach (5.4.1), is composed by to areas: one to the south of the main street, an OS of around 3 600 m2 with access to the bus stations at ground level and the main entrance to the underground public transport and the second, smaller one, to the north, with sharing services. The smallest are the two IOS from Mainz (5.2.1 and 5.2.2), where city blocks and lots are smaller.

Five of the eight IOS fall in to the typology *square* (5.1.3; 5.3.1; 5.4.1; 5.5.1), two are *open spaces located along green corridors* (5.1.2, 5.2.2) and one is a composite of a *street* with an adjacent *square* (5.2.1).
The selected IOS present the following morphological qualities with the indication of the number of times it is being assigned: entrée (3), hub (3), joint (3), field (2), garden (2), interface (1), and *Tiefenplatz* (1).

	IOpen space (OS)		
	Area	Typology and type	Morphology*
5.1.1. Hauptwache, Frankfurt am Main	ca. 15 900 m2	Fully pedestrianised square	Field Hub Joint
5.1.2. Willy-Brandt-Platz, Frankfurt am Main	ca. 11 500 m2	OS along green corridor	Interface Joint
5.1.3. Zoo, Frankfurt am Main	ca. 7 000 m2	Enclosed square	Entrée Hub Garden
5.2.1. Münsterplatz, Mainz	ca. 2 750 m2	Street with adjacent corner square	Entrée
5.2.2. Lessingstrasse, Mainz	ca. 1 500 m2	Corner OS along green corridor	Joint
5.3.1. Luisenplatz, Darmstadt	ca. 14 200 m2	Enclosed square	Hub Entrée
5.4.1 Marktplatz, Offenbach am Main	ca. 3 600 m2 southern square; 4 000 m2 both	Corner square	Field
5.5.1. Luisenplatz, Wiesbaden	ca. 8 600 m2	Square in pocket position	*Tiefenplatz* Garden

*Based on categories by Wolfrum, 2015.

Table 29. Area, typology and morphology of the IOS. Overview of answers to question B.1.

B.2. How is space allocation for pedestrians and cyclists?

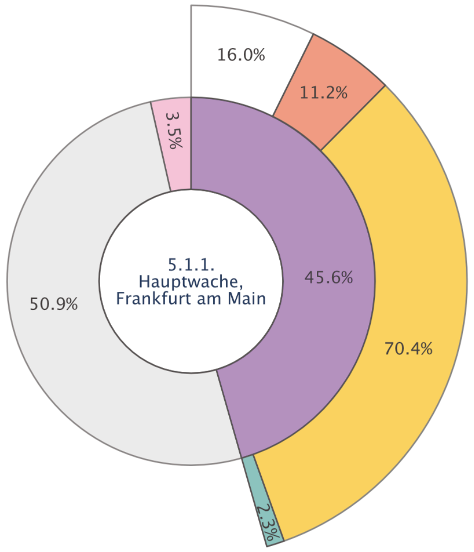
The access and network for pedestrians is in general well developed in all five cities. All of the areas have a continuous sidewalk network, some are wider than others. Depending on the street block size and width of the streets, the networks can be very dense or looser.
In the areas surrounding 5.1.1, 5.3.1 and 5.4.1 the majority of the open space is dedicated to pedestrians. Here, pedestrians can continuously cross an extensive area without having to take motorised traffic into consideration.

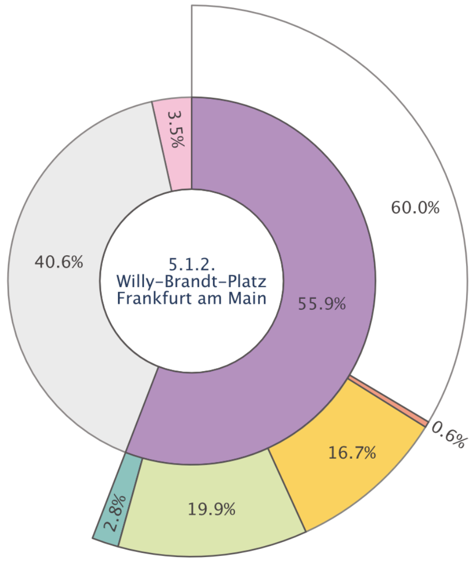
In general, the network for cyclists is poor and patchy in all the analysed areas. Very few have dedicated cycling lanes that are either marked with paint or have a structural separation - i.e., being on a higher level than the street or delineators (5.1.2, 5.2.1, 5.4.1). In some cases, pedestrians and cyclists have to share the sidewalk (5.1.3, 5.3.1, 5.5.1) or pedestrianised space (5.1.1) due to space constrains. In the special case of Lessingstraße (5.2.2), the linear park is designed for cyclists and pedestrians.
Often the places to stroll and linger are also used by cyclists, although in some cases they have to dismount and push their bikes.

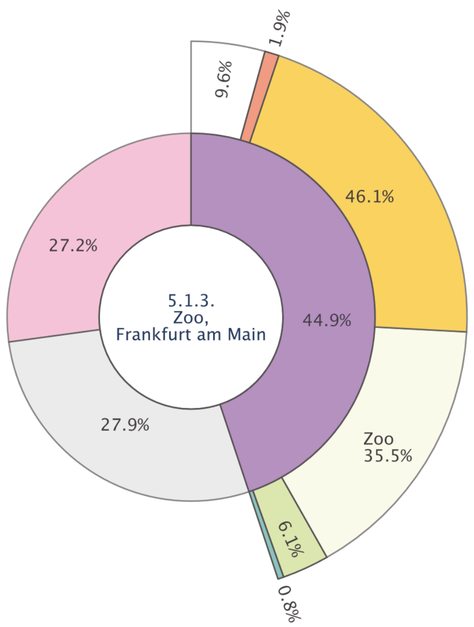
Figure 39 shows an overview of space allocation of the open space and building floor area in percentages in form of sunburst pie diagrams. Here, all the types of mapped spaces are shown. Table 30 presents an overview of the results of sub question B.2.

	Pedestrian network	Cycling network
5.1.1. Hauptwache, Frankfurt am Main	Continuous and extensive, both for walking (sidewalks) and lingering/strolling (squares, broader pedestrian streets) with adjacent shared areas.	Patchy dedicated network for cyclists connect to shared areas with pedestrians, denser towards the IOS.
5.1.2. Willy-Brandt-Platz, Frankfurt am Main	Continuous sidewalks with gaps on the border of the park due to prioritisation of paths within the green area. Spaces to linger and stroll are connected to the station's underground entrances.	Dedicated cycle lanes towards the east and south, inexistant towards the west (main station). Shared area within the IOS.
5.1.3. Zoo, Frankfurt am Main	Continuous sidewalks that lead towards the IOS, where users can linger/stroll with adjacent shared areas.	Very limited network. There are some marked crossings towards the east and dedicated paths appears to start from the IOS towards the east.
5.2.1. Münsterplatz, Mainz	Continuous and dense pedestrian network (sidewalks).	Dedicated cycle lanes are limited to Binger Straße - Große Bleiche bordering the IOS.
5.2.2. Lessingstrasse, Mainz	Continuous and dense sidewalks, several streets in the vicinity prioritise pedestrians.	Limited dedicated network with marked lanes on the Boppstraße.
5.3.1. Luisenplatz, Darmstadt	Continuous, dense and extensive, both for walking (sidewalks) and lingering/strolling (squares, broader pedestrian streets).	Some dedicated cycling lanes from east to west with infills of shared space with pedestrians.
5.4.1 Marktplatz, Offenbach am Main	Continuous, dense and extensive, both for walking (sidewalks) and lingering/strolling (squares, broader pedestrian streets) with some adjacent shared areas.	Limited dedicated network with marked lanes on the Berliner Straße.
5.5.1. Luisenplatz, Wiesbaden	Continuous, both for walking (sidewalks) and lingering/strolling (squares, broader pedestrian streets) with adjacent pedestrianised streets.	Patchy network that connects dedicated cycling lanes and shared areas with pedestrians.

Table 30. Description of the OS allocated for pedestrians and cyclists around the IOS, at a 250 radius. Overview of answers to question B.2.


5.1.1.
Hauptwache,
Frankfurt am Main
16.0%
11.2%
3.5%
45.6%
50.9%
70.4%
2.3%


5.1.2.
Willy-Brandt-Platz
Frankfurt am Main
3.5%
60.0%
40.6%
55.9%
0.6%
16.7%
19.9%
2.8%


5.1.3.
Zoo,
Frankfurt am Main
1.9%
9.6%
46.1%
27.2%
44.9%
27.9%
Zoo
35.5%
6.1%
0.8%

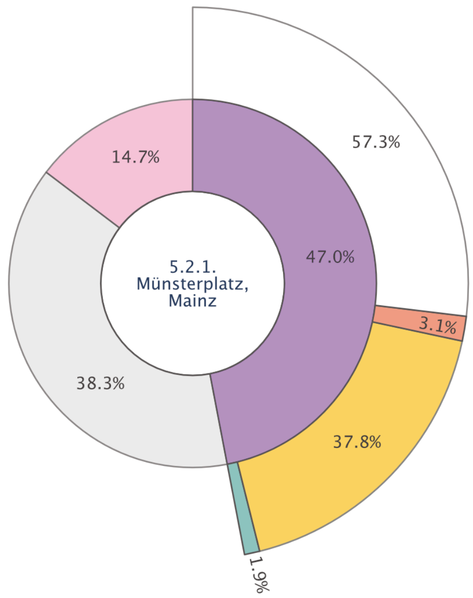

5.2.1.
Münsterplatz,
Mainz
57.3%
14.7%
47.0%
3.1%
38.3%
37.8%
1.9%

Figure 39. Sunburst pie diagram of space allocation in percentages. The first level presents three categories: building floor area, public and private open space. The second presents how public open space is allocated for different modes and users: motorised traffic, active mobility, and green.

B.3. How do the different modalities and infrastructure relate to the built environment (spatial configuration, composition and visibility)?

Public transport (PT) stops are highly visible and well indicated with signs and corresponding waiting areas. The exception would be 5.2.1 and 5.2.2. In the first, this is counteracted by its distinctive composition element (roofing at the square) and a uniform floor surface to make the area easily identifiable. In the latter, the trees enclosing the space make it a bit mor difficult to see at first glance. Still, the stops are located at medium VI.
Although every station has some type of element where information about public transport can be retrieved (digital or analogue), only 5.2.1 had something similar to the examples in section 3.3.1: an implemented stele with real time digitized information and the location of further mobility services.

While bike sharing stations, bicycle parking facilities and taxi stands are generally located in visually well-integrated areas in the majority of the IOS, not all of them are in areas with medium or high VI. The most visible placements for bike sharing services are 5.1.1, 5.1.3 and 5.4.1. IOS with placement in low VI areas are 5.1.2 and 5.3.1. The remaining four are placed at medium VI.
Car sharing and e-charging stations tends to be out of sight, except at 5.4.1.

Taxis, if available, are located in areas with medium to high VI and near the public transport stops. The only exception to this rule is 5.1.2, where the taxi stop is just around the corner, making it hard to quickly perceive and identify coming from the PT stop.

Designated parking spaces for cyclists are consistently in areas with high VI. Parking spaces for private cars have various forms: from lots, parks to underground areas. These spaces aren't usually in the direct view from the PT stops, unless its street parking or the pedestrian entrance to an underground parking. The latter is particularly interesting in 5.5.1, where the pedestrian entrance to the underground parking is integrated into the waiting area with info point and kiosk.

When available, info points are located in areas with high VI.

C. Activities and amenity quality

The last set of questions aimed to assess how the spatial configuration of elements and infrastructure within the IOS relates to (possible) activities and elements that support high amenity quality.

C.1. What other elements and infrastructure, besides the ones dedicated to mobility services, that support amenity quality and leisure activities can be found?

Seating and roofed areas are a scarce good, both for waiting for public transport or for optional activities. Three stations, i.e., 5.1.1, 5.2.1 and 5.5.1, have a higher amount -in comparison to the rest- of seating in form of benches, steps or low walls. 5.2.1 is also the only station that works with a distinctive composition element next to a uniform floor surface: the roofed waiting area with public toilette and benches. Two IOS have kiosks

Public green, a major component of amenity quality, is mostly sparse in all of the IOS that aren't along a green corridor or residential areas. Half of the IOS have a water fountain.
Only two have evident public toilettes.
Half of the IOS have outdoor gastronomy areas (5.1.1, 5.1.3, 5.4.1., 5.5.1). Four have kiosks (5.1.1, 5.2.2, 5.4.1., 5.5.1), one is empty at the moment (5.2.2).

Many of these spaces offer interesting examples of architectural landmarks and listed monuments. 5.1.1 has two historical buildings under monument protection and a monument. 5.1.2 is embedded in a green space that is a cultural heritage landmark and the theatre's foyer is under monument protection. There is a protected fountain and the Euro sign on site. 5.1.3 showcases zoo building. 5.2.1 is in front of the old Telegraph Office. 5.2.2 has some residential historical buildings under monument protection. In 5.3.1, the square is enclosed by a historical building to the north and it has two *jugendstil* fountains on both the north and south side of the square, which are under monument protection. Additionally, there are two monuments, being the *Ludwigsmonument* in the centre of the OS the most prominent one. 5.4.1 has one historical building under monument protection in front of the northern square. 5.5.1 is enclosed by historical building sunder monument protection from three sides and has two landmarks within the square.

C.2. What is the performative potential of the IOS? What can the user do in the space other than access transportation throughout the year?

All but one IOS (5.2.2) are regular sites of public life and participation, with demonstrations and rallies taking place. Only few regularly host markets (5.1.1, 5.3.1) and cultural events (5.3.1, 5.5.1). The same three also host seasonal cultural events and markets. 5.1.3 and 5.5.1 are starting points for guided tours of their surroundings.

As superficially assessed in sub question A.3., all areas have commerce, services or public facilities at ground floor level in the surrounding buildings. It is therefore safe to say that the spaces are also visited to access those services.

Outdoor gastronomy can be found in the four bigger IOS, with the exception of 5.4.1.

Table 30 shows an overview of the fixed and mobile elements and services for all-year-round leisure and amenity in the IOS (C.1.) as well as temporary uses and activities divided by seasonal and regular. It illustrates the proportion of multifunctionality for each IOS (C.2.).

	Continuous: leisure and amenities		Temporary uses and activities	
	Fixed	Mobile	regularly	Seasonal
5.1.1. Hauptwache	Greenery, seating, and water fountain. Kiosks at mid-level. Listed historical buildings and monument.	Outdoor gastronomy	Demonstrations and rallies, various markets	Cider festival Christmas market
5.1.2. Willy-Brandt-Platz	Greenery, seating, and water fountain. Green space is a cultural heritage landmark, the theatre's foyer is under monument protection.		Demonstrations and rallies, use as a green area/park	
5.1.3. Zoo	Greenery, seating, and water fountain.	Outdoor gastronomy	Meeting point for zoo guided tours, demonstrations and rallies, use as a green and blue area/park	
5.2.1. Münsterplatz	Seating, roofing, and public toilettes.		Demonstrations and rallies	
5.2.2. Lessingstrasse	Greenery and seating. (Empty) kiosk			
5.3.1. Luisenplatz	Water fountain, and *Ludwigsmonument* Kiosks scattered around the OS. The surrounding buildings are under monument protection.	Outdoor gastronomy	Demonstrations and rallies, information booths for different groups, cultural events, various markets	International citizens festival, Wine festival, Christmas market
5.4.1 Marktplatz	Public toilettes and roofing.		Demonstrations and rallies	
5.5.1. Luisenplatz	Greenery, seating, roofing, kiosk and *Oranienmonument*. Some surrounding buildings are under monument protection.	Outdoor gastronomy	Architecture guided tours, demonstrations and rallies	Christmas lights festival

Table 31. Multifunctionality of the IOS by fixed and mobile elements that support continuous leisure and amenities, and temporary uses and activities.

Part III: Final conclusions

7. Discussion and conclusions

The overarching goal of this dissertation was to develop and evaluate an analytical framework for urban open spaces where intermodality takes place (IOS). For this purpose, the research object was first defined and conceptualised in the field of tension between open space typologies from urban design and mobility station typologies from transport planning. I propose that IOS are multifunctional OS with an embedded mobility station where people can both access a wide range of new and public mobility services, as well as stay and, thanks to their amenity qualities, engage in optional and social activities in addition to the necessary ones.

The developed framework analyses form, functions and uses found in and around IOS. The assessed characteristics and measures were taken from the literature review (Part I: theoretical background and literature review) and mapped in the empirical study (Part II: Empirical analysis), presenting examples of current spatial configurations of IOS in the Rhine-Main Region.

This chapter presents a summary of the steps and results of the project and provides space for discussion on the analytical framework developed and the main research findings and challenges. From this, conclusions are drawn for the field of urban design with a focus on urban mobility. Finally, considering the various limitations of this work, recommendations for further research are provided.

Summary and discussion

Part I. The first step in building the theoretical background was to identify OS typologies and their characteristics, morphological qualities, and possible activities that suggest that an OS is well-visited and used in different forms (*performance*) through literature review.

In this step, the following typologies were identified as relevant when analysing IOS: ***streets***, *squares*, *linear systems* *(green corridors or paths*) and *incidental spaces*. These typologies are drawn from interdisciplinary discussions about OS that take form and (historical) function into account. The main parameter used to describe and categorise typologies is enclosure. Enclosure is defined in the project as the delimitation of space by buildings or boundaries – even temporary ones such as motorised traffic– that shape and give direction to the space. When defining the typology and analysing the morphology of OS, it is necessary and useful to take into account traffic-related boundaries, such as vehicular streets (motorways, city highways, etc.). These fragment OS, unless they are designed as shared spaces with priority for active mobilities; ideally with a design that communicates this, such surface at one level, with similar finishing or materials. The barrier is accentuated both by the physical space and design of the road (height differentiation, materiality and finish of the surface) and by the barrier posed by the fast-moving vehicles. The applied morphological qualities are Wolfrum's (2016) (see part II).

Lastly, activities that indicate a well-visited and multifunctional space were identified. As the focus is on mobility, the following activities and groups were deemed relevant when mapping onsite: people walking, cycling, waiting for public transport or changing modes, and sitting. Mapping these and surveying users' perceptions of the space could be connected to Wolfrum's performative potential as well. I wasn't able to map the majority of activities retrieved from literature review. It is therefore very difficult to make any statements regarding the IOS' performative potential, as stated in the upcoming section on limitations. Nevertheless, the workaround delivered some very basic mapping of current activities and attractors found on site, as presented in part II.

In a second step, the role of mobility in urban design was elaborated, mobility planning concepts that support sustainability were analysed, and the current state of the art regarding the design of new forms of mobility, especially mobility stations, was presented.

While the discussed planning concepts (TOD and SUM) share similar objectives -i.e., to reduce trips in private motorised vehicles (especially solo-driving), and to promote ecomobility by increasing use and trips in public transport or active mobility- only TOD delineates clear spatial requirements and consequences –such as planning around public transport, regulating land use and offering pedestrians and cyclists space. I suggest that this direct translation increases unambiguous applicability by spatial planning disciplines.

I found that mobility stations and their related concepts have several forms of spatial design and composition of the offered mobility services. From the implemented examples, only the concept of mobility hubs highlights the importance of the urban context with its land use and the availability of PT networks in and around the station. Furthermore, studies done at implemented mobility stations suggest that these are conducive to reducing CO2 emissions in the transport sector and thereby contributing to more sustainable urban development. Nevertheless, there are some risks to take into account. In stations where car sharing plays a major role, users of public transport and active mobility could switch to car sharing, for example. I suggest that this can be countered by giving preference to the availability and visibility of public transport and active mobility services.

Meanwhile, the conceptual models that analyse how mobility stations can contribute to sustainability include the urban context and land use in and around stations as relevant factors. These emphasize that, next to contributing to sustainable mobility by promoting multimodal mobility and thus reducing the use of private transport, mobility stations must also be *places* that play an active role in our social life. This understanding underlines an important issue that arises from the juxtaposition of the concepts of *mobility* and *spatial performance*: the potential to carry out activities.

Public open space is a finite resource that requires intelligent use of space to make it sustainable. It is sensible and appropriate to allow multifunctionality to foster potential whenever possible, as IOS aim to do. IOS are ultimately places where users can spontaneously decide whether to stay longer and pursue different activities or continue their journey in their preferred mode of transport by providing a range of business, social and mobility services combined with a high amenity quality in a comprehensible space. As expected, this is most possible in mixed-use areas that allow commerce at ground-level, provide sufficient space for greenery, shading or seating, and prioritise public transport users and active mobility. These conditions are prevalent in historic city centres, where the design and dimensions of the urban fabric and its open spaces were based on human needs and constraints – the 2 km radius referred to by Newman & Kenworthy (1999) as the "walking urban fabric". However, I have also found examples outside this radius where service provision replicates such conditions, albeit in a less intensive form.

Part II. The empirical analysis presents eight examples of IOS with different morphological and performative characteristics and varied mobility services in 5 large cities in the Rhine-Main Region at a 2 km radius from the centre of the Town Hall OS. The first result of the empirical analysis is the categorisation of IOS by types depending on spatial definition and traffic flow. The five categories are as follows: ***enclosed OS*** with traffic running through or under it; ***OS in pocket position*** with traffic running next to the OS; ***OS along a street segment or green corridor*** with traffic running through or under it; ***OS in corner position*** with traffic running along its two flanks; and ***fully pedestrianised OS*** with traffic running under or around it.
These types are site-specific and aren't necessarily transferable to every location In Europe. For example, the availability of certain mobility services or infrastructure is specific to the selected region. In fact, of the four typologies identified in Part I, no exmaple was identified as an incidental space according to Stanley et al.'s (2012) definition. The lingering areas of the two stations in Mainz would qualify as incidental spaces, as the open space is located at the edge of the transit border in a corner position. While the areas where mobility services are located are along the street or green corridor, the provision of this space is beneficial to people seeking covered waiting areas with seating, transforming what could easily be the spatial „remains" of the street layout into a space with access to further services or amenities. In this case, the frequency of visitors and the services available will determine whether the space is considered to be incidental or a square at any given time. This assumption, of course, must be studied.
The IOS are described with seven out of 15 of Wolfrum's morphological qualities. It is yet to be validated whether the IOS are described and perceived as such by the users onsite.

Because of these local properties and to record the process, the structure and steps taken in this explorative approach are described in more detail. The steps taken to construct the analytical framework may be of interest to international colleagues.

This doctoral dissertation has shown that IOS are generally located in areas with attractive commercial or mixed land use and these areas are, as usual for European cities, situated in the city centre or at its border. Surprisingly, the IOS Zoo, Frankfurt am Main and Lessingstraße, Mainz aren't. Nevertheless, the first has a major attraction: the Zoological Garden and a high number of mobility services (n=10). The latter is a residential neighbourhood with no public facilities or attractive landmarks, which begs the question: why are seven mobility services (a relatively high number for Mainz) offered in a radius of 250 m? I assume this has something to do with the city's population density. It makes sense to have a wide variety of mobility services in highly populated residential areas. This is especially important if the goal is to lower car ownership, promote more active modes or prioritise pedestrian activities. Judging by the high proportion of *Spiel-/ Wohnstraßen* in the area, the latter seems to be the case. After all, pedestrianisation combined with public transport planning for the whole city was an urban design and planning priority in German cities in the 1970s - not only for the historic and commercial city centre - as outlined in section 3.1. Nevertheless, I suggest that this unexpected result should be taken into account in further research. Moreover, these results argue for extending the 2 km radius to find other types of IOS outside the *walking fabric*.

As expected, the majority of presented IOS are major PT connection points, both at a local and a regional level. The diverse integration within the cities' transport networks suggests that, on the one hand, there is no apparent constraint to a certain type of PT network. Whether street-bound, rail-bound or mixed, it is possible to have an IOS in mixed PT networks, as in Frankfurt, and in bus-based networks, as in Wiesbaden. On the other hand, PMT networks do follow a trend: the IOS themselves or their surroundings are either pedestrianised or freed of PMT. Although with different coverage and measures, they do cater to the pedestrian experience.

The significance pedestrians are given becomes more apparent when analysing space allocation at a smaller scale: pedestrians tend to have a minimum of a third of the public OS. This includes next to sidewalks, squares and pedestrianised streets, freely accessible green spaces (as opposed to the green area of the Zoo, e.g.) and shared areas. The measures taken to this end range from major infrastructure investments such as tunnels to simple design measures such as closing a street to car traffic and adding it to the square at the same level.

Cyclists, on the other hand, have a poor and patchy network, even though every analysed IOS does have bike sharing and almost all have bike parking facilities. Moreover, these services are generally located in visually well-integrated areas in the majority of the IOS. These findings are a call to action to create more space to cycle. While shared areas with pedestrians can be a solution in areas that have little space, this should not be the norm given the location and significance of the presented IOS as connection points at local and regional levels, and the potential to signalise the cities' commitment to ecomobility.

The IOS presented are differently equipped to fulfil their function as places that actively contribute to our social life by supporting necessary, optional and social activities. The IOS accommodate a variety of temporary uses while maintaining continuous leisure and amenity services thanks to the spatial configuration of the elements and infrastructure.
In terms of temporary uses, all but one of the IOs (Lessingstrasse) are regular sites of public life and participation, hosting events such as demonstrations and rallies, and some host regular events such as markets and cultural offerings. These take place without disrupting much of the day-to-day operations of public transport and other mobility services. Lessingstrasse is probably the outlier due to its highly residential surroundings.

The majority of the continuous elements and infrastructure found on-site are clearly linked to public transport services, such as seating and covered areas. These are present in all the IOS and particularly at the public transport station, albeit rather sparsely. Very few extend seating and roofing to the rest of the OS. This is a negative point from an urban design point of view, as it doesn't give users a place to linger, but rather a place to circulate and nothing more.

Very few cities have distinctive design for their IOS. Willy-Brandt-Platz in Frankfurt am Main and Luisenplatz in Darmstadt have a cohesive floor design with uniform roofing with seating and some information elements in their waiting areas. A well-executed example is Münsterplatz in Mainz: it has a distinctive composition element (roofing at the square), a uniform floor surface to make the area easily identifiable and steles with real-time digitised information and the location of further mobility services. It is only missing visible bike parking areas. Cohesive design with real-time information is something that can be learned from the examples from Chapter 3.

Public green spaces, an important component of amenity quality, are rather sparse in all IOS that are not located along a green corridor or in residential areas. Where green spaces are provided, seating is provided to encourage people to linger. In the grey OS, seating is only provided in those IOS that are pedestrianised, allowing users to access to commerce and services directly from the circulation area. This becomes clear when comparing the Hauptwache in Frankfurt am Main and Luisenplatz in Darmstadt with Marktplatz in Offenbach am Main. The first two are fully pedestrianised, and while there are more or less designated areas for people to linger, stroll or access mobility services, the OS is used for all of these at the same time. Although the latter has the highest proportion of areas allocated to pedestrians (80.2 %) and a similar mix of usages as the first two, the corner location of the OS only allows interaction with the ground-floor commerce and services on the southern and western flanks, where the uses have no connection to the OS and thus do not contribute in any way to its attractiveness. Undoubtedly, ground-floor uses are very important determinants of the attractiveness of the OS, which all the examples have in the form of commercial services or public facilities. However, not all of them are easily accessible or extend their use towards the OS, as touched upon above. One attractive service, outdoor gastronomy, can be found in the four larger IOS, with the exception of the Marktplatz in Offenbach am Main.

Other valuable elements of amenity quality are water fountains and listed buildings or architectural landmarks, which are present in half of the IOS. These are spatially defining elements that strongly influence spatial composition, as suggested by Zucker (1953).

This dissertation underlines the significance of not only allocating adequate space for pedestrians but also selecting uses that interact with the public open space and installing infrastructure that enhances it, such as seating arrangements for visitors and passers-by. This is crucial for multifunctional spaces that should become places people like to use and visit. It is an open invitation to transport planning authorities to prioritize these aspects by integrating the urban context while planning mobility spaces and therefore making use of the vast untapped potential for sustainable urban planning, aiming to promote ecomobility and enhance liveability.

Conclusions

The first part of the dissertation explores how OS typologies and conceptualisations of space and place are interwoven, almost strung out, between their social and cultural meanings, their functions and measurable physical form. This, initiated by human sciences (see Lefèbvre, 1997) and carried forward in an interdisciplinary effort (see Begum, 2017; Cresswell, 2004; Hillier, 1984; Gehl & Gemzø, 2003; Pop, 2014; Tuan, 1977), isn't new. As seen in the discussion about mobility stations and sustainability, this tension also applies to mobility stations and the related concepts (see Amoroso et al., 2012; Monzón et al., 2016). The dialectical relationship between social practices and space to generate place argues in favour of the premise that OS should be designed and planned in such a way that optional and social activities are fostered and promoted, allowing them to be perceived as places by their user. This dissertation highlights the need to do this in OS that support urban mobility and to further qualify such mobility stations as IOS where possible. The relevance of this is underpinned by the previous findings presented in Part I and needs to be further explored through the representation of user perceptions and behaviours in IOS, for which the typification and detailed spatial description in Part II provides the basis.

Next to being places that play a role in our social life, IOS must also contribute to sustainable mobility by promoting multimodal mobility, potentially reducing the use of private transport and enabling dense and mixed-use urban structures, as envisaged by the German Government (Bundesministerium für Bildung und Forschung, 2018). For mobility stations, this means prioritising the urban context and the networks that support access to, from and within public transport. The study shows how this is done in IOS and advocated by TOD. Prioritising land-saving and multifunctional measures would also reduce tensions related to OS in dense areas and provide more spaces that support liveability. IOS can be classified as a space-saving measure as it provides a high-quality public transport service and infrastructure for cycling and walking, which in sum offer more efficient mobility alternatives than the car, which requires far more space and energy for each passenger kilometre travelled than any other mode of transport (Newman & Kenworthy, 2015).

This dissertation has provided a deeper insight into how IOS -multifunctional open spaces that support multi- and intermodality- are integrated into the urban fabric, a description of the design parameters and built form, and a typification that provides a framework that can help elucidate a common approach to intermodal open spaces from a transport planning and urban design perspective.

Limitations and outlook

As mentioned in the introduction, a major limitation of this study was the inability to gather homogenous and meaningful on-site data pertinent to users' behaviours and perceptions due to the COVID-19 pandemic. This made it difficult to make statements regarding spatial characteristics that support different activities -performance potential- and are tied to high amenity quality. The comparison of the quantitated measurers alone, without the intended behavioural and perception data, has limited significance in answering the question of whether these spaces are attractive or relevant to users' daily mobility. This must be taken into account in further research. Gathering on-site data is therefore a natural progression of this work. Behavioural and perception data can be then tied to the here gathered measures of space and syntactical values, such as visual integration. In addition, scale and building voids (e.g., entrances and windows), as highlighted by Krier (1979), need to be considered in this context.

CAD data from the respective city planning and cadastral office are very different from each other. Only one city provided land use and building use information. This variation in information lead to the use of the *Flächennutzungsplan*, as presented in section 4.5. This land use map doesn't allow to differentiate uses at different levels. Therefore, I think on-site mapping of the ground floor and upper floors uses would be much more conclusive.

Frankfurt am Main and Darmstadt do not have CAD data of stairs or subway entrances nor of the underground levels. Only Offenbach am Main had mapped stairs. This is data that is worthwhile gathering to expand on the dynamics between open public space and underground semi-public space and to study its contribution to the vitality and amenity quality in a mobility context. There are some studies only analysing underground levels, but not the relationship here mentioned, to my knowledge.

I was unable to obtain homogenous data for each station concerning: daily passenger numbers and service frequencies. These transport planning measures must be taken into account in a further step.

Cities expanded protected cycling infrastructure in the last two years, especially during the COVID-19 pandemic. This space allocation can be easily updated on-site.

Space allocation can also be further expanded and complemented with key factors of accessibility[39] in order to study the role of inclusive urban design (*Design for All/Universal Design*) in IOS.

[39] Accessibility, as used by designers and planners, points towards designed products, whether environments, objects, or services that are inclusive regardless of the restrictive motoric and cognitive skills of their users. This design approach aims to eliminate artificial restrictions of opportunities to use the environment and enable a broad majority to access the product.

Further empirical research will have to show the validity and usefulness of the analytical framework. It might explore the spatial translations of IOS in different areas of the country or even internationally. The framework can be adapted to other localities, expanding on spatial elements that different planning cultures utilise in order to provide a more or less balanced space for several modalities and activities, specially ecomobility.

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List of figures and tables

Figures

Tables

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Software

QGIS
Graphisoft ArchiCAD
Affinity Designer, Photo, and Publisher
Office applications: Excel; PowerPoint; Word
depthmapX - 0.30

Abbreviations

CIAM *Congrès Internationaux d'Architecture Moderne*; International Congress of Modern Architecture
hvv Hamburger Verkehrsverbund; Hamburg Transport Association
IOS Intermodal Open Space
ivm Integriertes Verkehrs- und Mobilitätsmanagement Region Frankfurt RheinMain; Integrated Transport and Mobility Management Frankfurt RhineMain Region
LNO *Lokalen Nahverkehrsorganisationen;* local public transport organisations
MT Motorised traffic
MVG *Münchner Verkehrsgesellschaft*; Munich Transport Company
NRW *Nordrhein-Westfalen*; North Rhine-Westphalia
OS Open Space
PMT Private Motorised Traffic
PT Public Transport
RMV *Rhein-Main-Verkehrsverbund;* Rhine-Main Regional Transport Association
RQ Research Question
SDG Sustainable Development Goals
SUM Sustainable Urban Mobility
SUMP Sustainable Urban Mobility Plan
TOD Transit Oriented Development
UN United Nations
VGA Visibility Graph Analysis
VI Visual Integration

Academic background of the author

01.03.2022	Defence (Dr.-Ing.) in Architecture and urban planning. Department of Architecture, Technical University of Darmstadt, Germany Doctoral dissertation: "Intermodal Open Spaces. An analysis of inner-city mobility stations in the Rhine-Main region"
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2005 - 2013	Diploma (Dipl.-Ing.) in Architecture and urban planning. Department of Architecture, Technical University of Darmstadt, Germany Urban design thesis: "Uni Campus Hamburg" under the supervision of Prof. i.V. Andreas Garkisch
08.2010 - 05.2011	Exchange student. Instituto Tecnológico de Monterrey (ITESM), Santiago de Querétaro, Mexico

APPENDIX

Site plans and plan materials

Hauptwache, Frankfurt am Main

Street network
Frankfurt am Main - Hauptwache

Primary   Secondary   Tertiary   Residential   Other

Underground   r = 500 m   1:10 000

Image data base: © OpenStreetMap contributors

Public transport network

Frankfurt am Main - Hauptwache

Commuter train | Subway | Tram | Bus | Night bus

Underground | Station | r = 500 m | 1:10 000

Image data base: © OpenStreetMap contributors

Land use

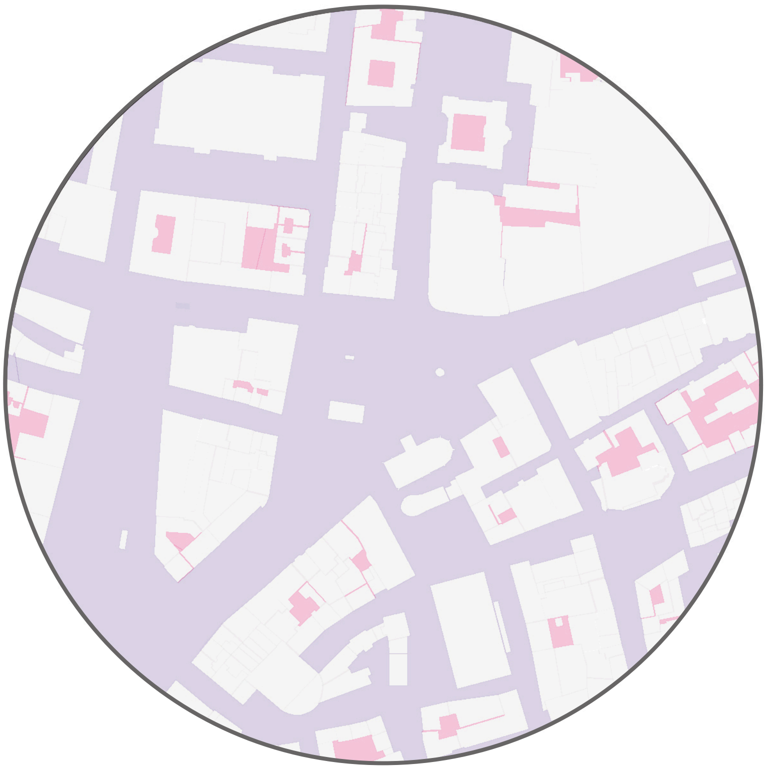
Frankfurt am Main - Hauptwache

Residential | Commercial | Public facilities

Green area | Water | r = 500 m | 1:10 000

Image data base: © OpenStreetMap contributors

Open space and developed land
Frankfurt am Main - Hauptwache



Building floor area | Open space public | Open space private

r = 250 m | 1:5 000

Image data base: © OpenStreetMap contributors

Space allocation pedestrians
Frankfurt am Main - Hauptwache

Path/ circulation
Shared area
Linger/ stroll
r = 250 m
Cycle/ pedestrian
Shared area segregated
Green
1:5 000

Image data base: © Stadtvermessungsamt Frankfurt am Main 08/2021

Space allocation cyclists
Frankfurt am Main - Hauptwache

Cycle lane	Shared area	Linger/ stroll	r = 250m
Cycle/ pedestrian	Shared area segregated	Green	1:5 000

Image data base: © Stadtvermessungsamt Frankfurt am Main 08/2021

Mobility services
Frankfurt am Main - Hauptwache

Public
- Stop
- Underground station
- Info point
- Taxi

Private
- Parking lot
- Car park
- Underground parking
- Charging station

Shared
- Car sharing
- Bike sharing

Modes:

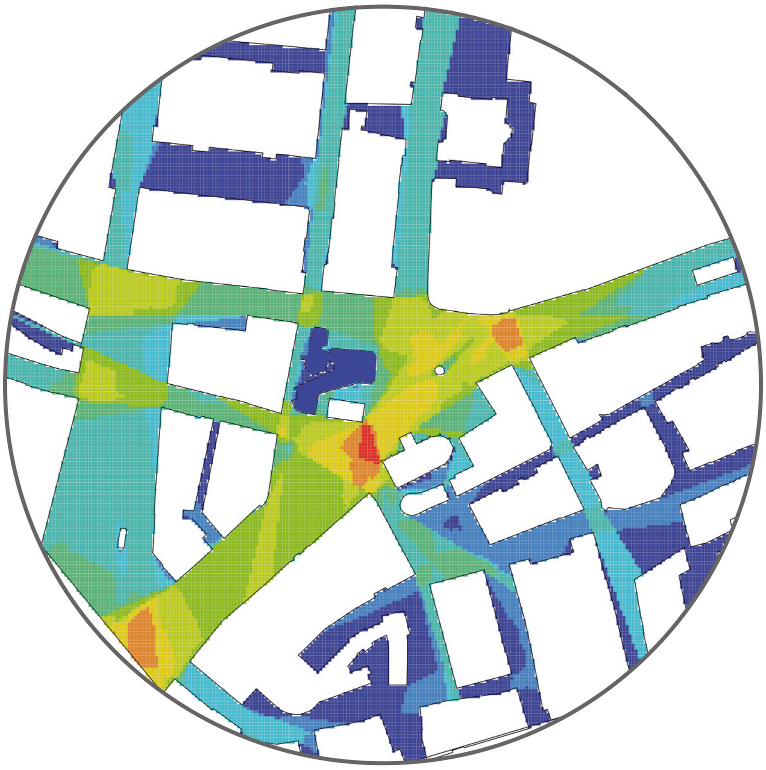
Commuter train | Subway | Tram | Bus | Night bus

Bicycle | Taxi | Car | r = 250 m | 1:5 000

Image data base: © Stadtvermessungsamt Frankfurt am Main 08/2021

VGA

Frankfurt am Main - Hauptwache



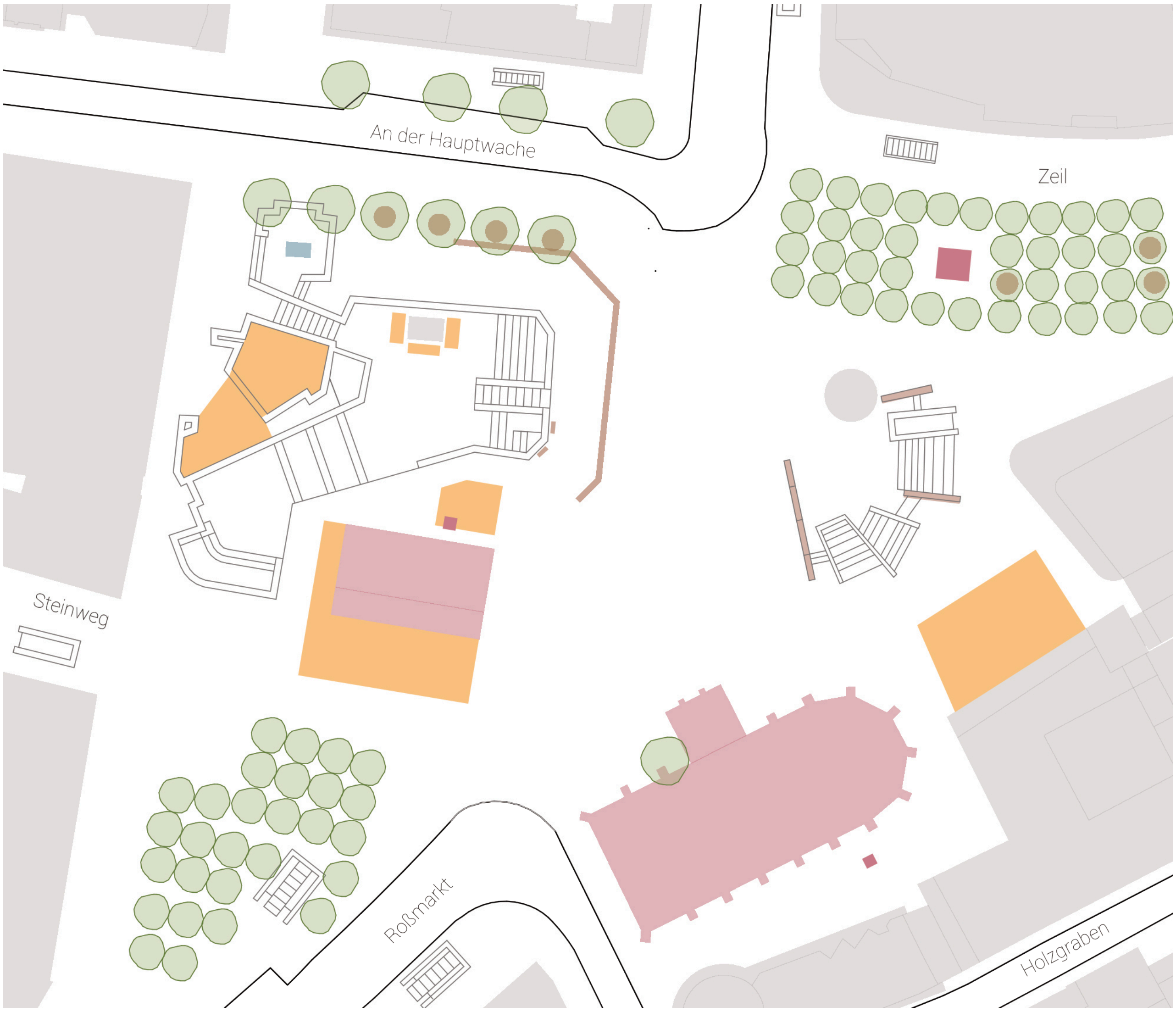
Visual integration color scale:

low high

r = 250 m 1:5 000

Image data base: © Stadtvermessungsamt Frankfurt am Main 08/2021

Amenities
Frankfurt am Main - Hauptwache



Outdoor gastronomy area
Seating
Monument/ Landmark
1:1 000
Greenery
Water/Fountain

Image data base: © Stadtvermessungsamt Frankfurt am Main 08/2021

Willy-Brandt-Platz, Frankfurt am Main

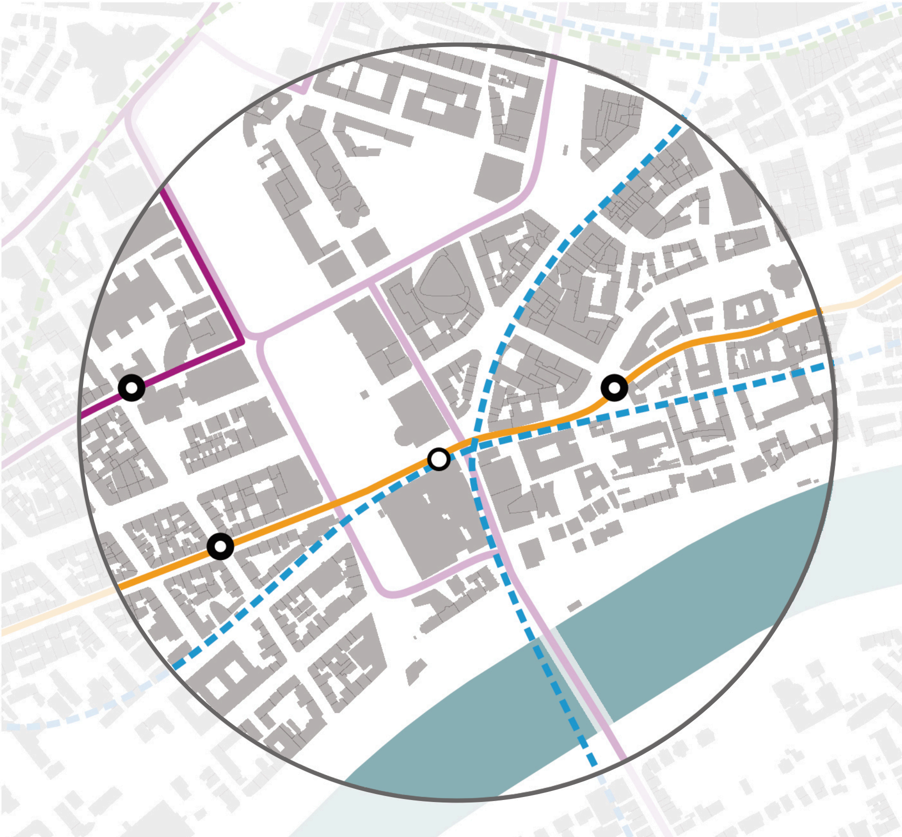
Street network
Frankfurt am Main - Willy-Brandt-Platz

Primary | Secondary | Tertiary | Residential | Other

Underground | r = 500 m | 1:10 000

Image data base: © OpenStreetMap contributors

Public transport network
Frankfurt am Main - Willy-Brandt-Platz



Commuter train Subway Tram Bus Night bus

Underground Station r = 500 m 1:10 000

Image data base: © OpenStreetMap contributors

Land use
Frankfurt am Main - Willy-Brandt-Platz

Residential	Commercial	Public facilities
Green area	Water	r = 500 m 1:10 000

Image data base: © OpenStreetMap contributors

Open space and developed land

Frankfurt am Main - Willy-Brandt-Platz

Building floor area | Open space public | Open space private

r = 250 m 1:5 000

Image data base: © OpenStreetMap contributors

Space allocation pedestrians
Frankfurt am Main - Willy-Brandt-Platz

Path/ circulation	Shared area	Linger/ stroll	r = 250 m
Cycle/ pedestrian	Shared area segregated	Green	1:5 000

Image data base: © Stadtvermessungsamt Frankfurt am Main 08/2021

Space allocation cyclists
Frankfurt am Main - Willy-Brandt-Platz

Cycle lane
Cycle/ pedestrian
Shared area
Shared area segregated
Linger/ stroll
Green
r = 250m
1:5 000

Image data base: © Stadtvermessungsamt Frankfurt am Main 08/2021

Mobility services
Frankfurt am Main - Willy-Brandt-Platz

Public

- Stop
- Underground station
- Info point
- Taxi

Private

- Parking lot
- Car park
- Underground parking
- Charging station

Shared

- Car sharing
- Bike sharing

Modes:

Commuter train | Subway | Tram | Bus | Night bus

Bicycle | Taxi | Car | r = 250 m | 1:5 000

Image data base: © Stadtvermessungsamt Frankfurt am Main 08/2021

VGA

Frankfurt am Main - Willy-Brandt-Platz

Visual integration color scale:

low high

r = 250 m 1:5 000

Amenities
Frankfurt am Main - Willy-Brandt-Platz

Outdoor gastronomy area
Seating
Monument/ Landmark
1:1 000
Greenery
Water/Fountain
Roof waiting area

Image data base: © Stadtvermessungsamt Frankfurt am Main 08/2021

Zoo, Frankfurt am Main

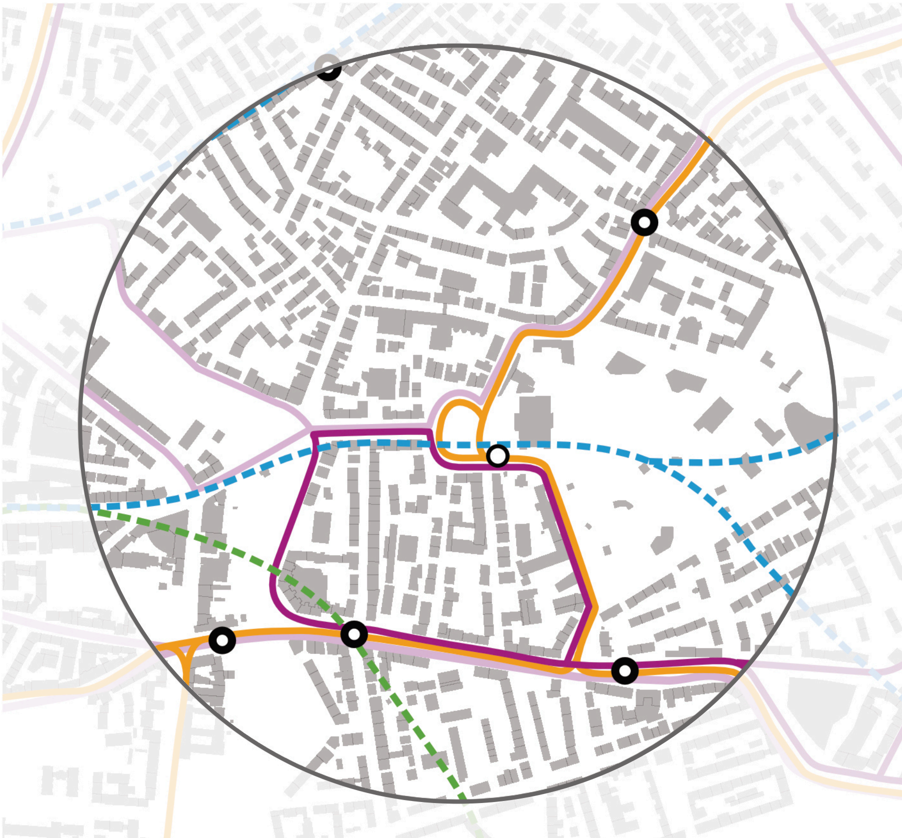
Street network
Frankfurt am Main - Zoo

Primary
Secondary
Tertiary
Residential
Other
Underground
r = 500 m
1:10 000

Image data base: © OpenStreetMap contributors

Public transport network

Frankfurt am Main - Zoo

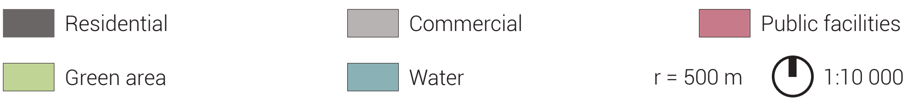


Commuter train | Subway | Tram | Bus | Night bus

Underground | Station | r = 500 m | 1:10 000

Image data base: © OpenStreetMap contributors

Land use
Frankfurt am Main - Zoo



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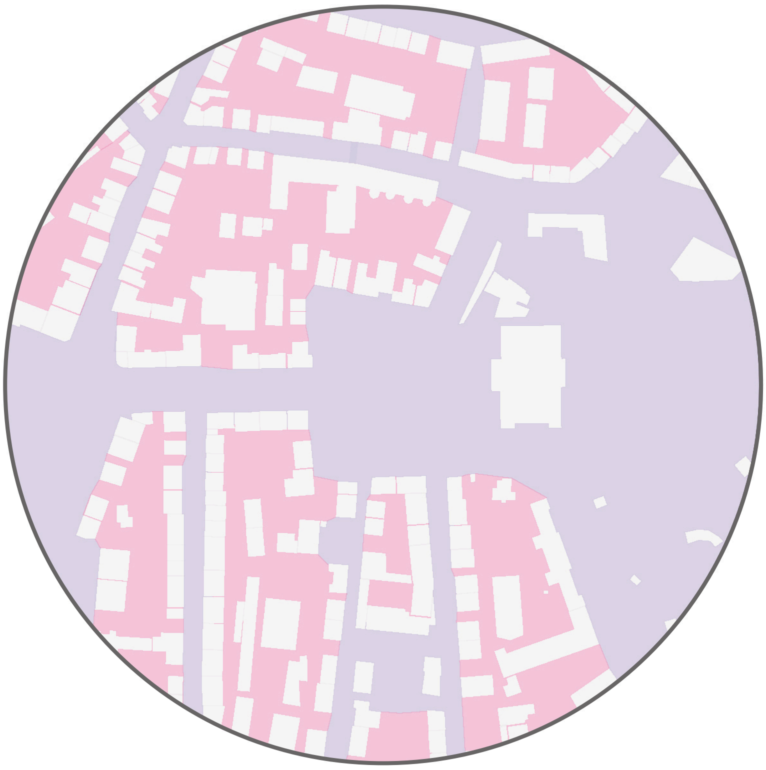
Open space and developed land

Frankfurt am Main - Zoo



Building floor area   Open space public   Open space private

r = 250 m   1:5 000

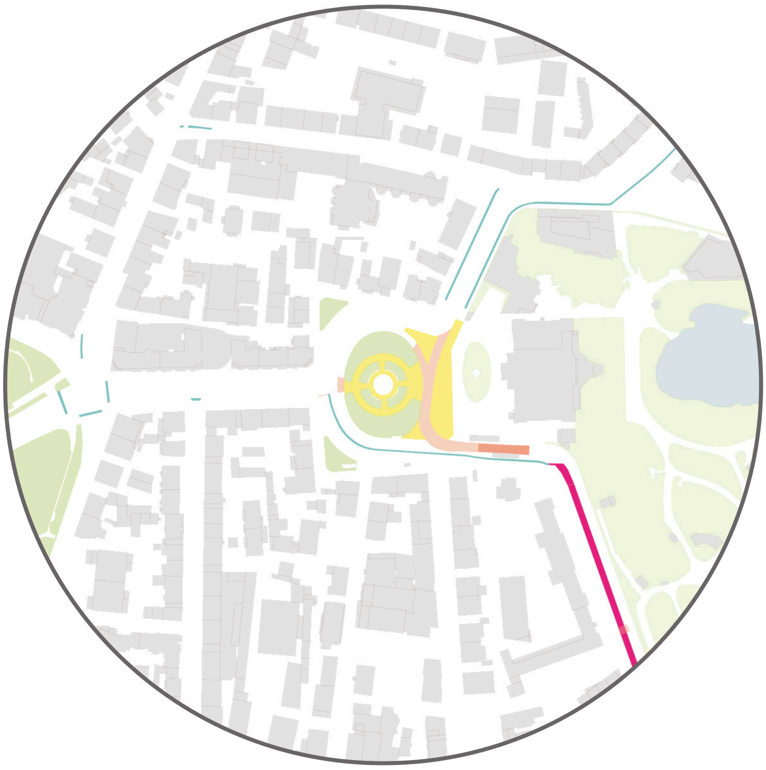
Image data base: © OpenStreetMap contributors

Space allocation pedestrians
Frankfurt am Main - Zoo

	Path/ circulation		Shared area		Linger/ stroll		r = 250 m
	Cycle/ others		Shared area segregated		Green		1:5 000

Image data base: © Stadtvermessungsamt Frankfurt am Main 08/2021

Space allocation cyclists
Frankfurt am Main - Zoo



Cycle lane	Shared area	Linger/ stroll	r = 250m
Cycle/ others	Shared area segregated	Green	1:5 000

Image data base: © Stadtvermessungsamt Frankfurt am Main 08/2021

Mobility services
Frankfurt am Main - Zoo

Public
- Stop
- Underground station
- Info point
- Taxi

Private
- Parking lot
- Car park
- Underground parking
- Charging station

Shared
- Car sharing
- Bike sharing

Modes:

Commuter train | Subway | Tram | Bus | Night bus
Bicycle | Taxi | Car | r = 250 m | 1:5 000

Image data base: © Stadtvermessungsamt Frankfurt am Main 08/2021

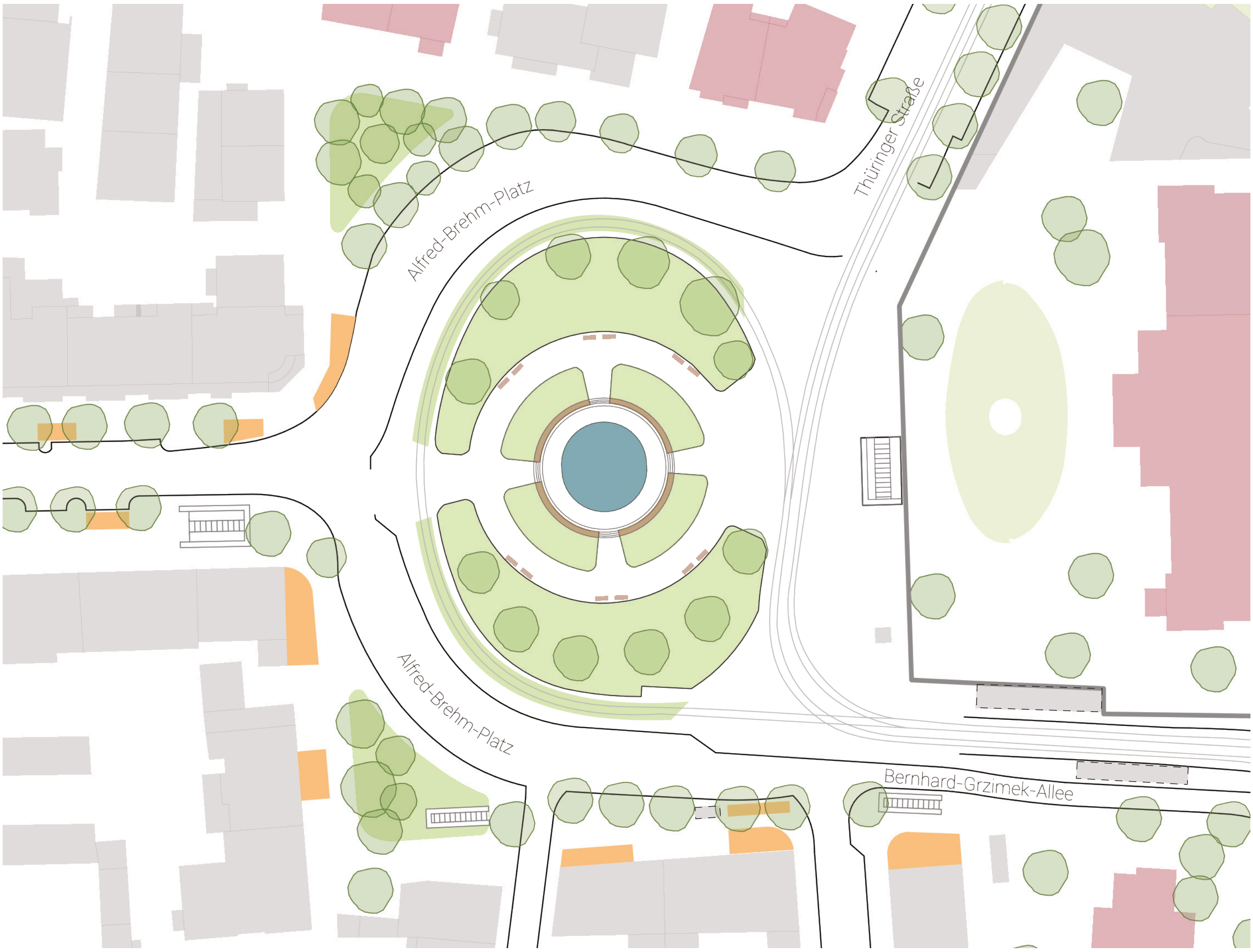
VGA
Frankfurt am Main - Zoo

Visual integration color scale:

r = 250 m

1:5 000

Amenities
Frankfurt am Main - Zoo



Outdoor gastronomy area
Seating
Monument/ Landmark
1:1 000
Greenery
Water/Fountain
Roof waiting area

Image data base: © Stadtvermessungsamt Frankfurt am Main 08/2021

Münsterplatz, Mainz

Street network
Mainz - Münsterplatz

Primary Secondary Tertiary Residential Other

Underground r = 500 m 1:10 000

Image data base: © OpenStreetMap contributors

Public transport network

Mainz - Münsterplatz

Commuter train | Subway | Tram | Bus | Night bus

Underground | Station | r = 500 m | 1:10 000

Image data base: © OpenStreetMap contributors

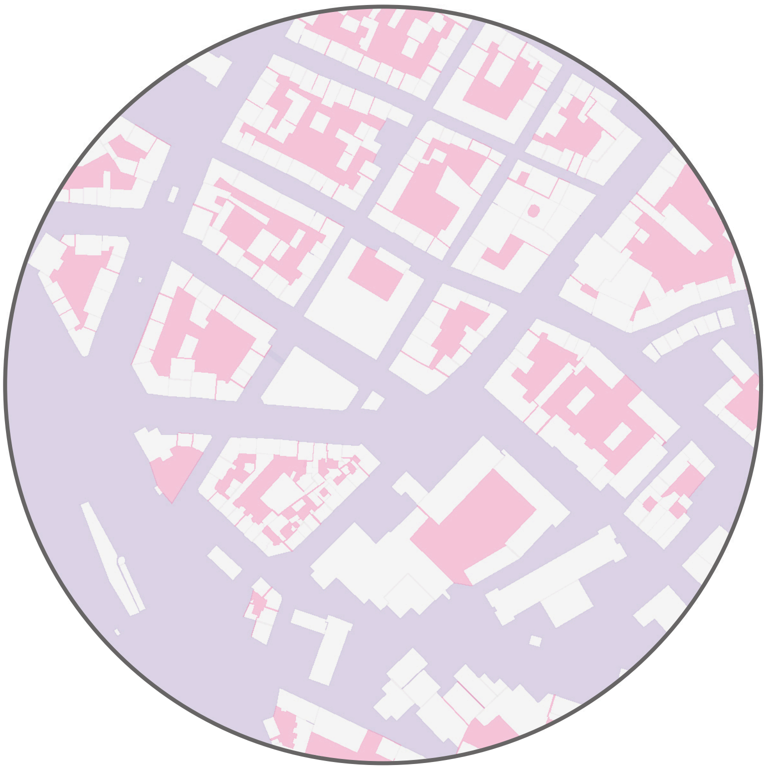
Land use
Mainz - Münsterplatz

Residential
Commercial
Public facilities
Green area
Water
r = 500 m
1:10 000

Image data base: © OpenStreetMap contributors

Open space and developed land

Mainz - Münsterplatz



Building floor area | Open space public | Open space private

r = 250 m 1:5 000

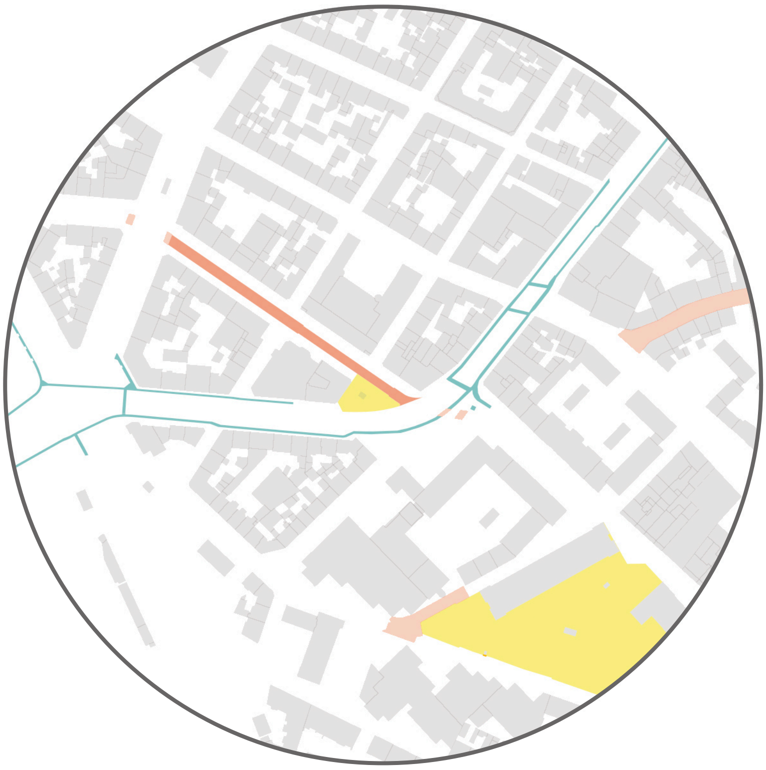
Image data base: © OpenStreetMap contributors

Space allocation pedestrians
Mainz - Münsterplatz

Path/ circulation	Shared area	Linger/ stroll	r = 250 m
Cycle/ pedestrian	Shared area segregated	Green	1:5 000

Image data base: © Stadt Mainz

Space allocation cyclists
Mainz - Münsterplatz

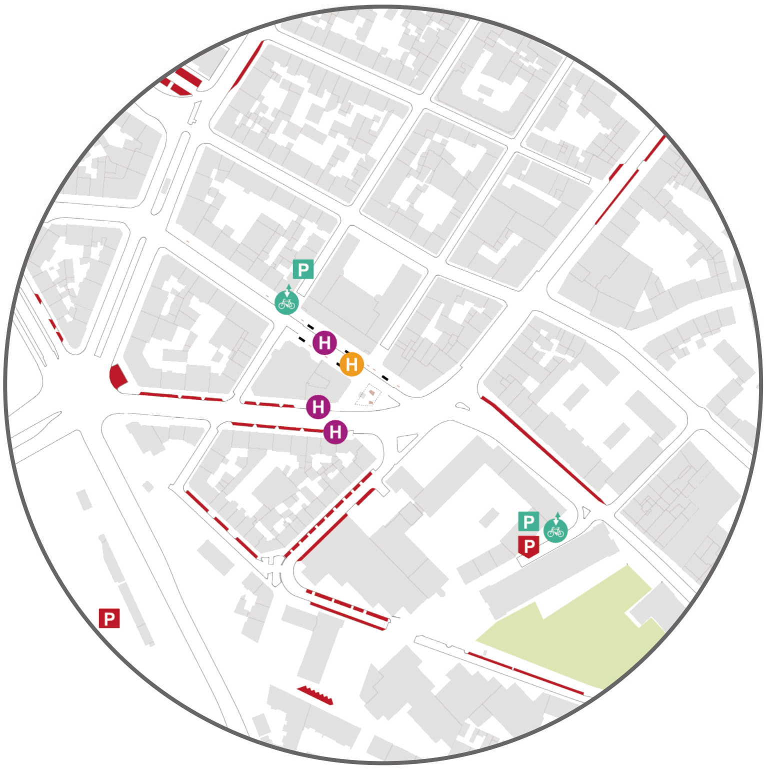


Cycle lane	Shared area	Linger/ stroll	r = 250m
Cycle/ pedestrian	Shared area segregated	Green	1:5 000

Image data base: © Stadt Mainz

Mobility services

Mainz - Münsterplatz



Public

- Stop
- Underground station
- Info point
- Taxi

Private

- Parking lot
- Car park
- Underground parking
- Charging station

Shared

- Car sharing
- Bike sharing

Modes:

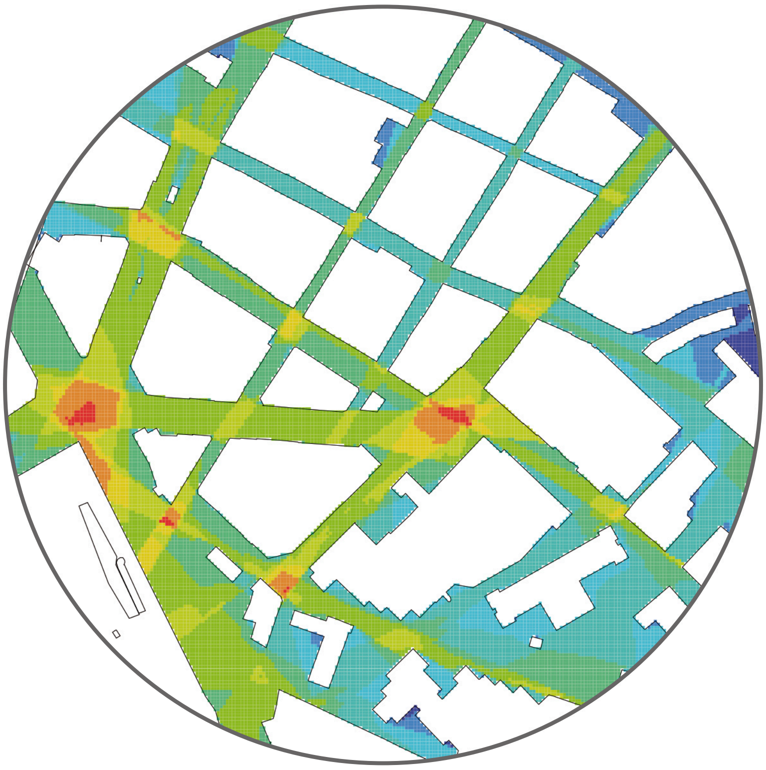
Commuter train | Subway | Tram | Bus | Night bus

Bicycle | Taxi | Car | r = 250 m | 1:5 000

Image data base: © Stadt Mainz

VGA

Mainz - Münsterplatz



Visual integration color scale:

low high

r = 250 m 1:5 000

Image data base: © Stadt Mainz

Amenities
Mainz - Münsterplatz

Outdoor gastronomy area
Seating
Monument/ Landmark
1:1 000
Greenery
Water/Fountain
Roof waiting area

Image data base: © Stadt Mainz

Lessingstraße, Mainz

Street network

Mainz - Lessingstraße

Primary Secondary Tertiary Residential Other

Underpass r = 500 m 1:10 000

Image data base: © OpenStreetMap contributors

Public transport network
Mainz - Lessingstraße

Commuter train | Subway | Tram | Bus | Night bus

Underpass | Station | r = 500 m | 1:10 000

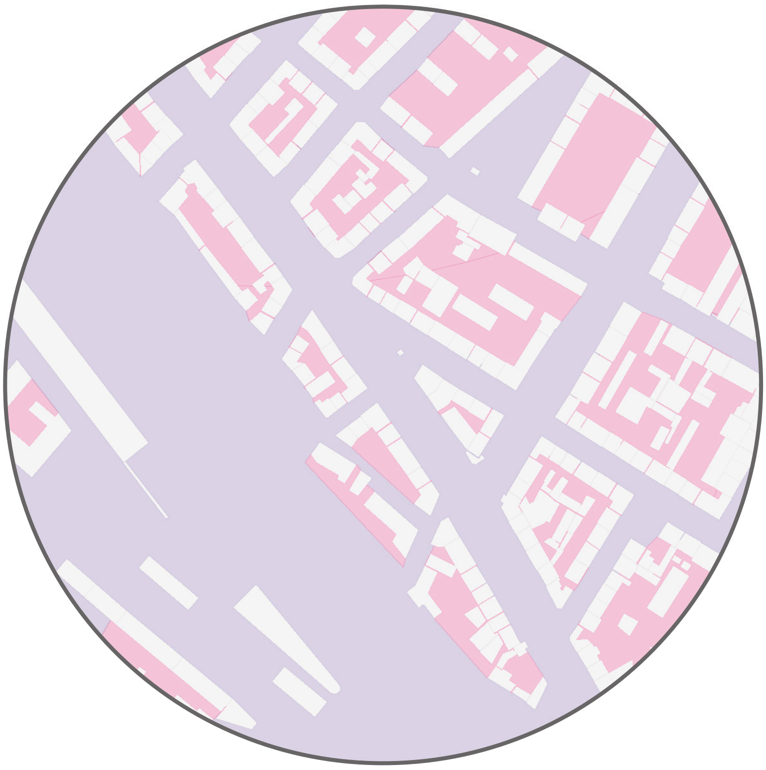
Image data base: © OpenStreetMap contributors

Land use
Mainz - Lessingstraße

Residential | Commercial | Public facilities
Green area | Water | r = 500 m | 1:10 000

Image data base: © OpenStreetMap contributors

Open space and developed land
Mainz - Lessingstraße



Building floor area | Open space public | Open space private

r = 250 m | 1:5 000

Image data base: © OpenStreetMap contributors

Space allocation pedestrians
Mainz - Lessingstraße

Path/ circulation

Shared area

Linger/ stroll

r = 250 m

Cycle/ pedestrian

Shared area segregated

Green

1:5 000

Image data base: © Stadt Mainz

Space allocation cyclists

Mainz - Lessingstraße

Cycle lane	Shared area	Linger/ stroll	r = 250m
Cycle/ pedestrian	Shared area segregated	Green	1:5 000

Image data base: © Stadt Mainz

Mobility services
Mainz - Lessingstraße

Public
- Stop
- Underground station
- Info point
- Taxi

Private
- Parking lot
- Car park
- Underground parking
- Charging station

Shared
- Car sharing
- Bike sharing

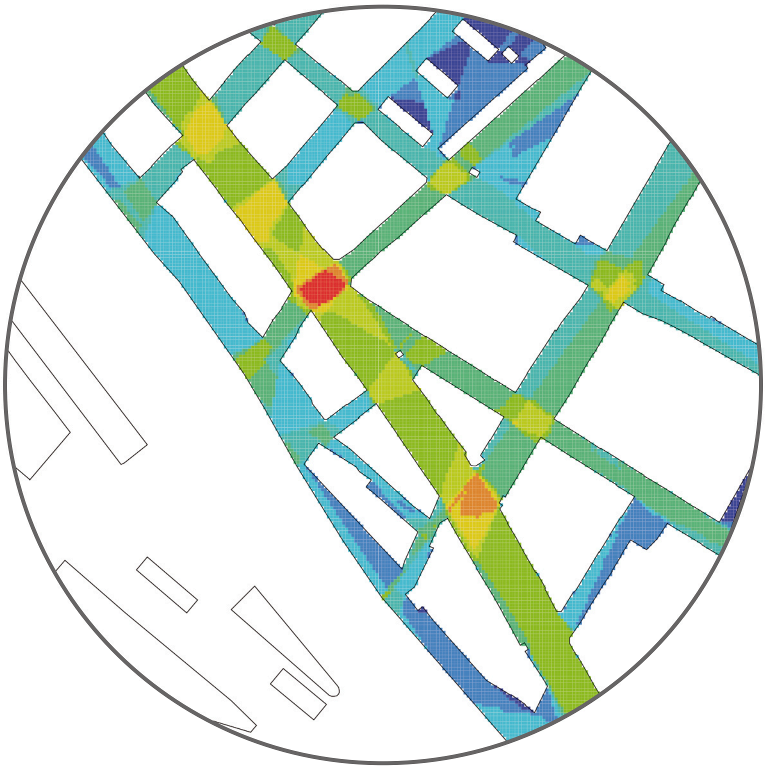
Modes:

Commuter train | Subway | Tram | Bus | Night bus

Bicycle | Taxi | Car | r = 250 m | 1:5 000

Image data base: © Stadt Mainz

VGA
Mainz - Lessingstraße



Visual integration color scale:

low high

r = 250 m 1:5 000

Image data base: © Stadt Mainz

Amenities
Mainz - Lessingstraße

Outdoor gastronomy area | Seating | Monument/ Landmark | 1:1 000

Greenery | Water/Fountain | Roof waiting area

Image data base: © Stadt Mainz

Luisenplatz, Darmstadt

Street network
Darmstadt - Luisenplatz

Primary Secondary Tertiary Residential Other

Underground r = 500 m 1:10 000

Image data base: © OpenStreetMap contributors

Public transport network
Darmstadt - Luisenplatz

Commuter train | Subway | Tram | Bus | Night bus

Underground | Station | r = 500 m | 1:10 000

Image data base: © OpenStreetMap contributors

Land use
Darmstadt - Luisenplatz

Residential	Commercial	Public facilities
Green area	Water	r = 500 m 1:10 000

Image data base: © OpenStreetMap contributors

Open space and developed land

Darmstadt - Luisenplatz

Building floor area   Open space public   Open space private

r = 250 m   1:5 000

Image data base: © OpenStreetMap contributors

Space allocation pedestrians
Darmstadt - Luisenplatz

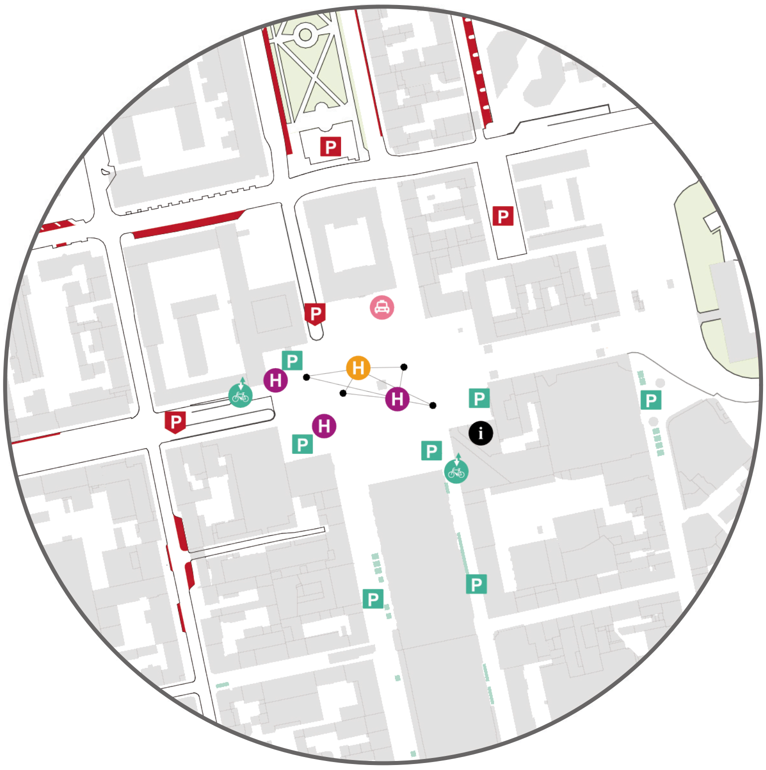
Path/ circulation	Shared area	Linger/ stroll	r = 250 m
Cycle/ pedestrian	Shared area segregated	Green	1:5 000

Image data base: © OpenStreetMap contributors with author's additions

Space allocation cyclists
Darmstadt - Luisenplatz

Image data base: © OpenStreetMap contributors with author's additions

Mobility services
Darmstadt - Luisenplatz



Public

Stop

Underground station

Info point

Taxi

Private

Parking lot

Car park

Underground parking

Charging station

Shared

Car sharing

Bike sharing

Modes:

Commuter train | Subway | Tram | Bus | Night bus

Bicycle | Taxi | Car | r = 250 m | 1:5 000

Image data base: © OpenStreetMap contributors with author's additions

VGA
Darmstadt - Luisenplatz

Visual integration color scale:

low high

r = 250 m 1:5 000

Image data base: © OpenStreetMap contributors with author's additions

Amenities
Darmstadt - Luisenplatz

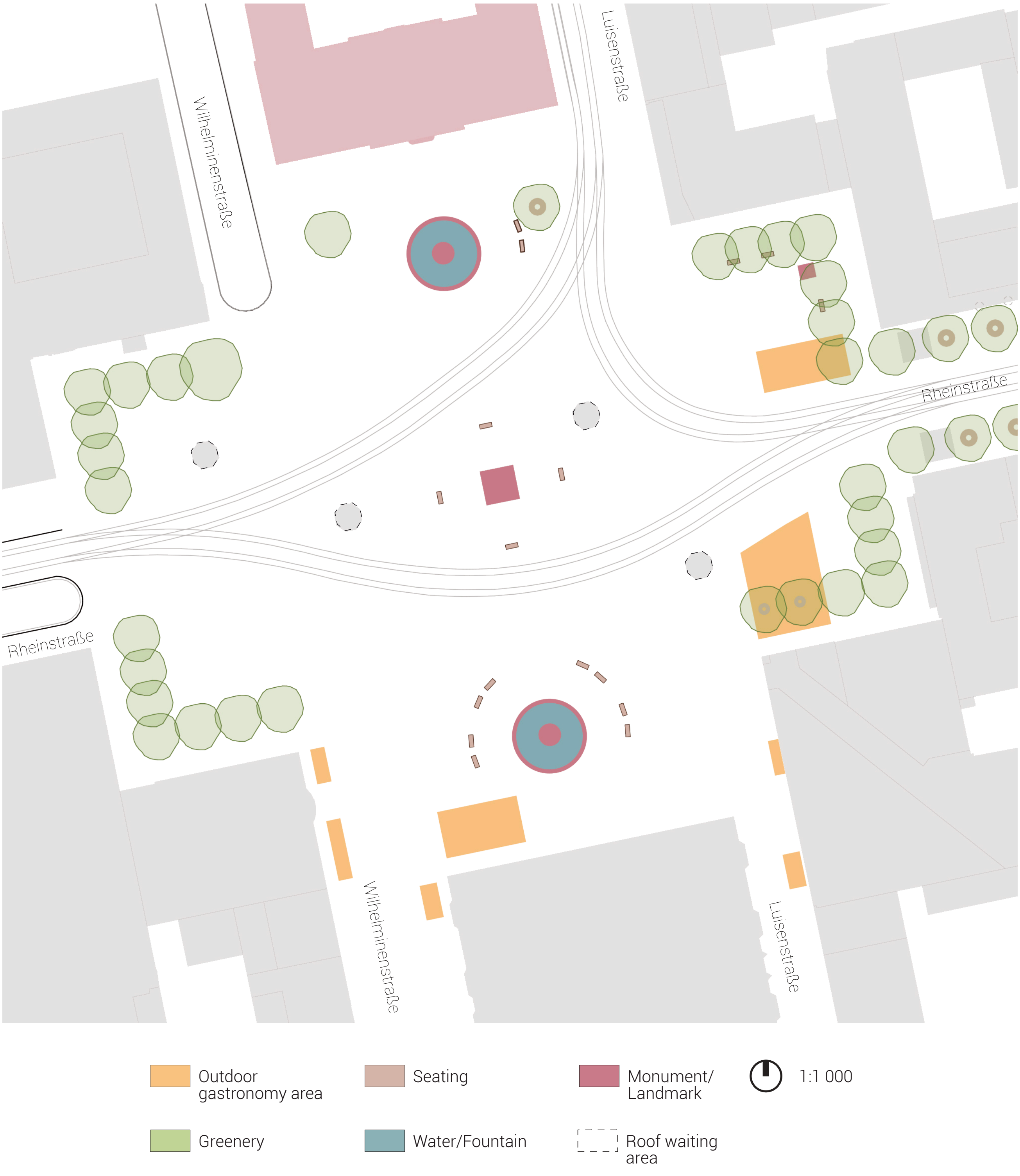


Image data base: © OpenStreetMap contributors with author's additions

Marktplatz, Offenbach am Main

Street network
Offenbach am Main - Marktplatz

Primary Secondary Tertiary Residential Other

Underground r = 500 m 1:10 000

Image data base: © OpenStreetMap contributors

Public transport network
Offenbach am Main - Marktplatz

Commuter train | Subway | Tram | Bus | Night bus

Underground | Station | r = 500 m | 1:10 000

Image data base: © OpenStreetMap contributors

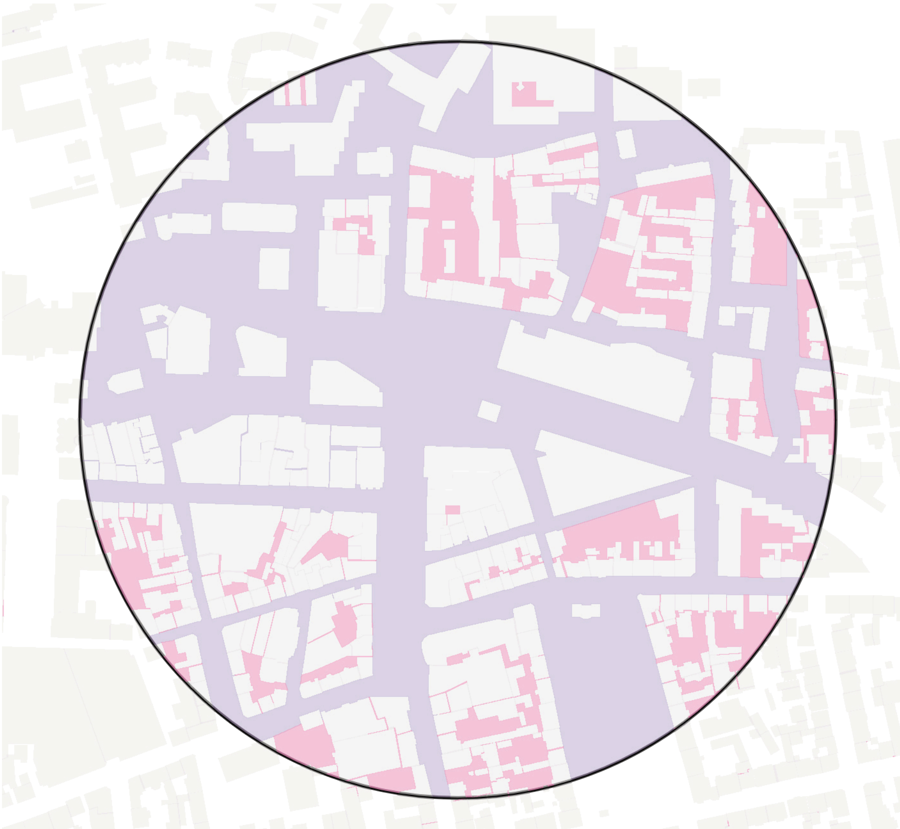
Land use
Offenbach am Main - Marktplatz

Residential	Commercial	Public facilities
Green area	Water	r = 500 m · 1:10 000

Image data base: © OpenStreetMap contributors

Open space and developed land

Offenbach am Main - Marktplatz



Building floor area   Open space public   Open space private

r = 250 m   1:5 000

Image data base: © OpenStreetMap contributors

Space allocation pedestrians
Offenbach am Main - Marktplatz

Path/ circulation	Shared area	Linger/ stroll	r = 250 m
Cycle/ pedestrian	Shared area segregated	Green	1:5 000

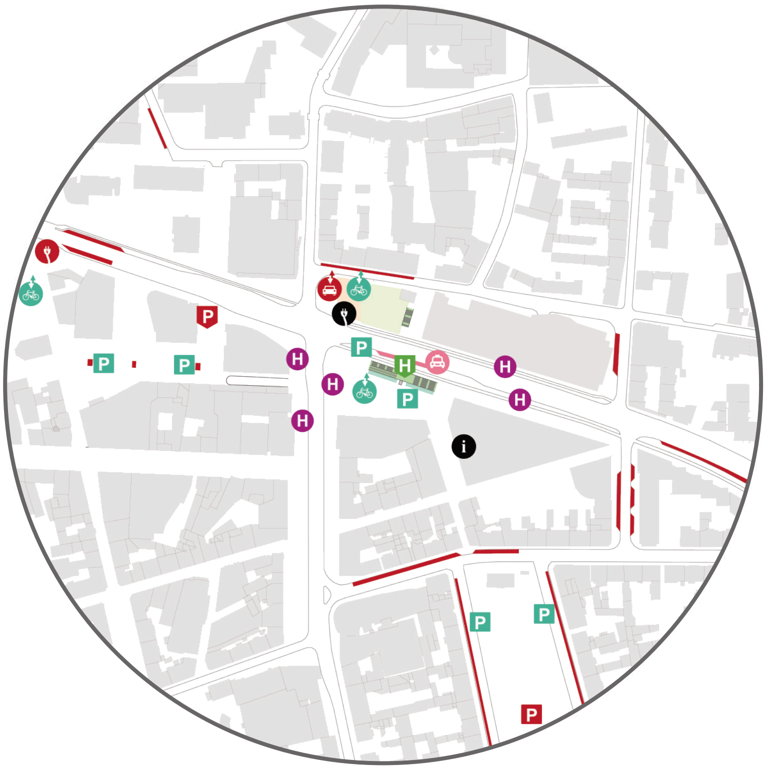
Image data base: © Stadt Offenbach am Main

Space allocation cyclists
Offenbach am Main - Marktplatz

Cycle lane	Shared area	Linger/ stroll	r = 250m
Cycle/ pedestrian	Shared area segregated	Green	1:5 000

Image data base: © Stadt Offenbach am Main

Mobility services
Offenbach am Main - Marktplatz



Public
- Stop
- Underground station
- Info point
- Taxi

Private
- Parking lot
- Car park
- Underground parking
- Charging station

Shared
- Car sharing
- Bike sharing

Modes:

Commuter train | Subway | Tram | Bus | Night bus

Bicycle | Taxi | Car | r = 250 m | 1:5 000

Image data base: © Stadt Offenbach am Main

VGA
Offenbach am Main - Marktplatz

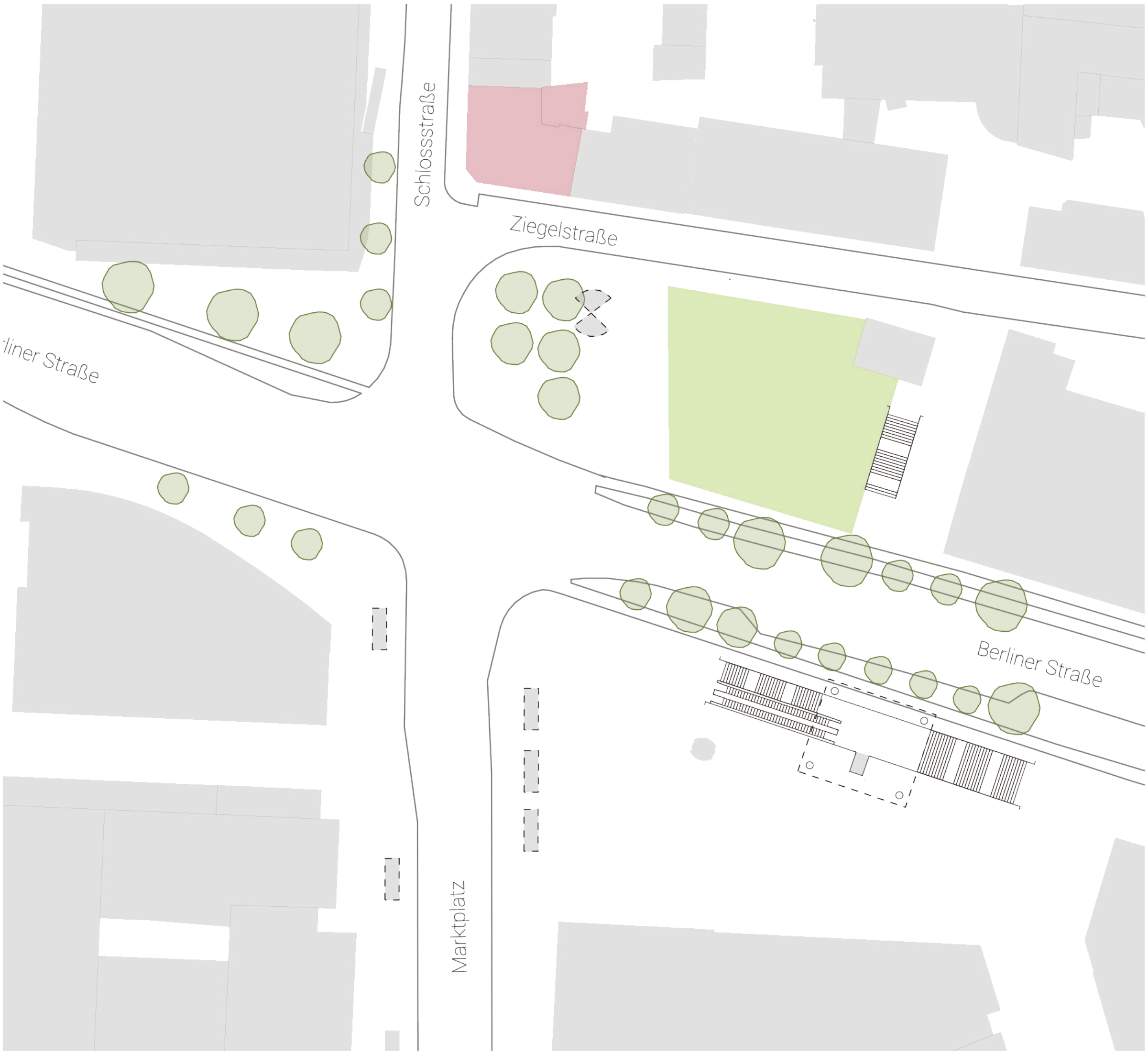
Visual integration color scale:

r = 250 m 1:5 000

Image data base: © Stadt Offenbach am Main

Amenities

Offenbach am Main - Marktplatz



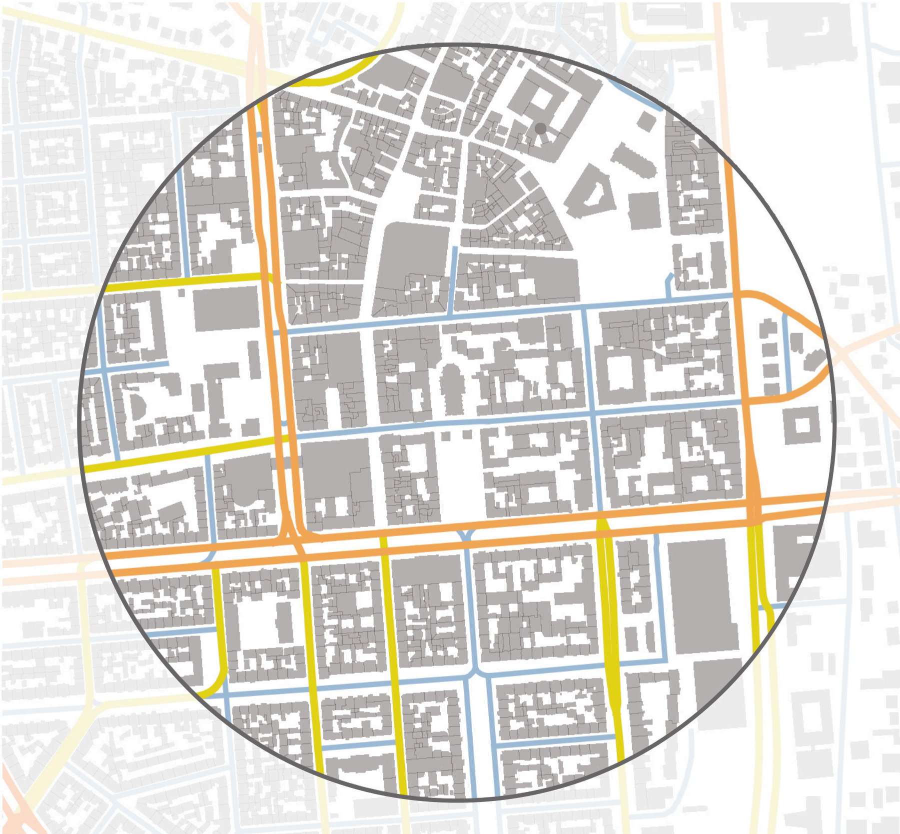
Outdoor gastronomy area
Seating
Monument/ Landmark
1:1 000
Greenery
Water/Fountain
Roof waiting area

Image data base: © Stadt Offenbach am Main

Luisenplatz, Wiesbaden

Street network

Wiesbaden - Luisenplatz

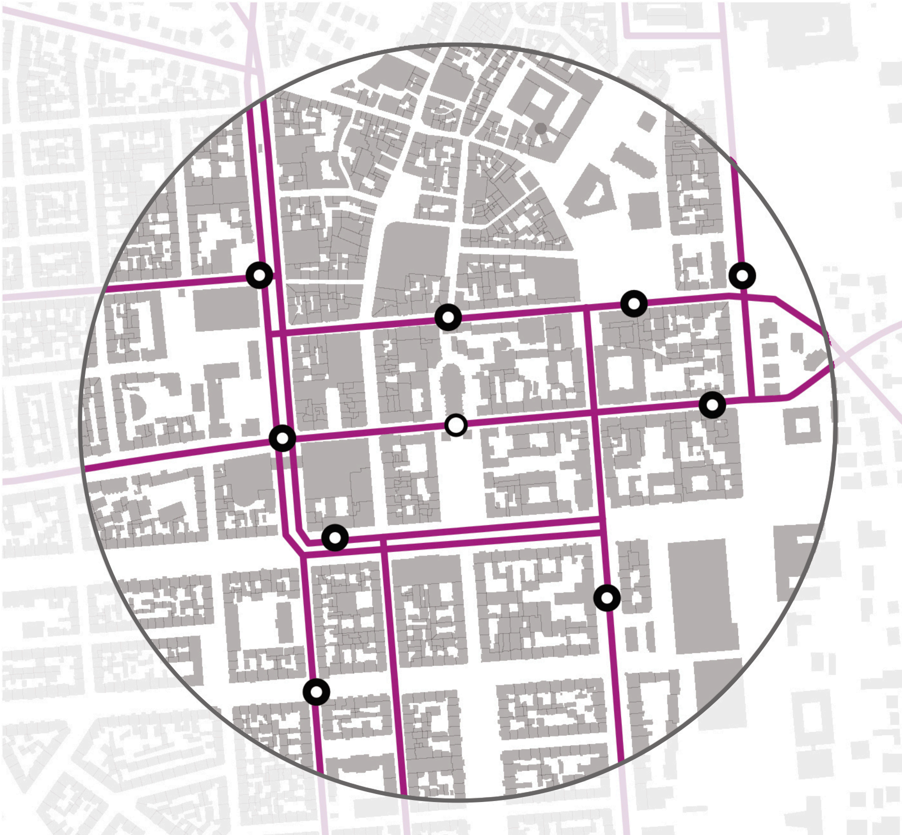


Primary Secondary Tertiary Residential Other

Underground r = 500 m 1:10 000

Image data base: © OpenStreetMap contributors

Public transport network
Wiesbaden - Luisenplatz



Commuter train | Subway | Tram | Bus | Night bus

Underground | Station | r = 500 m | 1:10 000

Image data base: © OpenStreetMap contributors

Land use
Wiesbaden - Luisenplatz

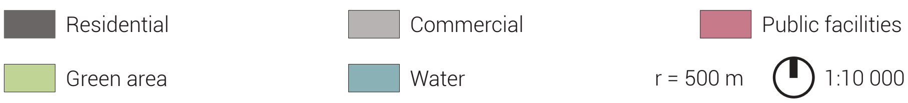


Image data base: © OpenStreetMap contributors

Open space and developed land

Wiesbaden - Luisenplatz

Building floor area | Open space public | Open space private

r = 250 m 1:5 000

Image data base: © OpenStreetMap contributors

Space allocation pedestrians
Wiesbaden - Luisenplatz

Path/ circulation	Shared area	Linger/ stroll	r = 250 m
Cycle/ pedestrian	Shared area segregated	Green	1:5 000

Image data base: © Stadt Wiesbaden

Space allocation cyclists
Wiesbaden - Luisenplatz

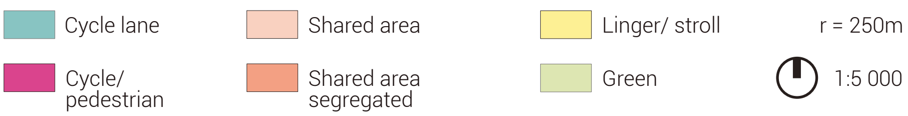
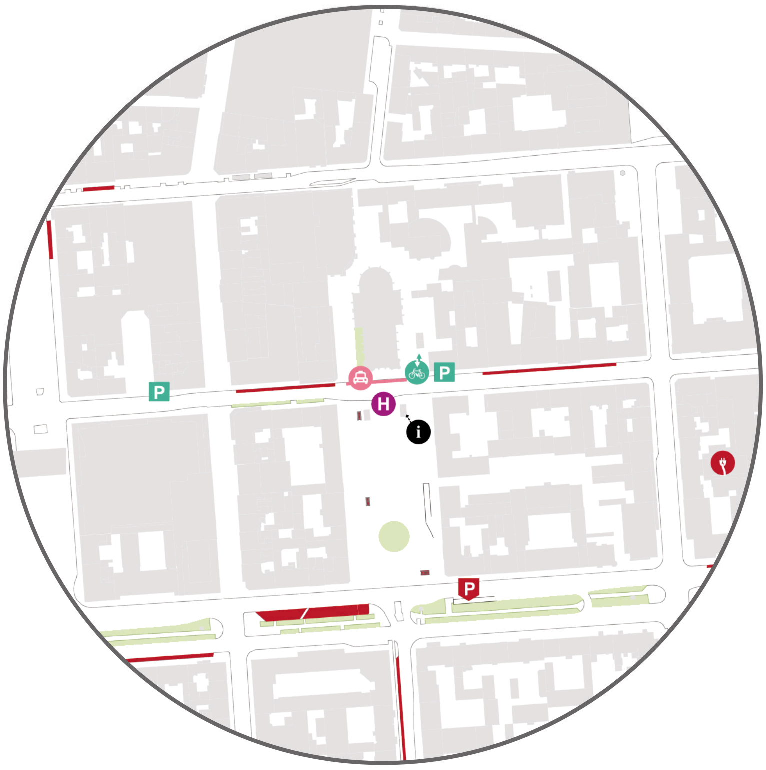


Image data base: © Stadt Wiesbaden

Mobility services

Wiesbaden - Luisenplatz



Public

- Stop
- Underground station
- Info point
- Taxi

Private

- Parking lot
- Car park
- Underground parking
- Charging station

Shared

- Car sharing
- Bike sharing

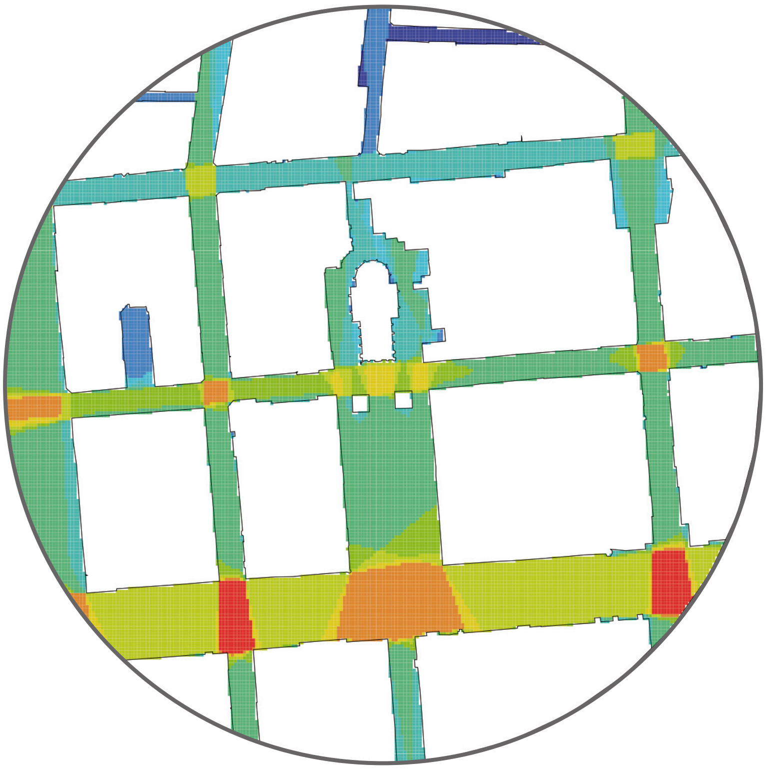
Modes:

Commuter train | Subway | Tram | Bus | Night bus

Bicycle | Taxi | Car | r = 250 m | 1:5 000

Image data base: © Stadt Wiesbaden

VGA
Wiesbaden - Luisenplatz



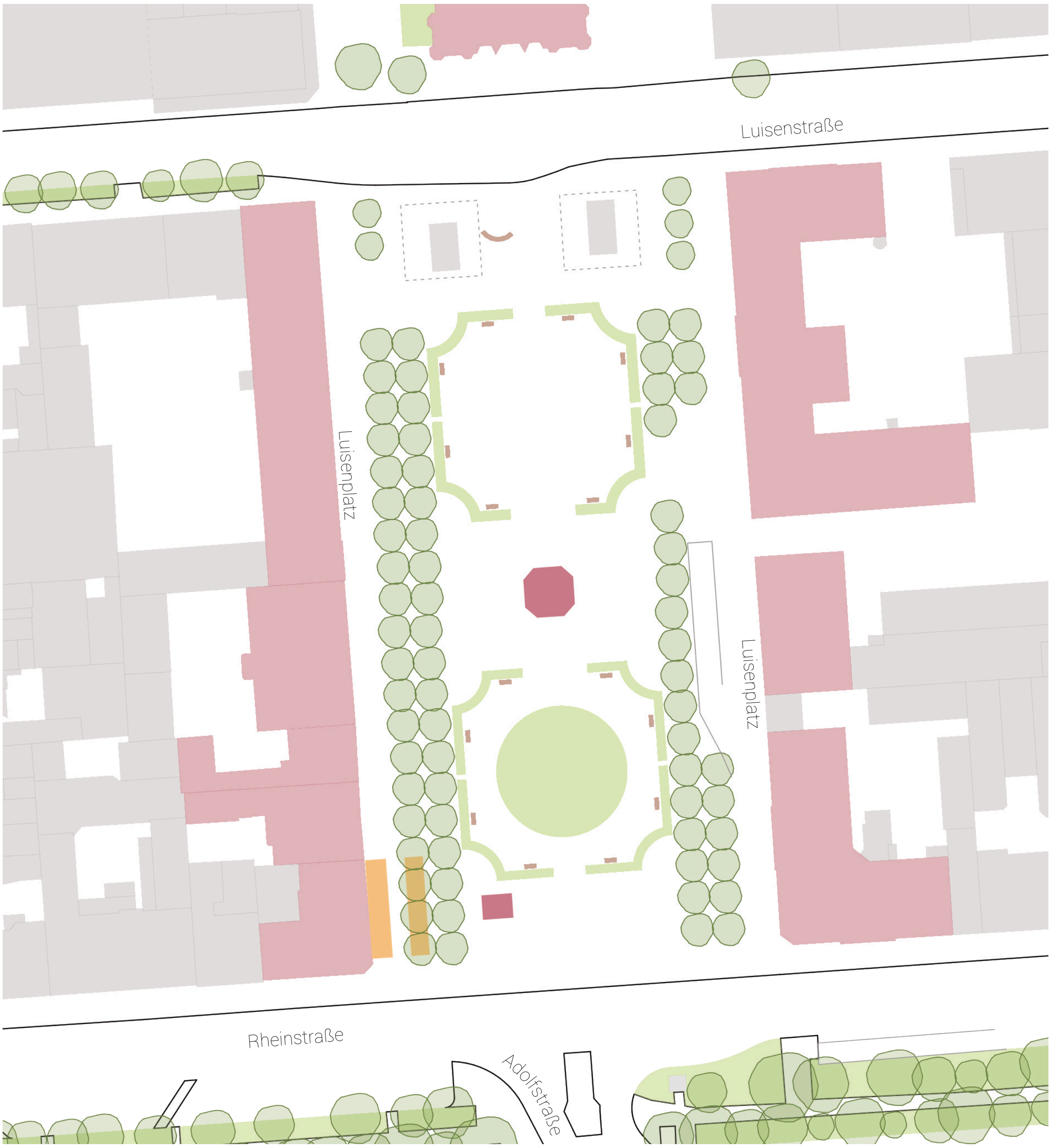
Visual integration color scale:

low high

r = 250 m 1:5 000

Image data base: © Stadt Wiesbaden

Amenities
Wiesbaden - Luisenplatz



Outdoor gastronomy area
Seating
Monument/ Landmark
1:1 000
Greenery
Water/Fountain
Roof waiting area

Image data base: © Stadt Wiesbaden

Systematic literature review criteria

1. Inclusion criteria

Language	English or translated into English from other languages	
Information sources	Electronic data bases	
	Google Scholar	https://scholar.google.com/
	ULB TU Darmstadt	https://hds.hebis.de/ulbda/EBSCO/Advanced
	HeBIS	https://portal.hebis.de/servlet/Top
	Avery Index to Architectural Periodicals	https://rzblx10.uni-regensburg.de/dbinfo/detail.php?bib_id=tuda&colors=&ocolors=&lett=f&tid=0&titel_id=546
Information type	Books, Scientific Papers, Academic Journals, Thesis Dissertations Past systematic literature reviews Reports, studies, grey literature	
Timeframe	a. 2006-2020; b. 1993-2020; c. 2013 - 2020 [see p. A-84]	
Geographical location	Predominantly Europe (and North America)	
Publication status	Published or university repositories	

2. Exclusion criteria

Information type	Commercial studies / studies from private companies
Geographical location	Global South / Developing countries

3. Search strategy

Qualitative and quantitative data
Internet search using websites mentioned in Section 1: Electronic Databases
Only the first 50 hits from each search will be checked for relevance. References of studies included in the review will also be searched for any further relevant citations missed by the above search.

4. Search criteria

Prioritise peer reviewed literature, studies from local or national governments, international institutions.
For detailed keywords and leading questions on each topic (a., b., c.), turn to p. A-84

5. Study selection

Literature shall be selected independently by author (M. Halblaub Miranda) and assistant (F. Fatima).
The studies shall be screened based on their titles and abstracts
Full studies shall be obtained, read entirely and analysed if they fulfil the criteria of inclusion or exclusion.
This selected literature shall be reviewed by author.

6. Data collection process

Relevant data shall be extracted from studies that fulfil criteria of inclusion.
This would include definitions, guidelines concepts and their comparisons and case studies.
The collected data shall be summarized and synthesized
Literature search results will be uploaded to the local department server.

7. Risk of bias across studies

Following steps shall be taken to mitigate risk of bias amongst studies:
Frameworks by international organizations shall be studied.
A diverse set of case studies shall be analysed.
A protocol shall be created.

4a. Search criteria: Sustainable Urban Development (SUM)

Concepts or keywords including but not limited to the following:
Sustainable Urban Mobility (SUM)
SUM Measures
Sustainable Urban Mobility Plan (SUMP)
SUMP Case Studies

Questions to be answered by the review:
How is SUM defined? When did this planning concept arise? How has it evolved since then? What is the internationally recognized definition?
How can they be emulated in different cities? What factors need to be taken into account beforehand? What is the framework or procedure to be followed?
What is a SUMP? What are its characteristics and objectives? What are the benefits of SUMP? How can SUMP be integrated into planning?
What are the key differences between the two concepts? How do stakeholders, visions and timeframes differ between the two?
How is SUMP being implemented in cities? What is the state of the art in Europe? Is there a difference in the implementation of SUMP amongst different countries?

4b. Search criteria: Transit Oriented Development (TOD)

Concepts or keywords including but not limited to the following:
Transit Oriented Development (TOD)
Walkability, Non-motorized transport; Mixed Land Use, High Density, Transit
TOD and Environment
TOD Frameworks and Guidelines
TOD and Urban Liveability
Contemporary implementation of TOD; Case studies of TOD

Questions to be answered by the review:
How is TOD defined? When did this planning concept arise? How has it evolved since then? What are different types of TOD? What are the benefits of TOD? What are the components of TOD?
How are the concepts walkability and non-motorized transport connected with/influenced by TOD? How do they [Mixed Land Use, High Density, Transit] facilitate the concept of TOD?
How is TOD useful in reducing GHG emissions?
What are the criteria for TOD? What parameters can be used to assess neighbourhoods before introducing TOD?
What frameworks exist for this? Have they changed since the introduction of the concept?
What are specific guidelines to implement TOD?
How does TOD impact urban liveability? Are there case studies / evidence to prove it?
What is the state of the Art in Europe? How is the concept of TOD different as compared to the United States?
How is TOD being implemented in European cities?

4c. Search criteria: Mobility Stations, Mobile Stations, Mobility Points, Mobility Hubs, Intermodal Exhange Stations (IESs)

Concepts or keywords including but not limited to the following:
Mobility ***
– Stations
– Points
– Hubs
Mobile Stations
Intermodal Exchange Stations (IESs)

Questions to be answered by the review:
What are Mobility ***/Mobile Stations/IESs? Where and when did the concept arise? What was the need to create them? How did they evolve?
How can they be categorized? What are their benefits? Difference between the various concepts and their implementation.
Components and Services of Mobility ***/Mobile Stations/IESs; Tiers of Integration of Mobility ***/Mobile Stations/IESs; Case studies of Mobility ***/Mobile Stations/IESs
What is the perception, acceptance, impact on mobility behaviour, car ownership, and CO2 emissions of Mobility ***/Mobile Stations/IESs in various cities in Germany?

Enjoy being on the move!