Integrating Active and Public Transportation Modes in Berlin

An evaluation research study to the Radbahn U1 project

Shankar Narayanan Iyer

Supervisor: Alvaro Valera Sosa

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Statement of authenticity of material

This thesis contains no material which has been accepted for the award of any other degree or diploma in any institution and to the best of my knowledge and belief, the research contains no material previously published or written by another person, except where due reference has been made in the text of the thesis

Shankar Narayanan Iyer

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Abstract:

Integrating Active and Public transportation modes has been a topic of foremost importance for major cities around the world. It is believed to be a healthy, eco-friendly and economical solution for the urban traffic related issues. Major European cites, like Copenhagen and Amsterdam are leading by example in resolving traffic related issues by integrating Active and Public transport network in the city. The Senate department of Urban Development and the Environment in Berlin, has recently taken strides towards strengthening the biking infrastructure in the city by formulating a new "Biking strategy" to encourage the citizens to use bikes over private motorized vehicles. Aligning to the principles of which, a group of visionary architects and urban planners came up with a bike project, called "Radbahn", which aims to use the forgotten space under the city's oldest U-bahn route (U1) and use it for active travel purposes.

This study was an evaluation research, conducted under the working framework of Walkability for Health on the "Radbahn" cycle track to examine its role in integrating active and public modes of transportation. The first objective of the evaluation research was to examine the immediate built environment conditions around the track and perform Macro-level factor study to determine the most suitable and the least suitable sections for active travel. Following it, the second objective of the study was to identify streets with high scope of active travel and conduct Meso-level factor study to bring out the conditions of walking and biking at the junctions and street segments connecting the radbahn. Lastly, the final objective of the research was to conduct a detailed Meso-level study on the two sections selected from Macro-level study and examine the condition of Active path continuity and Active block connectivity. Further, the research discussed the outcomes of each evaluation and suggested recommendation to the project to improve the condition in integrating active and public modes of transportation in Berlin.

Keywords: Radbahn, Walkability for Health, Active travel, Active path continuity, Active block connectivity.

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1. Introduction

An established Integrated transportation system is of utmost importance in major cities around the world, as they play a vital role in integrating movement of citizens and goods in the city. The public transportation system of a city plays a vital role in integrating transportation networks, as it provides opportunity for mass commuting within the city. An Integrated public transportation system can be defined as integration of different transport modes working on different transport networks to improve the connectivity in a city (Palaikova. B, 2013). Moreover, in the present age of rapid urbanization, cities need to provide smarter, sustainable and economical solutions of transportation issues. With seventy percent of the world's population projected to live in urban setup by 2030, the transportation system in the cities will see a huge rise in demand for a sustainable and uninterrupted way of commuting (ARUP 2016). Additionally, integrating the public transportation by causing minimal to no environmental deterioration will be the key looking forward. The high rise in future demand of integrating transportation in cities can only be fulfilled by making public transportation more attractive, affordable and efficient for the system. This will be majorly achieved by creating solid infrastructure for public transportation which would attract citizens to use the facility and ditch the motorized private vehicles.

According to a study by European Union (2012), to tackle the problems of traffic related congestion and pollution, the major cities in Europe are seeking for smarter solutions in transportation. One of the most understated approach used by the some of the modern cities to reduce the traffic related issues is by strengthening the infrastructure of active commuting. The cities of Copenhagen and Amsterdam with their path breaking achievement of integrating active transportation with their public transportation, have pioneered their way to tackle this global issue. The role of active travel (walking, biking and all other mode of non-motorized commuting) is usually undermined in our daily life activity. The walk from our home to the nearest public transport outlet or a walk towards the car at the parking lot two blocks away from the work place is usually neglected in the modal share of our daily travel. However, these non-motorized/ active movement of citizens needs to be channelized in a way to achieve better synchronization with the public transportation facility in the

cities. To achieve this foot, a city requires a vibrant city administration authority for the support in policy making and a visionary academic backing.

Following the path of the transportation model of Copenhagen and Amsterdam, the Senate Department for Urban Development and the Environment in Berlin has taken strides towards strengthening the integration of active and public modes of transportation. In 2013 the Senate Department for Urban Development and the Environment came up with a new biking strategy for the city to encourage biking amongst the citizens. The city administration has encouraged an active participation from the citizens by providing them platform to voice their suggestions for improving biking in their neighbourhood. This study was done on one of such solutions suggested by a group of visionary architects and urban planners in the form of a cycle track named “Radbahn”. The cycle track of “Radbahn” focuses on providing a traffic free movement for the bikers in the city of Berlin under the city’s oldest U-Bahn route (U1).

Further, the project promises to provide a shared space for active commuters along the periphery of the route of U1 to enhance the socio-economic value of the area around the track. Furthermore, the project plans to provide mobility hubs at selected U-Bahn stations for the commuters to increase the number of bike related egress trips in the region. In unique manner, this track, ranging 9 km in approximation, passes through various neighborhoods and sees varied built environment conditions. And, this thesis is an evaluation research study seeking to examine the role of the renowned “Radbahn” track in achieving Integration between the public and active transportation modes in Berlin under the working framework of “Walkability for Health”.

2. Background

A renowned study by the Strategies for Public Transport In Cities (SPUTNIC) reveal that, a non-integrated mode of transport network causes problems to the riders which ultimately reduces the ridership and in turn increases the usage of private vehicles. Addressing the "comfort" level of the commuter, the report further acknowledges the lack of 'one ticket for one journey' policy as a major flaw in the effort of making the journey more comfortable. The lack of option for the commuters to travel with a single ticket on different networks of public transportation makes the system less efficient in attracting commuters. Secondly, the report pinpoints at the lack of knowledge in tariff system among the riders, due to independent network usually lead to complex rider experience, which becomes an unattractive trait for the network leading to a gradual fall in its ridership. Lastly, addressing the issue of "waiting time", the report emphasis on the importance of a well synchronised transport network for a city. Further the study reports that the lack of harmonised transport network forces the riders to spend considerable amount of time in waiting, which reduces the appeal of the network despite having good riding conditions (SPUTNIC, 2009). Complimenting the study of SPUTNIC, a qualitative study by European Environmental Agency (EEA), (2010) emphasise that, with the help of technological advancement, the modern city needs to incorporate integrating ticketing system to increase the bus occupancy rate and thereby reduce the emission per bus journey.

Considering the factors from the study done by SPUTNIC and EEA, the city of Berlin has a world class infrastructure in public transportation. The city is catered with multiple networks of public transportation in the form of Buses, Trams (restricted to former east berlin), Trains (S-Bahn), Metro trains (U-Bahn), and Regional trains. The citizens enjoy an uninterrupted, well synchronised and comfortable journey while traveling in city. Despite the quality and the reach of the public transport networks, the city has not been successful in reducing the share of private motorized journey. This foot can be understood by comprehending the situation of the active commuters and the level of integration with the public transportation in the city. However, before investigating the modal share and condition of the active commuters in Berlin, it is only important to understand the role of Active travel in a city's wellbeing.

Relationship between Active and Public transport networks

Active mode of transportation, which includes walking, biking and other means of non-motorised/ human powered mode of movement, is widely used but highly understated mode of transportation which constitutes a significant share in our daily trip to our destination. They are an integral part of our daily trip from home to destination and back to home (e.g. reaching to the nearest bus stop or train station by means of walking or biking). Since active mode of transportation is not preferred for longer distance travel, coordinating them with public transportation would enhance the efficiency of both the transportation modes, as it doubles the benefits that each mode offers to the riders. (Buehler. R, Pucher. J, 2009). Active mode of transportation has believed to help in providing last mile connectivity for the public transport network. While the vulnerable section of the society (i.e. Senior citizens, children and parents with children in trolley) use walking as a mode to reach the nearest public transit point, the non-vulnerable section uses both walking and biking to reach from their destination to the nearest point of public transport network. This shows the close relationship and interdependency of active and public mode of transportation. Since the interdependency, the overall travel experience of the rider depends on the factors such as safety, comfort and user friendliness of both modes of transportation. Therefore, it is of utmost importance to make conditions more favourable and encouraging for citizens to use active and public mode of transportation.

Godefrooij. T (2012) emphasises on creating a chain between active and public transport using strengths of both the modes in order to reduce the usage of private motorised vehicles. He further advocates that, it is important to establish the links between public transport and active transport to integrate them in a system. For instance, while public transport is suitable for uninterrupted and long-distance movement from one part to other part of the city with comparatively lower level of penetration, active transport can be used for short distance, inner urban trips with higher level of penetration due to denser networking system. (Godefrooij. T,2012) However, we need to analyse the integration of public transportation with biking and walking distinctively.

Biking, a comparatively faster mode of active transportation, is mostly preferred by fit and physically abled section in our society. Paper planes e.V., (2017) claim biking to have all the solutions for the problems of owning car. They advocate for biking by stating numerous

advantages that it holds over cars, some of which were; a) the role of biking in keeping us healthy, fit and slim, b) the role of biking in making a fast and flexible short distance trips in the neighbourhood, c) the economic advantages for cities, regions and local retailers from bikers, d) the cost efficiency of biking over owning and maintaining a car. (Paper planes e.V., 2017). Further, they go on to term 'biking' as a new taste of lifestyle for many in the Urban world by depicting biking as a modern way of living and defining a person's individuality. According to their study, 13% of car owners admitted of having difficulties in concentrating more than pedestrians and bikers. Another study by them confirm that bikers experienced 40% less stress than commuters who use other means of transport. (Paper planes e.V., 2017). These renowned studies help in prove that, biking is not just a solution for road congestion and elevated levels of noise and air pollution, but it is also vital in keeping the commuters physically, mentally and economically better off than using a motorized vehicle for commuting.

A famous study by FLOW project (2016) on congestion of roads states that the solution for the new age problem of road congestion lies in the expansion of bike lanes and pedestrian way and not in the expansion of the roads. The study vouches for regulating infrastructural reforms in European countries for bike lanes and pedestrian ways by improving the conditions of bike lanes and pedestrian paths, creating more convenient road crossing, installing better signing, by rephrasing of traffic signals and by providing better parking facilities for bikes. FLOW project (2016). However, one of the major reasons why commuters use private motorised vehicles over public transport system is the poor condition of egress trip. Brands. T *et al,* (2014) state that many countries lack multimodal approach to tackle the issue of integrating active commuters with the public transport network. The lack of infrastructure for biking to combine with public transport network reduces the option of the commuters to use biking as an option for egress trip.

Godefrooij. T (2012) backs the theory of strengthening the biking infrastructure at public transport transits such as bus and tram stations, metro and train terminals to provide commuters option to use biking as an option for egress modal. Further, he recommends options to improve the availability of bikes for egress trip, such as:

- Usage of own bikes; with a provision to take personal bikes in trains and buses, the commuters would be encouraged to use bikes and discouraged to use cabs or shared cars in the egress trip.
- Bicycle hiring service; An option of hiring bikes from the train or bus stations with an ease of operation would encourage commuters to use bikes actively on a regular basis.
- Public bikes; providing the option of public bikes from an authorised public transport network would also serve the purpose of attracting commuters to use bike as a favourable mode of transportation. (Godefrooij. T,2012)

Further he claims that a system is as strong as its weakest link, and terms 'bike parking' as the missing link in integrating public transport and biking. Following which he advocates for a parking facility with the following characteristics:

- Ease of route: The location and the route towards and away from the parking facility would influence the commuters to use or ditch the parking facility. The place of parking should ideally be walkable and easily assessable from the nearest public transit spot.
- Ease of operation: The system becomes more attractive if it is efficient and easy to operate. For instance, a parking system with easy charging and locking mechanism is more attractive than a complicated parking system. This would play a vital role in larger scheme of play.
- Protection against theft and vandalism: Parking system with assurance against theft and vandalism is a basic criterion preferred by the commuters. The level of trust on a system is directly proportional to the usage of the system.
- Weather proof and durable: Regions with heavy rain, snow or sun must be equipped with shed, roof or physical barrier over the bicycles to keep them unaffected by the change of climate. This criterion would fall under ideal infrastructural requirements for a parking system and encourages commuters to use bikes in all seasons.
- Low cost or integrated fares: The concept of integrated fare system for parking bikes at any public transit spot would give the commuter the freedom of movement with the bike. The flexibility of using buses, trains or trams with a personal bike and

the freedom to park at any public transit parking spot would give higher degree of penetration for bikers. (Godefrooij. T, 2012)

By gradually tackling the above-mentioned factors efficiently, modern cities can help in strengthening the condition of active bikers. With suitable changes in policies and regulations, these changes can be attained over an abbreviated period of time. However, it is important to understand the influence of such changes on the walking community, as it shares the common built environment with pedestrians. The aspect of safety, ease of access to the nearest public transport mode, visibility, degree of connectivity and path continuity play a major role in accessing a given study area for pedestrian track.

Walking can be considered as a primary mode of transport as it helps in reaching to the nearest public transport transit or helps to reach the parking lot from our work place. Litman. T, (2017) states that improving the quality of public transport includes making conditions more favourable for pedestrians to reach the nearest public transit outlet. He believes walking in a "*bike-transit-walk*" trip type and walking towards the parking lot three blocks away as equally important as walking has a significant share in both the trip types. Further, he goes to state that, the actual share of walking is always three to six times more than the statistics, as the stats do not consider walking from parking lot to the destination as a part of the trip (Litman. T, 2017). The role of walking in our daily trip is highly understated and not many studies have emphasised on the understanding the factors affecting the conditions of pedestrians. Countries with low temperatures and higher rainfall (Scandinavian countries, Netherlands and so on.) have higher rates of active transport than some of the countries with better climatic conditions, due to supportive public transport service and land use policies as well as positive community attitude. (Litman. T, (2017). This goes on to show that climate is no barrier if the community and the service providers cooperate and work towards integrating walking and biking with public transport.

After understanding the role of active commuters in a city's public transportation network, and the importance of integrating public transportation with pedestrians and bikers, it is now necessary to understand the situation of the Public Transportation System in Berlin.

Public Transportation in Berlin

The city of Berlin has multiple network of public transportation which connect 170 S-Bahn train stations spread over the city with 15 lines connecting them,10 underground lines connecting 143 stations.[1] , and the trams which can only be found in former east Berlin areas extending over a track length of 293 km connecting 377 stations in 22 different lines. The bus service in Berlin is the oldest mode of public transportation, which has over 1300 bus running in 375 different routes. The frequency of these public transport network range between 10-20 mins over various routes.[2]. Along with the aforementioned network, the city has one of the most extensive bike networks in the world with 620 km of bike lanes which includes mandatory cycle paths (150kms), off- road bicycle route (190kms) bike lanes on the road (60kms), shared bus lanes open to cyclists (70kms), combined pedestrian and bike lanes (100kms) and marked bike lanes on the side walk (50kms). Further, bikers have provisions to carry bikes in S-Bahn, U-Bahn, Trams and on night buses aiding to further integration of biking with other modes of transportation. Despite the extensive network of public transportation and biking infrastructure, the citizens of Berlin use their private vehicle extensively, the private motorized transportation occupy 31% of the total share of the transportation in the city.

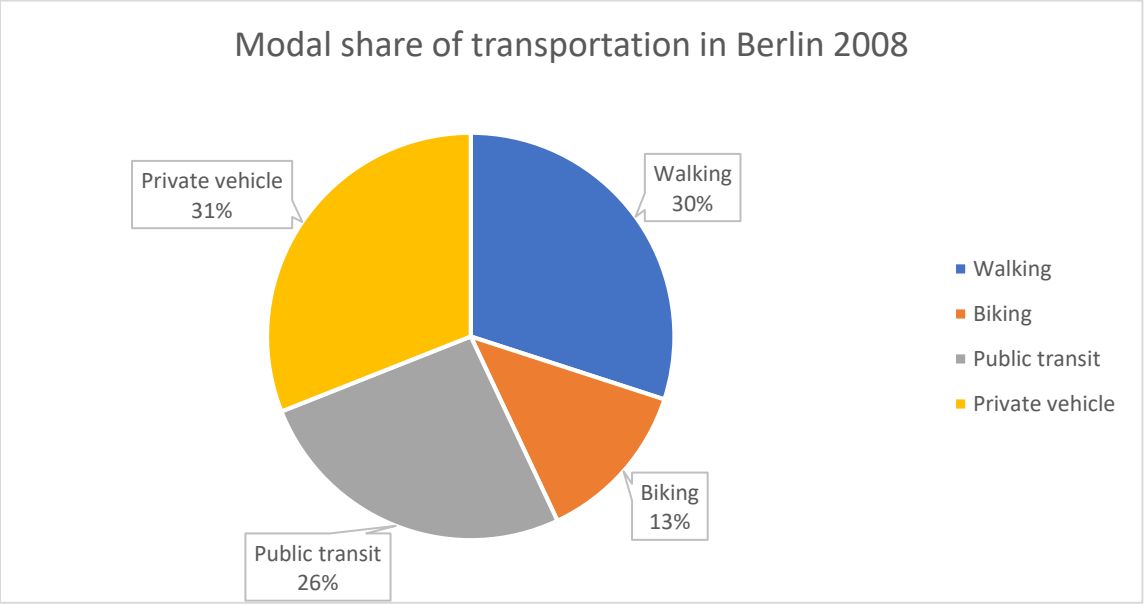

Figure 1: Modal Share of Transportation in Berlin

[1] https://www.settle-in-berlin.com/everything-wanted-know-public-transportation-berlin-never-dared-ask/
[2] https://en.wikipedia.org/wiki/Bus_transport_in_Berlin

According to the Senate Department for Urban Development and the Environment, 1.5 million journeys are completed by biking in Berlin. And to further encourage biking in the city, the Senate Department for Urban Development and the Environment came up with seven arguments to encourage people to choose biking as preferred mode of transportation over cars and other motorised mode of transport. See Appendix 1 for description.

Following the argument for using bikes over cars and motorised modes of transportation, the committee came up with set of strategic goals to integrate biking with the existing public modes of transportation. See Appendix 2 for description.

Aligning with the goals laid by the Senate Department for Urban Development and the Environment, the city has seen encouraging signs from independent biking community pitching their ideas to improve the situation of biking in the city. One of the encouraging ideas pitched by the group of enthusiastic architects and urban planners is the project of "Radbahn**".**

The Project "Radbahn" is an initiative taken by a registered charitable association called paper planes e.V. and its eight founding members. The project aims to utilise the forgotten space below the U1 track running between Zoologischer Garten and Warschauer Strasse. The cycle track passes along diverse neighbourhoods and surroundings in seven different sections namely Promenade, Under the roof, In the park, By the water, Eye of the needle, Hot spot and spree feeling. The track Radbahn starts 400 meters from the U bahn and S bahn Zoologischer garten station and ends over the Oberbaubrucke over the river Spree. This project, of laying a vibrant cycle track along the U1 route, is one of its kind. Further, to understand the cycle track in detail it is important to look at each section in detail.

Radbahn U1 Project:

Promenade

The first section of radbahn, the promenade, starts next to famous Christmas market, 400 meters from the S-Bahn and U-Bahn Zoologischer garten. The track in the promenade section is proposed to be laid in the median dividing the 47m wide road mostly deserted with no active environment. According to the designers at Paper planes e.V, the section lacks concrete biking infrastructure and introducing the bike track would add more than one

reason for active utilisation of the deserted median region in Promenade. The study done by the chief designers at Paper planes e.V also provide insight on importance of shared space for pedestrians and bikers in the promenade section.

Figure 2: Promenade

Further, the study suggests dividing the 12-meter median section in 9 meters and 3 meters strip for pedestrians and bikers respectively to encourage people to use the forgotten space in the section. The cycle track passes through U-Bahn Wittenbergplatz station, which acts as a major public transport outlet for the region with an enormous potential for integrating active commuters with the public transportation network. Overall, the section has immense potential in using the vast spare area for active pedestrian and biking use along with giving scope to generate economic benefits with stalling leisure outlets along the centre of the boulevard. However, the study throws minimal light on the built environment conditions of the street joining the radbahn track to analyse the degree of active travel integration with the radbahn track.

<u>Under the roof</u>

The second section of the radbahn track, “Under the roof”, starts immediately after the radial boulevard of ‘An der Urania’. Shortly prior to the Nollendorfplatz U-bahn station, the U2 route emerges from the ground on the viaduct, thereby providing protection for the bike track of radbahn for the reminder of the section. Paper planes e.V, (2017). The section sees two major U-bahn station in Nollendorfplatz and Buloowstrasse with extensive bus

connectivity around the U-bahn stations. The chief architects of the project identify Nollendorfplatz as a perfect spot for mobility hub. They describe the mobility hub as a tool to disseminate information to the car users about the possible ways of avoiding usage of personal motorised vehicles and provide them with alternative modal share for their current travel option.

Figure 3: Under the Roof

The planners of the project have also screened out parking space for bikers, charging section for e-cars and e-bikes sharing, normal rental bikes and pickup stations for mobility services. Paper planes e.V, (2017). The figure below depicts the possible space allocation for the services mentioned above.

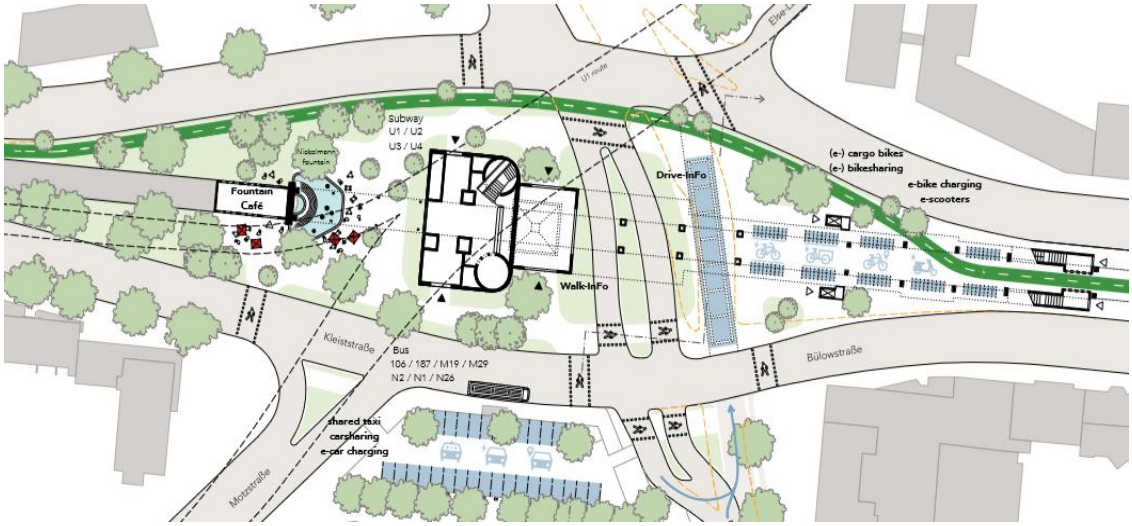

Figure 4: Mobility Hub plan at Nollendorfplatz

Overall, the section of “Under the roof” has infrastructural advantage over the previous section in terms of safety with the presence of viaduct. Moreover, the section has mobility hub which possess enormous potential in creating awareness among the private vehicle users to use an alternative, more eco-friendly and economical mode of transportation by using the radbahn track along with the public transport provision. However, the study lacks the consideration of the type of land use and the condition of the roads for active travel joining the radbahn track.

In the Park

The third section of the radbahn track, “In the Park”, starts at the Bulowstrasse moving away from the railway viaduct. Interestingly, the architects of the project aim to generate electricity for the whole track from the solar roadways in this section. According to Paper planes e.V, (2017), the section of “In the park” has three alternative route option which will considered on weighing up the pros and cons of each route. The first route (dark blue line) leaves the park to join the schoneberger bridge on the northern side of the Landwehr canal as shown in fig below. The second route (green line) leaves the park to pass over a newly built cycle bridge and the third option (purple line) is to pass the southern Anhalter pedestrian bridge.

Moreover, the choice of the path can also depend on the upcoming new train line of S21 which joins the section at the Gleisdreieck station.

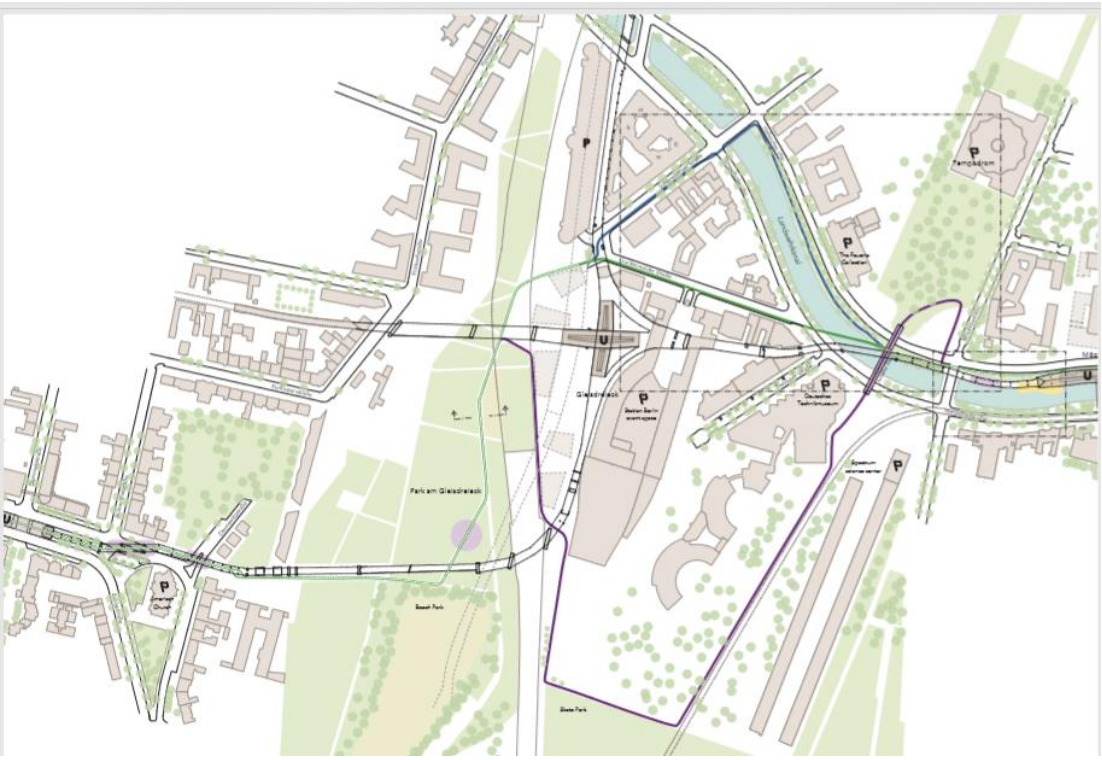

Figure 5: In the Park

Overall, this section has its unique characteristics of vast range of highly pedestrianised and bike friendly path with no intervention of the roads joining the surrounding neighbourhood, a unique land use pattern which is different from the general urban tissue. However, the study lacks consideration of the connectivity of the immediate neighbourhood and the possible relation between them.

<u>By the water:</u>

The fourth section of the radbahn track, “By the water”, starts just before the U-bahn Mockernbrucke station on the north of the Landwehr Canal for about 1 km. The project aims to bring back life at the shore of the canal by setting up an Urban beach called the “Mockern Beach” near the Mockernbrucke station. According to Paper planes e.V, (2017), this beach will catalyse in creating social and recreational environment for the commuters and the future residents around area. While the path under the viaduct, next to the canal will be allotted for the pedestrians, the bikers will be allotted an on-street path adjacent to the viaduct. This section has two U-bahn stations and extensive bus network catering the needs the residents around the track.

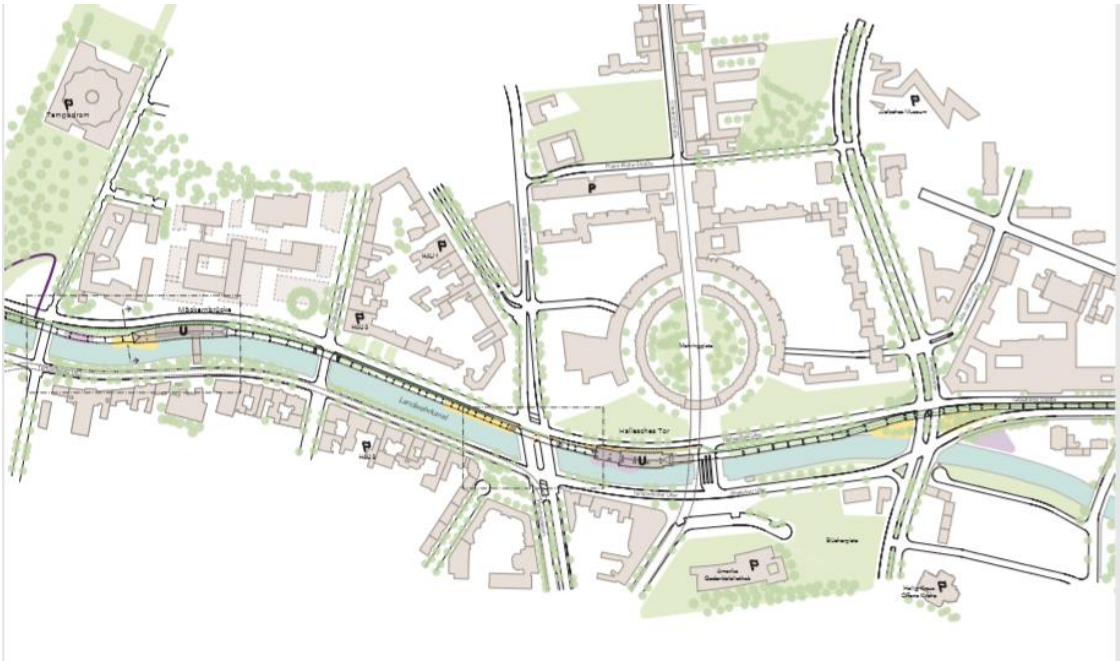

Figure 6: By the Water

Overall, the section has immense potential to create an active travel atmosphere with space for recreation and safe path for active commuters.

<u>Eye of the Needle</u>

The fifth section of the radbahn, “Eye of the Needle”, begins as the track leaves the Landwehr canal. The section, with narrow, highly motorized path, is surrounded by walls of the surrounding properties. With large segments of intersection less path along with parking facility under the viaduct, the section perceives to be as less attractive for the active commuters. A gradual expansion of the area allotted for active commuters is necessary as the current physical infrastructure is rigid and needs constant changes. Majority of this section contains a narrow concrete jungle on either side until the section reaches wassertorplatz. Additionally, this section lacks extensive public transport facility around the track rendering unfavourable condition for integrating active and public modes of transportation.

Figure 7: Eye of the Needle

Overall, this section lacks active commuter friendly environment and will require gradual modification in the space allocation and safety standards aspects for active commuters.

Hotspot

The sixth section of the radbahn track, “Hotspot”, starts just prior to the U-Bahn kottbusser Tor station on Skalitzer strasse. The area around Kottbusser Tor is majorly crowded with people using the U-bahn services along with the highly commercialised activity around the station. The section has an advantage of active commuter friendly environment with smaller blocks with more intersection, thereby giving more path options for the pedestrians and bikers. Moreover, despite complex island situation near the Gorlitzer Bahnhof, the section requires minimal infrastructural changes under the viaduct to provide traffic free commutation for active commuters to reach their U-bhan destination. The section also sees extensive bus connectivity near major U-bahn stations showing adequate connectivity between different networks of public transportation.

Figure 8: Hotspot

Overall, the section of Hotspot lies in one of the most well connected and highly commercialised area. With such high number of roads connecting at two major U-bahn station, the study on connectivity and continuity will become ever so more important.

<u>Spree Feeling</u>

The seventh and the last section of the radbahn, “Spree feeling”, starts at the skalitzer strasse and continues under the viaduct to join the U-Bahn Schleisisches Tor, where track leaves the viaduct and to go around the famous diner Burgermeister and to join the viaduct again. This route is surrounded by many public outlets (such as café, restaurants and Bars). Despite having less number of intersections, the section has decent bus connectivity along with the U-Bahn schleisisches Tor station which helps pedestrians to connect with the adjacent neighbourhood.

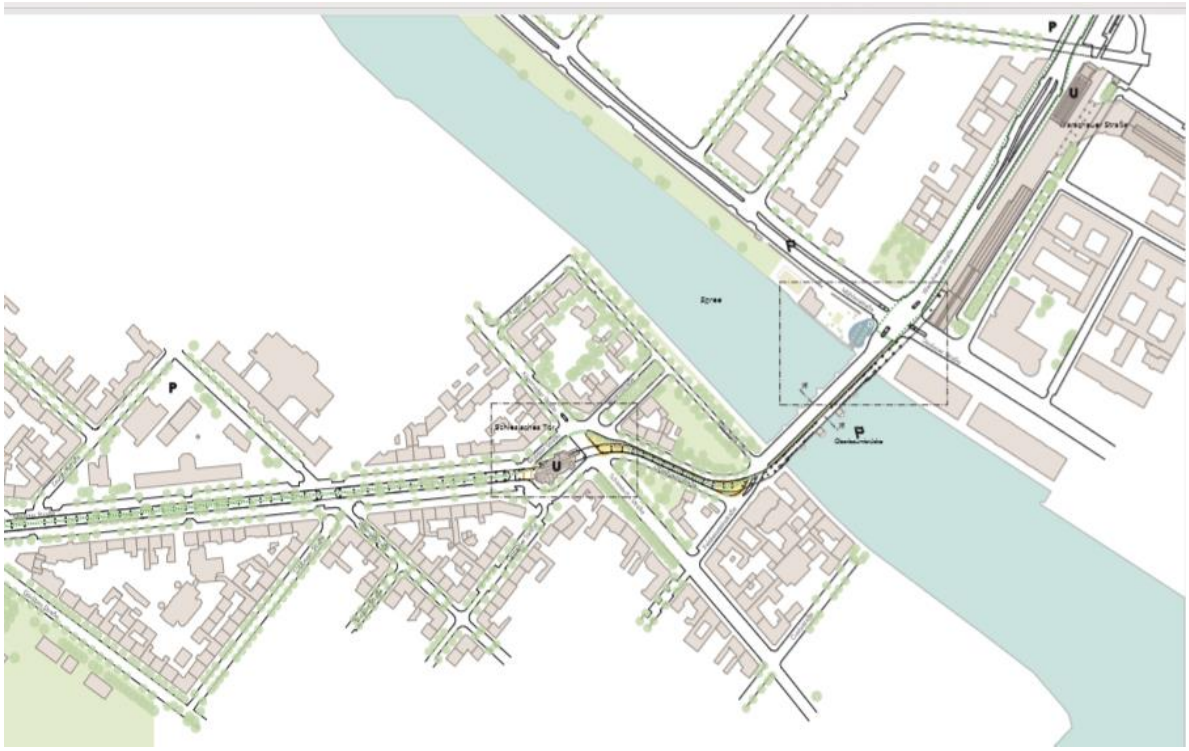

Figure 9: Spree feeling

The track of radbahn ends at the scenic Oberbaumbruck bridge at the intersection of Stralauer strasse with a potential establishment of a bike station and information point. Overall, the section has good potential to be an example of good active environment for pedestrians and bikers. However, the complete analysis will be incomplete without studying the condition of biking and walking on the roads joining the radbahn track.

<u>Opportunities provided by Radbahn U1 project</u>

Primarily, the implementation of the radbahn track will directly improve the condition of biking around the track, as it will provide the most efficient route to travel between Zoologischer garten and obermaumbrucke. Additionally, it will also provide an opportunity to improve the social and economic condition of the area around the track.

- The project will provide an ideal platform to setup new commercial outlets in the median of the boulevard. This will in-turn will lead in providing a “socially engagement environment” for the pedestrians.

- The setup of mobility hubs at selected U-Bahn stations will provide an opportunity to generate egress trips for bikers, which would help in integrating bikers with the public transport.

The role of this study

While the project provides an ideal platform for biking, it lacks the consideration of immediate built environment factors which have a vital role to play in the success of radbahn. This evaluation research study, aimed to investigate the factors pertaining to the immediate environment of the radbahn track, to examine the role of the cycle track in Integrating active and public modes of transportation. To evaluate the factors of built environment, the study followed the working framework of "Walkability for Health". The following section throws light on the framework of "Walkability for Health".

Walkability for Health

Walking, an understated mode of transportation, falls under the category of active mode/ non-motorised mode of transportation. As an integral part of daily trip to destination, walking is the primary mode of transportation involved in our day to day events. The framework of walkability for health studies the relationship between built environment and the physical behaviours of walking and biking of people in a given neighbourhood. (A. Valera Sosa, 2016). The tool considers tangible and germane factors associated with travel pattern of human beings depending on the built environment. The framework has been divided into three major categories namely Meso, Macro and Micro level factors, where each category evaluates the conditions for ease of walking at different scale.

A. Valera Sosa, the chief designer of the framework advocates that, the different periods of past considered varied factors to assess the degree of walkability and bikabilty for a neighbourhood. Acknowledging the difference in approach, he stated that the research in the mid 90's concentrated on understanding the factors of built environment that stimulated pedestrian activity and triggered path preference, and there by giving major importance to the macro-level scale of the city. This included the factors affecting the proximity of destinations and directness of travel between destinations. He further states that, through the same period, research organisations made constant efforts to gather

qualitative and quantitative data from the built environment to arrive at concrete results. The tool mainly emphasised on physical features such as side walk width, number of bike lanes, presence of marked crosswalks and other physical features on the street, which helped in making the experience of pedestrians and bikers comfortable. This constituted the Meso-level analysis of the neighbourhood. Further throwing light on the methods of evaluation used in 2000's, he states that, the study of walkability focused on individual reactions and termed them as Micro-level scale of the city. This study drew relationship between walking patterns and factors such as effects of transparency, the complexity related to the principle front of built structures, and image of street elements. (A. Valera Sosa, 2016).

This evaluation research study, complied to the indicators mentioned in the framework of "Walkability for Health" and evaluated the project for Macro and Meso level factors, following which the research performed a detailed study on selected sections from the Macro level study. The following section describes the major research question, objectives and the indicators used in evaluation research study to answer the major research question.

3. Research Question and Objectives

With a growing biking population in Berlin, the city is unable to meet the standards and scale up the requirements of the biking community. The Senate department of Urban development and the environment is therefore under pressure to come up with proper planning and execution of future biking projects, which includes prominent levels of safety, comfort and inclusivity of the vulnerable sections of commuters in active mode of transportation. This study focuses on examining one of the potential future project which has been put forward by a group of passionate urban planners and architects from Paper planes e.V, in "radbahn". Aiming to examine the degree of integration between active and public transport network in Berlin, this study tried to answer the following major research question:

"How can implementation of Radbahn help in integrating Active and Public modes of transportation in Berlin?"

In order to answer the above research question, the study adhered to the following set of objectives under the framework of 'Walkability for Health' to determine the role of radbahn in integrating active and public modes of transportation in Berlin.

Main Objectives:

- Firstly, the study aimed to critically review the sections of Radbahn for Macro level factors and determine the most favourable and unfavourable sections for active travel.
- Secondly, the study identified the streets with high scope of active travel activity and performed Meso level study on them.
- Lastly, the study focused in conducting a Detailed Meso level factor study on two of the selected sections from the Macro study and determine the level of connectivity and continuity of active travel.

The study of Macro scale factors included observing the Density and Diversity around the radbahn track. Density included, studying the Population density, land use pattern and transport provision around the radbahn track to determine the most frequently used path by commuters.

1.1. Density

1.1.1. Population density: graphical representation of the population along the Radbahn track.

1.1.2. Uses: graphical representation of land use types along the Radbahn track

1.1.3. Public transport provision at 150m and 600m from the Radbahn track. Assessing the number of stops and stations for buses local metro, urban express trains.

Factors such as population density, land use and public transport provision were considered to depict the potential users of radbahn track and other modes of transport around the track. This analysis helped in understanding the relation between commuters of public transport and possible users of radbahn.

1.2. Diversity

1.2.1. Public transport coverage along the track of Radbahn.

a) Buses

b) Local metro (U-bahn)

c) Urban express train (S-bahn).

Further, the Macro scale study included mapping the transportation coverage around the radbahn track in the Diversity study. This study helped in determining the main axis of active traveller pathway. Moreover, this factor aided to determine the frequently used streets by pedestrians and bikers to reach the nearest public transport outlets on which the study could perform basic Meso level factor study.

The next step in the research was to identify the type of a) intersections, b) street segments and, c) street hierarchy and classification. This study was done to check the level of safety and ease of connectivity for the active commuters on the streets joining the Radbahn track, with high amount of active travel activity. With the help of colour coded satellite maps the study shows the intersection type, street segment type and street hierarchy and classification to project the sections with active travel friendly environment.

From the results of the Macro level factors, the study identified the “most suitable” and the “least suitable” section for active travel conditions, on which a detailed Meso level study was performed. These two selected sections were then examined to understand the

situation of active path continuity and active block connectivity. The study of Meso scale factors involved: Vehicular Impact, Pedestrian block connectivity and Pedestrian path continuity.

2.1 Vehicular Impact

2.1.1. Street Hierarchy: Highlighting arterials, collectors, local streets and supplementary roads along the radbahn track.

2.1.2. Street classification: Highlighting areas such as transit corridors, boulevards, commercial alleys, yield, shared or considered green alleys.

2.1.3. Street Grid

2.1.3.a. Street blocks: Highlighting the number of block under the study area.

2.1.3.b. Street segments: Observing the number of segments studied.

The above-mentioned factors were used to notice if the streets in the study area were motorised or active traveller friendly. Determining the existing conditions of the streets connecting the radbahn track would help in dictating the degree of success in integrating the active commuters with the radbahn track.

2.2 Pedestrian block connectivity

2.2.1. Pedestrian crossing number: Marking the number of crossing along the radbahn track

2.2.2. Pedestrian crossing analysis: To note if the intersections are T-intersections and if the intersections are fully marked, marked or unmarked type.

These indicators helped in analysing the current condition of connectivity for active travellers from one street block to the subsequent ones by mapping the types of intersection between them.

2.3 Pedestrian Path continuity

2.3.1. Street element analysis: This was used to highlight the main elements of the street segments such as lanes, on-street parking, buffer area, building strips and furniture strips.

The above-mentioned indicators helped in analysing the degree of active travel continuity along the radbahn track. The study of the street segments assisted in understanding of the area allotted for active and motorised travellers. Which in turn helped in understanding the role of radbahn in improving the path continuity along the street section.

With a detailed study of Macro and Meso scale factors, the study thrived to find the degree of active travel friendliness around the radbahn track area. The next section throws light on the methods and the methodology that were used in the study to answer the above-mentioned question.

4. Research Methods

To achieve the objectives in the above-mentioned section, the study adopted a unique conceptual methodology to cover the study of the radbahn track. While it was of prime importance to examine the role of radbahn in integrating active travellers with the public transportation, it was important to study the built environment factors around the track which would play a vital role in determining the ridership of radbahn track. Therefore, following the working framework of 'Walkability for Health', the study focused on studying the Macro level factors in the first place to identify the conditions of 'Density' and 'Diversity' to find the most-suitable and least-suitable sections in the radbahn for the active travel condition. These selected sections were later tested for active block continuity and path connectivity in the detailed Meso level factor study.

However, to have an understanding of the basic Meso level factors of each section, the research conducted a study on each intersection and the street segment that led towards the radbahn track. Following this conceptual method, the research was able to meet the desired objective. To accomplish the above-mentioned conceptual method, the research adopted both qualitative and analytical approach. During the primary stage, the study used photographic survey approach to focus on notable factors around the track of radbahn that would influence the commuting experience of pedestrians and bikers. The photographic survey was vital in capturing the built environment conditions on the street segments and the intersection joining the radbahn track.

Thereafter, with the help of secondary data from online sources such as; fis-broker maps, open street maps and the online literature on radbahn, the research accomplished the process of data collection. Using the data obtained from the secondary sources, the research performed Macro level study to obtain a pattern of various factors on the sections of radbahn to find the most favourable and unfavourable section. Abiding to the framework of 'Walkability for Health', the research further performed a detailed Meso scale analysis to find the active path continuity and block connectivity on the two selected sections.

<u>Research Limitations:</u>

This research excluded the aspects of "detailed designing" from the framework of walkability for health and catered only to the 'planning' aspect of the built environment

around the radbahn track. The major reason to omit the study on ‘design’ aspect of the built environment around the track was the enormous size of the area under study. The detailed design consideration of each street segment and intersection was not feasible to perform. However, the results of the current study can be used, and the observations can be extrapolated for the Micro- level study (Design aspect) of the streets joining the radbahn. To give a brief insight on the factors of micro-level study, the research states the factors that can be studied in the penultimate section of Annex. Lastly, the evaluation research study focuses only on the immediate built environment of the radbahn for the macro and meso level study (one block on either side). This gives a further scope for the study to be performed in adjacent blocks to the immediate built environment around the radbahn track.

5. Findings:

Macro level:

At the Macro level, the study accessed the factors of Density and Diversity to understand the active travel dynamism around the radbahn track. To further understand the effectiveness of the track, it was only important, for the study bring out the current conditions of Density and Diversity around the cycle track. Under density, the study focused at bringing out the population density, land use type and the public transport provision around the radbahn. The population density around the track helped in understanding the amount of human presence which would help in gauging the level of utility of roads through trip generation or trip attraction factor in each section. Secondly, the land use pattern around the track was divided in nine distinct categories namely: residential use, mixed use, core areas, small business use, public facilities, utility area, traffic area, weekend cottages and green open areas to highlight the type of activity prevailing in each section around the track. The type of land use helped in understanding the major spots of trip attraction and further help in mapping the major public transport outlets that were present around the track. This study aided in mapping out the most frequently used path by the active commuters to reach the nearest public transport outlet. The factor of public transport provision helped in measuring the diversity and the scale of connectivity around the radbahn track, assisting in understanding the ease of reaching radbahn from various parts around the track.

The data for Population density (people/area) and land use type used in the research were accessed through the GIS database from Berlin senate called the Fis- Broker. The transportation provision data for number of Bus stands, U-bahn and S-bahn stations were obtained through open street maps, google maps and were further verified during the photographic survey by the author.

The Population densities were categorised in nine different brackets as shown in the fig ranging from 1-4 people/ Ha to more than 550 people/ Ha. The study mainly focused on finding uniform patterns of population densities with minimal irregularities around the track for ideal active travel environment. The research further focused on finding the different

land use type as mentioned above, to find the relation between population densities and land use types. To check the hotspots of walking and biking, the research concentrated on the location of various land use types. In the last factor under densities, the research aimed to find the number and location of the public transport outlets around the vicinity of radbahn track to check for extensive connectivity and integration of radbahn track with the public transportation in the neighbourhood. With a thorough study on the above-mentioned factors, the research brings out the most suitable and the least suitable track for active travel environment and their integration with existing public transportation.

The next section showcases the study done on each section for Macro level factor, and further tabulates the results for clear understanding.

Section: Promenade

Factor: Population Density

Observations:

- Four Hundred meters from the S-Bahn and U-Bahn Zoologischer Garten station, starts the "Promenade" section in the Boulevard of Tauentzienstrasse. This section is situated in the central region of Schoneberg District, surrounded by commercial setups on either side of the track.

- The fig in Annexes 3 shows an irregular dip in population density in traces on the western and south-eastern side of the track.

- Further, the map depicts a uniformly higher rate of population density in the southern side of the radbahn track, showing the busiest blocks in the region.

- Overall, the region is moderately populated with majority of blocks having the population density in and around the range of 151-250 people/Ha with minute indiscretions.

Factor: Land use

Observations:

- The fig in Annexes 3 shows that, the section 'Promenade' coincides with one of the busiest commercial region of the city. The track is surrounded by shopping

complexes and commercial buildings with the major land use type being "Core areas" and the "Mixed use".

- The section is dominated with service type of Active and Food Environment. While the active environment in promenade is majorly concentrated in the central region near the radbahn track, the food environment is spread evenly throughout the section.

- The section also has Health care settings within the range of one block on either side of the track. These settings are adjacent to the roads and are accessible by foot and vehicle, showing the ease of connectivity.

- Overall, the section is dominated with blocks "Mixed Use" and "Core Area Use" with services of Active and Food environment showing the commercial landscape of the section.

Factor: Transport Provision

Observations:

- From the fig in Annexes 3 we can observe that, the promenade section has extensive bus connectivity with 19 bus stops catered for the section. The region also has one U-Bahn station running along the boulevard of Tauentzienstrasse. The U-Bahn station is connected with bus stops connecting buses running in different routes. This facility helps in increasing networking and reducing transit time for the passengers while switching to a different network of public transportation.

- However, the section lacks bus connectivity from North to South direction with only one route joining the North and the South, thereby rendering poor conditions for integrating public and active mode of transportation in the rest of the region.

- The major cluster of bus stops are found near plots with mixed use and core use depicting an ideal trip ending situation for a commercial district.

- Overall, the section is very well complimented with bus network to travel in East-West direction but lacks connectivity in the North-South region thereby rendering moderate levels of connectivity.

Factor: Transport Coverage

Observations:

- The fig in Annexes 3 depicts the transportation coverage in the region to be good, considering a dense coverage along the boulevard and the fewer region falling towards the upper limit of the 600m radius.

- Interestingly, the bus and U-Bahn network render service to the western, central and eastern region. While the south-western region lacks dense coverage, with very few blocks ranging in the latter side of 600m radius from the nearest public transport outlet.

- Overall, the region has a good transport coverage with negligible amount of area on the fringes of the dotted circle.

<u>Section report</u>

From the observations, the research brings out the following report on factors of Density and Diversity for the section of Promenade.

Density:

Section Name	Factor	Population Density		Land Use			Transportation Provision
Promenade	Sub-Factors	Scale	Irregularity	Versatile	Adequate Services	Green area and Social Environment	Adequate and Integrated
		Moderately High	Minute	No	Yes	Yes	Moderate

Table 1: Density (Promenade)

Density (Promenade)

Diversity:

Section Name	Factor	Transportation Provision		
Promenade	Sub-Factor	Major zone in 150m Radius	Blocks in the Upper limit of 600m Radius	Overall Coverage
		Yes	No	Good

Table 2: Diversity (Promenade)

Section: Under the Roof

Factor: Population Density

Observations:

- The "Under the Roof" section falls in the central Schoneberg district of Berlin, with residential and commercial buildings on either side of the track.

- From the fig in Annexes 3 we can see that, this section has only one block in the range of 71-150 (person/ha), showing the region with a comparatively lower population density.

- Further, the map shows a consistent increase in population in the southern region of the radbahn track to that of northern side, depicting the busiest zone in the section to be in the southern zone. Furthermore, the maps also show plots with "residential use" to be densely populated as compared to the plots with "mixed use" on either side of the cycle track.

- Also, the area of plots in the northern region is comparatively large as compared to that of south, with fewer outlets for services showing the reason for lower population density in the north to that of south

- The section, majorly, is covered with blocks ranging from 151-550 person/ha, showing the high occupancy and utility rate in the section.

Factor: Land use

Observations:

- The section of "Under the roof" is dominated by residential blocks and plots with mixed land use. The fig in Annexes 3 shows a uniform distribution of two kinds of land use throughout the section.

- The section has all four types of service namely active, food, social and healthcare environment, making it a versatile section with a good trip attraction factor.

- The southern region is dominated by outlets for food services, and contains smaller blocks with more intersection and paths, thereby rendering ideal conditions for connectivity for commuters, by providing more options to walk and bike. It further goes on to show the busy streets with active travel atmosphere in the section.

- The region has two healthcare settings (one on both north and south of radbahn track) which are located to the nearest U-bahn and bus stations, showing ideal location for healthcare centre.

- In general, the southern region has outlets located at much closer distance, which provides an encouraging active transport environment for pedestrians and bikers.

- Overall, the section is dominated with two kinds of land use with provision for all type of service environment located at walkable distance from the nearest public transport provision.

Factor: Transport Provision

Observations:

- The section has two major U-bahn stations in U-Bahn Nollendorfplatz and U-bahn Bullowstrasse located at near proximity. From the Fig () in the Annexes 3 it further clear that, the bus stands are placed around the U bahn- stations with buses running in different routes and directions.

- More importantly, the bus routes are evenly placed in both the directions, making it a suitable region to integrate active and public mode of transport.

- From Fig in Annexes 3 it is evident that, the blocks are smaller in area, thereby providing more option for pedestrians and bikers to choose the desired route of travel to reach the destination.

- Further, the region holds a significant share of residential buildings, depicting the origins of trip from the region.

- It is clearly visible that the area with mixed use are supplied with transport facility, which is also a block away from the residential buildings. This setup helps in encouraging commuters to use the pedestrian path to reach the nearest public transport outlet and brings out the more frequently used active travel path.

- Overall, the section has adequate transport provision in every zone with ideal location of the stops.

Factor: Transport Coverage

Observations:

- The region has an impressive range of transportation coverage with all the blocks having walkable accessibility to the nearest public transport outlet.

- The fig in Annexes 3 helps us to understand that, the region has even distribution of buses travelling in North- South and East-West direction showing ideal environment to integrate pedestrians with public transport in the both directions around the radbahn track.

- Overall, the region has excellent transport coverage with all the blocks covered well within the radius of 600m from the nearest bus or U-bahn stops.

Section Report:

From the above-mentioned observations, the research brings out the following report on the factors of Density and Diversity for the section of Under the roof.

Density:

Section Name	Factor	Population Density		Land Use			Transportation Provision
Under the Roof	Sub-Factors	Scale	Irregularity	Versatile	Adequate Services	Green area and Social Environment	Adequate and Integrated
		High	No	Yes	Yes	No	Moderate High

Table 3: Density (Under the roof)

Diversity:

Section Name	Factor	Transportation Provision		
Under the Roof	Sub-Factor	Major zone in 150m Radius	Blocks in the Upper limit of 600m Radius	Overall Coverage
		Yes	No	Good

Table 4: Diversity (Under the roof)

Case of Exception:

The section "In the park" of the radbahn track possess conditions dissimilar to the conditions seen in general urban tissue. The section starts at the entrance of the park near the bus stop Dennewitzplatz and runs through the vast space of highly pedestrianised and biker friendly environment in shconeberger weise. The track ends at the shore of the Spree river near German Museum of Technology. The section has three different options of traversing Landwehr Canal which are: 1) northern route over schoneberger bridge, 2) A new bicycle bridge and 3) Using Anhalter bridge on the southern side of the track. e.V. Paper planes, (2017)

Figure 10: In the park

The section with currently no roads connecting the track has traffic free active environment conditions. However, for the current research on Active path continuity and Active block connectivity, the study requires paths and neighbourhood connecting the radbahn track directly. Therefore, on the count of a) Lack of connecting roads towards the radbahn track and b) already existing highly pedestrianised and biker friendly environment, the study excludes the section of "In the Park" section from the study of Active path continuity and Active block connectivity.

Section: By the Water

Factor: Population Density

Observations:

- The "By the water" section of radbahn falls in the western Kreuzberg district of Berlin with a wide range of land use pattern on either side of the cycle track.

- From the fig in Annexes 3 shows that, the central region of section which coincides with the residential and mixed-use land type is denser in population as compared to the other type of land use.

- Interestingly, significant amount of area in this section, has almost no population density, showing lack of trip attraction character of the area. The region contains large blocks of land with less intersections and deviations, making it a lesser pedestrian and biker friendly environment.

- The region, overall, has moderate population density due to higher concentration of population on one side while large open space with no population on the other side.

Factor: Land use

Observations:

- It is clear from the fig in Annexes 3 that, the region has 7 distinct types of land use namely residential, mixed use, core area, public use, small business and utility area, making it a versatile location.

- The residential regions are spread from the west to east side along the main road with transport outlets around it.

- The regions with mixed use and residential use are densely populated with a below average rate of trip attraction in rest of the zones in the region showing streets with potentially higher rates of biking and walking.

- In general, the section has a non-uniform type of land use with patches of various kinds spread all over the section. However, the area of Residential, mixed use and public spaces are larger than the other kinds and are well connected with bus service.

Factor: Transport Provision

Observations:

- From fig in Annexes 3 we can learn that, the region is catered with transport provision along both the East- West and North-South direction, showing impressive connectivity range. Also, the U-Bahn stations are well connected with bus stops running at different routes.

- The region has S-bahn connectivity on the north-west border, providing more options for the commuters to reach other parts of the city with the train facility.

- The zones of core use and mixed use are very well supplied with bus stops making the public transport connectivity more effective.

- However, the section has large blocks and fewer intersections in the western region creating a partially unfavourable condition for pedestrians to reach for the nearest public transport outlets.

- Overall, the section is very well supplied with buses, U-bahn and S-bahn service and is intensively connected making it a favourable environment to integrate active transport with the existing public transport.

Factor: Transport Coverage

Observations:

- From the fig in Annexes 3 we can read that, the region is well catered with the bus transport spread over the region along the U-bahn route. However, the central and the eastern zone have denser transport coverage as compared to the North-western side zone.

- Additionally, the availability of S-bahn service makes the region well connected with other parts of the city and suitable for long distance travel for commuters.

- Overall, the section has a very good standard of transport coverage with almost no region running in the upper limit of the 600m radius circle.

Section Report:

From the above-mentioned observations, the research brings out the following report on the factors of Density and Diversity for the section of "By the water".

Density:

Section Name	Factor	Population Density		Land Use			Transportation Provision
By the Water	Sub-Factors	Scale	Irregularity	Versatile	Adequate Services	Green area and Social Environment	Adequate and Integrated
		Moderately High	Yes	Yes	Moderately High	Yes	Yes

Table 5: Density (By the Water)

Diversity:

Section Name	Factor	Transportation Provision		
By the Water	Sub-Factor	Major zone in 150m Radius	Blocks in the Upper limit of 600m Radius	Overall Coverage
		Yes	No	Good

Table 6: Diversity (By the Water)

Section: Eye of the Needle

Factor: Population Density

Observations:

- The "Eye of the Needle" section lies in the western region of Kreuzberg district in Berlin with major residential blocks and public facility land on either side of the track.

- The section is highly populated on the periphery of the main road in the eastern zone. However, the western zone is scarcely populated apart form few patches of dense blocks.

- The section has large blocks with minimum intersection and deviation, creating unfavourable walking and biking environment in the southern side while the northern side has more option for change in direction and path for the commuters.

- From the fig in Annexes 3 we can see that, the major population density ranges from 251-550 Person/ Ha, also with some blocks ranging from 5-71 Person/Ha. Overall, the section is moderately populated.

Factor: Land use

Observations:

- The section has 4 types of land use namely the residential uses, Public facilities, Green and Open area and mixed uses.

- The fig in Annexes 3 shows residential buildings to be in the central and eastern side of the section, showing possible points of trip generation. However, the major residential layouts are not catered with bus stops showing lack of connectivity.

- With a single block of mixed use of land, the section lacks points of trip attraction. Further, the section has very few services provisions indicating poor trip attraction ability. Furthermore, the section has no health care setting which is not ideal for integrating the vulnerable section of active commuter.

- The blocks in the northern side of the track are smaller as compared to large blocks in southern side, showing better conditions for the active environment in the norther side of the track.

- Overall the section has poor conditions for active commuters with no health care setting, very few active areas, poor connection of residential layout and long distance of connectionless streets.

Factor: Transport Provision

Observations:

- The presence of bus stops next to the U-Bahn Prinzenstrasse station makes it good example of inter network connectivity for integrating different modes of public transport.

- It is clear from Fig in Annexes 3 that, the section has adequate transportation provision at the central, northern and eastern zone, however the western zone lacks

points of connectivity to the rest of the region, making it a disconnected zone for both active and public transport users.

- The section has smaller blocks in Norther side of the track and large blocks with fewer options of selecting path in the southern side of radbahn, creating a partially unfavourable condition for pedestrians.

- Overall, the lack of bus routes in the western zone and south eastern zone combined with long spells of roads without intersection in the section rules against the integration of public transport with active transport.

Factor: Transport Coverage

Observations:

- Transport coverage in this section is good in patches. While the central and the North Easter zone have dense coverage, the North western and western zones lack transport coverage.

- Combined that with minimal intersection and deviations makes it an unfavourable environment for the pedestrians and bikers.

- Overall, from the fig in Annexes 3 we can observe that, there are sizeable number of blocks which come in the periphery and outside the 600m radius area from the nearest public transport outlet. These condition play against the integration of public transport with active transport.

Section Report

From the above-mentioned observations, the research brings out the following report on the factors of Density and Diversity for the section of Eye of the Needle.

Density:

Section Name	Factor	Population Density		Land Use			Transportation Provision
Eye of the Needle	Sub-Factors	Scale	Irregularity	Versatile	Adequate Services	Green area and Social Environment	Adequate and Integrated
		High	Yes	Very Less	No	Yes	No

Table 7: Density (Eye of the Needle)

Diversity:

Section Name	Factor	Transportation Provision		
Eye of the Needle	Sub-Factor	Major zone in 150m Radius	Blocks in the Upper limit of 600m Radius	Overall Coverage
		No	Yes	Moderate

Table 8: Diversity (Eye of the Needle)

Section: Hotspot

Factor: Population Density

Observations:

- The "Hotspot" section falls in the central Kreuzberg district in Berlin with residential, mixed use buildings on either side of the track.

- Due to its higher residential and mixed-use type land, the section is heavily populated along the radbahn track. However, the population density in the southern zone is marginally more than that in the northern zone.

- From the fig in Annexes 3 we can observe that, this section has a mix of large and small blocks on either side of the track, making it partially good for walking and biking.

- A small plot with the population density range of 31-70 shows a minute deviation from the rest of the section, which is highly populated. Overall, the section is highly populated with majority of the blocks ranging from the population density of 251-550 and beyond Person/Ha.

Factor: Land use

Observations:

- The section contains 4 types of land use namely Residential use, Open and green space, Public Facilities and Mixed Uses. The public space and Green and Open area is accumulated on the eastern side with the southern zone dominated by residential layouts and northern section with a good mix of residential and mixed-use layouts.

- From fig in Annexes 3 we can learn that, the regions of residential uses have higher population density than other kinds of land use. Moreover, the residential section has high amount of food outlets making it a strong point of trip attraction. Furthermore, the section also is supported with two health care settings very close to the nearest bus station, rendering effective connectivity for vulnerable section of commuters.

- The area with mixed land use contain food outlets, social gathering points and active commercial shops. The service outlets are easily accessible considering their location in the blocks.

- Overall, the section is dominated with two kinds of land use with high amount of service outlets distributed evenly on north and unevenly on south of the radbahn track. Further, the blocks have points of connectivity with public transport within walkable distance making it a suitable location for integrating active and public transport.

Factor: Transport Provision

Observations:

- The "Hotspot" section is excellently catered with bus stands travelling in different routes. The direction of the bus routes covers the whole section leaving almost no block disconnected with the rest of the region.

- It is evident from the fig in Annexes 3 that, there are 21 bus stops and 2 major U-Bahn stations making it an extensively connected section with the possibility of reaching any block within walkable distance of the nearest bus or U-Bahn stop.

- The bus stops are well placed within the walking distance from the "residential buildings" and "mixed use" plots, making it an excellent example of integrating public and active transport system.

- Overall, the connectivity of the section is extensive and point of connectivity are placed at walkable distance from the places of trip generation and trip attraction.

Factor: Transport Coverage

Observations:

- The section has an impressive range of transport coverage covering every block in the section. The blocks near U-Bahn stations have a great coverage over 150 meters range.

- It is further clear from fig in Annexes 3 that, the rest of the blocks in this section are completely covered in the 600 meters range radius from the nearest public transport stop.

- Overall, the section is very well covered and connected with nearest public transport outlet, giving an ideal environment for pedestrians to use the public transport.

Section Report:

From the above-mentioned observations, the research brings out the following report on the factors of Density and Diversity for the section of Hotspot.

Density:

Section Name	Factor	Population Density		Land Use			Transportation Provision
Hotspot	Sub-Factors	Scale	Irregularity	Versatile	Adequate Services	Green area and Social Environment	Adequate and Integrated
		Very High	No	Yes	Yes	Yes	Yes

Table 9: Density (Hotspot)

Diversity:

Section Name	Factor	Transportation Provision		
Hotspot	Sub-Factor	Major zone in 150m Radius	Blocks in the Upper limit of 600m Radius	Overall Coverage
		Yes	No	Good

Table 10: Diversity (Hotspot)

Section: Spree Feeling

Factor: Population Density

Observations:

- The section "Spree feeling" is situated in the eastern Kreuzberg district in Berlin with a versatile land use type surrounded on either side of the track. This section marks the end of the radbahn track on the other side of the scenic Oberbaumbrucke bridge.

- The section has very low population density on the northern and eastern side of the section where the population density ranges from 1-70 Person/Ha.

- Notably, from the fig in Annexes 3, the population density of the blocks on the south of the track is found comparatively higher to that of the north at most points in the section. Interestingly, this pattern coincides with the residential and mixed land use being highly populated while the public facility, small industry and utility area being scarcely populated.

- Overall, the section is moderately populated with a good mix of "highly populated" zones and "scarcely populated" zone.

Factor: Land use

Observations:

- The section of "Spree feeling" has a versatile land use pattern with 6 different land use type namely, residential uses, small business, mixed uses stretched over the section. The major types being Residential use, Mixed land use and public facilities.

- Food environment dominates the service outlet in this section, with almost every block containing multiple food outlet, making it more attractive environment for the commuters (Annexes 3). However, there are few active and social environment in the central and eastern zones of the section.

- The section also has two health care settings on the south of the radbahn track. The settings are located at a walkable distance from the nearest public transport setup, thereby rendering suitable conditions for commuters using public transport service and pedestrians.

Factor: Transport Provision

Observations:

- The section is catered with 14 Bus stops and 1 U-Bahn station, with bus stops in every alternate block baring the north-west region in the section. The U-bahn station is well connected with bus stops thereby improving inter network connectivity.

- The fig in Annexes 3 shows that, the transport provision is spread evenly throughout the region baring the north-western zone rendering a scope for improvement for the public transport system.

- Overall, the transport provision is good in the region with the point of connectivity well spread over the land use of diverse kinds. However, due to lack of points of connectivity in the north-western blocks, the region takes a minute hit in integrating pedestrians with the public transport in the region.

Factor: Transport Coverage

Observations:

- The section has a very good standard of public transport coverage. The major transportation coverage is to be seen in the central zone near the U-Bahn Scheisiches tor station and near the eastern zone near the end of the track.

- While the north-western zone is not very well catered with bus stops, the eastern and south -eastern ends are well connected with bus stops (Annexes 3). However, almost all the blocks are covered by the 600-meter radius circle showing a great degree of coverage in the section.

- Overall, the section has a good range of transport coverage baring few blocks in the north -east section, making it a good example of public transport coverage.

Section Report:

From the above-mentioned observations, the research brings out the following report on the factors of Density and Diversity for the section of Spree feeling.

Density:

Section Name	Factor	Population Density		Land Use			Transportation Provision
Spree Feeling	Sub-Factors	Scale	Irregularity	Versatile	Adequate Services	Green area and Social Environment	Adequate and Integrated
		Moderately High	Yes	Yes	Moderate High	No	Moderate Low

Table 11: Density (Spree Feeling)

Diversity:

Section Name	Factor	Transportation Provision		
Spree Feeling	Sub-Factor	Major zone in 150m Radius	Blocks in the Upper limit of 600m Radius	Overall Coverage
		Yes	Few	Good

Table 12: Diversity (Spree Feeling)

Overall Report:

Macro level factors:

Density:

Section Name	Factor	Population Density		Land Use			Transportation Provision
	Sub-Factors	Scale	Irregularity	Versatile	Adequate Services	Green area and Social Environment	Adequate and Integrated
Promenade		Moderately High	Yes	No	Yes	Yes	Moderate
Under the Roof		High	No	Yes	Yes	No	Moderate High
By the Water		Moderately High	Yes	Yes	Moderate High	Yes	Yes
Eye of the Needle		High	Yes	Very Less	No	Yes	No
Hotspot		Very High	No	Yes	Yes	Yes	Yes
Spree Feeling		Moderately High	Yes	Yes	Moderate high	No	Moderate Low

Table 13: Density (Radbahn track)

Diversity:

Section Name	Factor	Transportation Coverage		
	Sub-Factor	Major zone in 150m Radius	Blocks in the Upper limit of 600m Radius	Overall Coverage
Promenade		Yes	No	Good
Under the Roof		Yes	No	Good
By the Water		Yes	No	Good
Eye of the Needle		No	Yes	Moderate
Hotspot		Yes	No	Good
Spree Feeling		Yes	Few	Moderate

Table 14: Diversity (Radbahn track)

Explanation:

Following within the framework of "Walkability of Health", the research found congruence with the rhetoric of the geographical relationship between population density and land use type. In the case of each section of radbahn, it was clearly notable that the plots used for mixed use and residential purpose saw a higher degree of occupancy which followed the norms of the theory of geographic relationship between land use type and population density. The theory of geographical relation, backs a relationship between a particular land use type and population density (Webber. M.J, 2010). This study helped in establishing a pattern between two factors, which in the study of active travel pattern, was helpful in finding the most frequently used path by the active commuters.

Drawing from the ideology of the study by Deutsche Gesellschaft fur Technische Zussamenarbeit (GTZ) the research focused on finding out suitable active travel conditions which could reduce the number of motorised trip generation factor. According to the report, the land use pattern and transportation provision had a integral relation, which in hindsight affected the transport planning of the city (Petersen. R, 2004). According to the same report, an area with high population density, and versatile land use pattern, which included various social and economic activities, helped in maintaining short distance between the origin and the destination of the average trip generated in that region (Petersen. R, 2004). These condition, which are ideal for non-motorised and active travel trips, was the next factor used to evaluate the radbahn track while following the framework of walkability for Health. Thereafter, the study primarily focused to map the plots with varied land use type and supportive public transport provision in the section. This in retrospection helped in bringing out the areas around the radbahn track suitable for integrated active and public transport trip type.

From the theoretical backing of above mentioned literatures and the framework of walkability for Health, the study was successfully conducted, and the results from the Macro level study helped the author to identify the most suitable (Hotspot) and least suitable (Eye of the needle) section for active travel purpose. Further these sections were tested under a Detailed Meso-level study to examine the factors of active path continuity and active block connectivity. However, for the basic understanding of Meso level factors, the next section

brings out the results of Meso level study performed in the evaluation research on the streets joining the radbahn track with high scope of active travel activity.

Meso Level:

After understanding the factors of density and diversity around the track of radbahn, the study now focused on understanding the conditions of the intersections and street segments of the roads leading towards the radbahn track. This study aimed to find the level of active travel connectivity and path continuity for active commuters on the streets that possessed higher potential for active travel commutation. From the observations made in the study of Macro-level factors, the research screened out the following type of streets to further perform Meso-level factors study on them:

- Streets connecting the neighbourhood to the nearest public transport outlet leading towards the radbahn track. As this indicator helped in measuring the easy of accessibility towards the nearest public transport outlet for the active commuters.
- Street connecting the residential plots, mixed-use plots, educational institutes and commercial area towards the radbahn track.

Deduced from a well-known study on Integrating non-motorised transport with public transport, conducted by Dr. Amer. A *et al,* (2009) this research focused on studying the ease of accessibility of public transport around the track of radbahn to measure the level of integration. Further, a quantitative study on the choice of transport modes in city of Berlin, clearly showed that, the citizens tend to use public and active transport more often while traveling to work, university, home and shopping (Horn. B, 2015). Hence these criteria helped in mapping out the most frequently used routes by active commuters around the radbahn track. On these routes, the evaluation research was performed to examine the inclusivity of active travellers by reading into the conditions of the street segments and intersection that prevailed around the radbahn track. Subsequently, the findings from the study were tabulated at the end of each section.

Section: Promenade

Observations:

- Street hierarchy and classification: From the fig in the Annexes 4, it is evident that the section of Promenade has three road types joining the radbahn track namely, commercial shared, Boulevard and yield street. The section dominated with buildings of core areas and mixed use are connected to the radbahn with commercial shared and boulevard road type. While the yield streets are provisioned for the active commuters to reach the green and open area.
- Intersection type: The fig in Annexes 4 shows that, the condition of intersections in the Promenade is active travel friendly. The intersections joining the radbahn are majorly marked, barring in few instances of dead ends. Additionally, the lone yield street in the section has pedestrianised intersection indicating suitable condition for active users.
- Segment type: From the fig in the Annexes 4, it is unblemished that, despite having highly pedestrianised condition in the roads joining the radbahn track, the active travel conditions are poor considering the lack of biker friendly environment. Apart from the boulevard in the eastern side of the track, no roads joining the radbahn have distinct cycle track. The lack of separate bike tracks in these roads give rise to condition of lack of safety for the bikers and the pedestrians. Section report:

Street Hierarchy and classification:

Section	Motor vehicle friendly	Active commuter friendly
Promenade	Yes	Moderately

Table 15: Street Hierarchy and classification (Promenade)

Intersection type:

Section	Fully Marked	Marked	Unmarked	Pedestrianised	Dead-end situation
Promenade	0	36	14	4	3

Table 16: Intersection type (Promenade)

Segment type:

Section	Pedestrian friendly Environment	Bike friendly Environment
Promenade	Good	Poor

Table 17: Segment type (Promenade)

Section: Under the Roof

Observations:

- Street hierarchy and classification: The fig in the Annexes 4 shows that, the "Under the roof" section has roads under five distinct types of street classification namely; neighbourhood street: which prevail in the western end of the section with residential and mixed land use type around it. Commercial alleys: which are located next to the major commercial outlets with mixed land use. Commercial shared: Which have equal amount of residential and commercial activity around it. Residential shared: Which are present in the centre of the section with thickly populated residential buildings around them. And the lone yield street in the section near the U-Bahn Bullowstrasse station. The section provides good pedestrian condition but lacks ideal biking conditions on the roads joining the radbahn track.

- Intersection type: The fig in the Annexes 4 depicts that, the section has a mix of Fully marked, marked, unmarked and dead-end type of intersection. The street joining the U-Bahn Nollendorfplatz has two dead end conditions which are non-encouraging for active commuters. The section has three instances where the intersections are without any markings, these conditions tamper the active commuter safety conditions leading to decrease in active travel commuter ridership.

- Segment Type: The fig in the Annexes 4 gives a clear picture of the type of segment in this section of radbahn. Apart from the commercial alley which joins the U-bahn

Nollendorfplatz station, the rest of the section is catered with roads without a provision of cycle track. This adverse condition for the biking ridership will indirectly affect the ridership of radbahn track.

Section report:

Street Hierarchy and classification:

Section	Motor vehicle friendly	Active commuter friendly
Under the Roof	Yes	Moderate

Table 18: Street Hierarchy and classification (Under the Roof)

Intersection type:

Section	Fully Marked	Marked	Unmarked	Pedestrianised	Dead-end situation
Under the Roof	8	30	20	1	3

Table 19: Intersection type (Under the Roof)

Segment type:

Section	Pedestrian friendly	Bike friendly
Under the Roof	Good	Poor

Table 20: Segment type (Under the Roof)

Section: By the Water

Observations:

- Street Hierarchy and classification: The fig in the Annexes 4 shows that, the section of "By the water" has mixture of types of road in the North-South direction. The commercial and residential shared roads are present next to the residential and mixed land use type in section of central zone. The section also has large stretch of

neighbourhood main street and boulevard roads connecting the north and south of the radbahn track. The section provides moderate conditions for the pedestrians and bikers on the roads joining the radbahn track.

- Intersection type: From the fig in the Annexes 4, we can infer that section has large blocks with fewer intersections on either side of the track. However, these intersections are marked with no dead-end situations making it an average section for active travel experience.

- Segment type: The overall condition for biking and walking is reasonably good considering number of roads with separate bike lanes joining the radbahn track. (Refer Annexes 4)

Section report:

Street Hierarchy and classification:

Section	Motor vehicle friendly	Active commuter friendly
By the water	Yes	Moderate

Table 21: Street Hierarchy and classification (By the water)

Intersection type:

Section	Fully Marked	Marked	Unmarked	Pedestrianised	Dead-end situation
By the Water	0	30	12	0	2

Table 22: Intersection type (By the water)

Segment type:

Section	Pedestrian friendly	Bike friendly
By the Water	Moderate	Moderate

Table 23: Segment type (By the water)

Section: Eye of the Needle

Observations:

- Street Hierarchy and classification: The fig in the Annexes 4 shows that, the section has three distinct types of roads joining the radbahn track namely; Neighbourhood street: which are located next to a varied land use type of residential, public space and mixed used type. Residential streets: Present in the highly dense residential zone and, Green alley: which is located next to the residential setups. The section fails to provide good pedestrian and biking conditions on the roads joining the radbahn track.

- Intersection type: The fig in the Annexes 4 depicts that, the roads in this section have mixed amount of unmarked and marked intersections with few pedestrianised intersections near the green alley roads. Overall the condition of the intersection is below par standards for safe pedestrian and bike commutation.

- Segment type: The fig in the Annexes 4 shows the lack of roads with bike lanes connecting the radbahn. The zones with residential use are highly pedestrianised. However, they are not catered with bike lanes, making it an unfavourable condition for biking in the surroundings of radbahn.

Sectional report:

Street Hierarchy and classification:

Section	Motor vehicle friendly	Active commuter friendly
Eye of the needle	Moderate	Moderately low

Table 24: Street Hierarchy and classification (Eye of the needle)

Intersection type:

Section	Fully Marked	Marked	Unmarked	Pedestrianised	Dead-end situation
Eye of the needle	0	15	21	3	1

Table 25: Intersection type (Eye of the needle)

Segment type:

Section	Pedestrian friendly	Bike friendly
Eye of the needle	Poor	Poor

Table 26: Segment type (Eye of the needle)

Section: Hotspot

Observations:

- Street Hierarchy and classification: From the fig in the Annexes 4 we can see that, the section of hotspot has diverse range of road classification. However, there is a distinctive difference between the roads in the north to the roads in the south of the radbahn. The northern side of the radbahn sees a high range of residential shared and commercial streets, while the southern section has neighbourhood streets, neighbourhood main streets and boulevards joining the cycle track. The section provides good pedestrian condition but lacks ideal biking conditions on the roads joining the radbahn track.

- Intersection types: The fig in the Annexes 4 depicts the high number of intersections on both the sides of the track, thereby, providing more path provision for active commuters. However, the section has many unfavourable pedestrian conditions with high number of dead-ends and unmarked intersections.

- Segment type: From the fig in the Annexes 4 we can study that, the segment type is highly pedestrianised however, with very few roads with distinct bike lanes. The

overall condition of active travel is average despite small blocks with good connectivity to public transport.

Sectional report:

Street Hierarchy and classification:

Section	Motor vehicle friendly	Active commuter friendly
Hotspot	Yes	Moderate

Table 27: Street Hierarchy and classification (Hotspot)

Intersection type:

Section	Fully Marked	Marked	Unmarked	Pedestrianised	Dead-end situation
Hotspot	0	16	38	14	8

Table 28: Intersection type (Hotspot)

Segment type:

Section	Pedestrian friendly	Bike friendly
Hotspot	Good	Poor

Table 29: Segment type (Hotspot)

Section: Spree Feeling

Observations:

- Street hierarchy and classification: Studying from the fig in the Annexes 4, we can infer that the section of "Spree feeling" has four distinct types of roads joining the cycle track. The densely populated area, in the south, which is of residential land use type is connected with residential shared streets, commercial street and

neighbourhood street showing the diversity of road type in the dense areas of the section. Further, the section sees a boulevard near the end of the radbahn connecting the track, with an active biking condition. The section provides good pedestrian condition but lacks ideal biking conditions on the roads joining the radbahn track.

- Intersection type: The fig in the Annexes 4 shows that, the section has considerable amount of dead-end leading towards the radbahn track, showing poor level of connectivity from one block to other with fewer path options. However, the end of the radbahn section is well connected to the road with fully marked intersections. Overall, the section has a poor intersection condition with significant number of dead-ends and unmarked intersections.

- Segment type: Looking into the fig in the Annexes 4 we can see that, substantial number of roads around the radbahn track are highly pedestrianised with safe buffer region to make it a safe walkable space. However, like most of the sections of the radbahn, the roads connecting the cycle track lack separate bike lanes rendering poor conditions for bikers joining radbahn.

Sectional report:

Street Hierarchy and classification:

Section	**Motor vehicle friendly Environment**	**Active commuter friendly Environment**
Spree Feeling	Yes	Moderate

Table 30: Street Hierarchy and classification (Spree Feeling)

Intersection type:

Section	Fully Marked	Marked	Unmarked	Pedestrianised	Dead-end situation
Spree Feeling	5	20	10	0	9

Table 31: Intersection type (Spree Feeling)

Segment type:

Section	Pedestrian friendly Environment	Bike friendly Environment
Spree Feeling	Good	Poor

Table 32: Segment type (Spree Feeling)

Overall Report:

Street Hierarchy and classification:

Section	Motor vehicle friendly	Active commuter friendly
Promenade	Yes	Moderate
Under the roof	Yes	Moderate
By the Water	Yes	Moderate
Eye of the Needle	Moderate	Moderately low
Hotspot	Yes	Moderate
Spree Feeling	Yes	Moderate

Table 33: Street Hierarchy and classification (Radbahn track)

Intersection type:

Section	Fully Marked	Marked	Unmarked	Pedestrianised	Dead-end situation
Promenade	0	36	14	4	3
Under the roof	8	30	20	1	3
By the Water	0	30	12	0	2
Eye of the Needle	0	15	21	3	1
Hotspot	0	16	38	14	8
Spree Feeling	5	20	10	0	9

Table 34: Intersection type (Radbahn track)

Segment type:

Section	Pedestrian friendly Environment	Bike friendly Environment
Promenade	Good	Poor
Under the roof	Good	Poor
By the Water	Moderate	Moderate
Eye of the Needle	Poor	Poor
Hotspot	Good	Poor
Spree Feeling	Good	Poor

Table 35: Segment type (Radbahn track)

Explanation:

From the study of Street hierarchy and classification, it was depicted that the streets joining the radbahn track had majorly favourable pedestrian environment condition with an exception of "Eye of the Needle" section which had moderate pedestrian friendly conditions. However, the state of bike infrastructure was poor in almost all the roads that join the radbahn section. This lead to terming most of the sections of radbahn as "Moderate" for active commuter friendly environment. Further, the study also depicted friendly environment for the motorised vehicle on almost all the roads joining the radbahn track barring the section of "Eye of the Needle" and therefore this lead to terming most of the sections as "Good" for motor vehicle friendly environment.

From the evaluation of intersection type, the study found that the intersections made by the roads connecting radbahn had significantly higher number of unmarked intersections. Furthermore, the study also depicted the lack of fully marked intersections, with only 2 sections having handful of fully marker intersections at the junction of radbahn.

From the examination of segment type, the study found that with an exception of "By the water" section, the other sections provided "good" conditions for pedestrians on the roads leading towards the radbahn track. However, the conditions of biking were equally poor on all the section with an exception on "By the water" section. For the major stretch of radbahn, the roads joining the track lacked a strong biking infrastructure on either side. This showed a major weakness in the project which needed to be considered, as it would affect the potential ridership of the project and the level of inclusivity of active commuters around the radbahn track.

Selected sections for further study

With the understanding of the factors at the Macro level and basic study of Meso level, the author now performed a detailed Meso-level factor study on two of the selected sections from the Macro-level study (i.e. Hotspot and Eye of the Needle). Following the framework of Walkability for Health, the Meso level factors were broadly classified in three categories namely: Vehicular impact, Active Path Connectivity and Active Path Continuity. The classifications were based on various aspects of active travel experience. The author focused on using parameters from each category to examine the active travel experience. At the end of both sections, the research tabulates the degree of active travel friendliness and gives an individual sectional report.

The research measured vehicular Impact factor with the help of using high resolution images from google maps to map the streets joining the radbahn track. These images were then edited in AutoCAD to highlight the boundaries of streets, built up area and green space. In the study of street hierarchy and classification, the streets were classified into Arterial, collector, local street and supplementary roads. This study helped in understanding of the type of roads that are connected to the radbahn track. Further, the study included mapping the number of grids and street segments that were present on the roads that were leading towards the cycle track. This study was done to see the degree of path options or mobility available for the active commuters. However, this study was extended to roads and intersections joining the connecting roads of radbahn.

The active path continuity factor was studied by using google earth image as base map and further using AutoCAD to bring out the streets and built area differentially. The street segment analysis was done on both the sides of the streets including the sidewalks. A single street segment was the section of street between two consequent intersections (excluding the intersections). With the help of photographic survey and google map images, the streets were classified in nine different categories based on the active travel conditions**.** This indicator helped in mapping streets friendly for pedestrian and biking environment.

The active path connectivity factor was examined with the help of images from the photographic survey and hi resolution images of google maps. In this study, all the intersections were numbered and further were classified as T-intersection and 4-way

crossing (full intersection) to check for better path connectivity and networking factors. Further in the study of path connectivity, the intersections were categorized under five categories namely, unmarked, marked, fully marked, pedestrianized and dead-end type. Distinctive color coding was used to depict the intersection type as shown in fig () Annexes 5. This factor helped in understanding the ease of connection for pedestrians and bikers from one block to the other.

The next section examines the Detailed Meso factors for the 'Least Favorable section' (Eye of the needle) followed by the 'Most favorable section' (Hotspot). Following the description of which, in both section, the sectional report tabulates the results for simple and brief understanding.

Least Favorable section: Eye of the Needle

Active Block Connectivity

Observation:

- Intersection type and number: From the figs in Annexes 5 we can infer that, this section which is deemed as the least favorable section based on the Macro level factor analysis has almost equal number of full intersection and T-intersection. The presence of large number of T-intersection in pedestrianized road makes the walking experience less pleasing as the commuter has less path changing options. The presence of which is also added by the misery of long intersection less blocks on the southern side of radbahn track near the residential layouts. Despite having yield streets near the residential setup, the roads lack intersection making it less encouraging path for pedestrians to choose.
- Intersection coding: Looking into the fig in Annexes 5 we can study that, the intersections which lead to the pedestrianized roads lack pedestrian or bike lane marking. This condition, despite having a favorable condition by "pedestrianizing" the road, is rendered unfavorable due to the lack of marked intersection. Moreover, the roads joining the radbahn tracks majorly lack markings. These intersections coincide with the roads which are pedestrian friendly and lead up to the most

densely populated residential setups. This section, despite having few favorable conditions for pedestrian lack marking at the intersection, making it a poor condition for active block connectivity.

Active Path Continuity

Observation:

- Segment number and coding: The maps from the figs in Annexes 5 show distinctive difference between the northern and the southern side of the radbahan. The northern section has more street segments which imply more path options and ease of changing direction. These conditions are absent in the southern region with large intersection less street segment. Further, the section lacks roads with separate bike lanes joining the radbahn. These conditions show poor path continuity along the line of radbahn.

Vehicular Impact

Observations:

- Street hierarchy: From the fig in Annexes 5 we can see that, the radbahn track, is joined by 'neighborhood streets' in the central zone of the section. These roads connect the radbahn track to the land use of various type, however, the residential areas are connected by 'residential shared' and 'yield street' type of roads.

- Number of blocks and segments: From the figs in Annexes 5 we can study that, the section has large difference in the grid sizes and number of segment. The favorable conditions of which are present on the northern side of the radbahn track. Due to lack of more path options and poor path connectivity and continuity and more appropriateness for motorized mode of travel, the section scores low on active travel friendly environment.

Section Report:

Factor: Vehicular Impact

Section Name	Factor	Vehicular Impact	
Eye of the Needle	Sub Factor	Active User Friendly	Motorized User Friendly
		Poor	Good

Table 36: Vehicular Impact (Eye of the Needle)

Explanation: The study terms this section as a "Poor" example for "Active User friendly" factor. The size of the blocks on the southern side of the track, along with the lack of path option for bikers and pedestrians joining the radbahn track, make the conditions work against rendering active-user friendly environment.

Factor: Active Path Continuity

Section Name	Factor	Active Path continuity	
Eye of the Needle	Sub Factor	Active User Friendly	Motorized User Friendly
		Poor	Good

Table 37: Active Path Continuity (Eye of the Needle)

Explanation: When compared with the land use pattern of the section, it can be seen that the regions with higher chances of active travel activity, lack distinct bike lanes. With only three out of ten streets joining the radbahn track having provision for biking, the section is termed as "Poor" for Active path continuity.

Factor: Active Block Connectivity

Section Name	Factor	Active Path Connectivity	
Eye of the Needle	Sub Factor	Active User Friendly	Motorized User Friendly
		Poor	Good

Table 38: Active Block Connectivity (Eye of the Needle)

Explanation: The study identifies the section "Eye of the needle" as a "Poor" example of Active path connectivity due to the lack of marked intersections leading towards the radbahn track. Additionally, the conditions of intersections near the residential and core areas are unfavorable, considering the risk factor for the bikers when coupled with the condition of bike lanes on those streets.

Most favorable section: Hotspot

Active Block Connectivity

Observations:

- Intersection type and number: From the fig in Annexes 5 we can see that, the section of "Hotspot" contains large number of roads joining the radbahn track on either side. Notably, the section has large number of T-section accumulated in one of the major intersection (near U-bahn Kottbusser Tor), showing poor active travel environment in that zone. However, the other roads joining the radbahn track have full intersection providing free flow of the vehicles coming towards the cycle track, rendering good conditions for active travel connectivity.

- Intersection coding: From the fig in Annexes 5 it seen that, the streets joining the radbahn track at the U-Bahn Kottbusser tor have poor unmarked intersections. Moreover, the intersections on the northern side of the tracks have more unmarked

and dead-end conditions showing unfavorable active travel conditions. However, the southern section has better active travel conditions with more pedestrianized and marked intersection rendering good conditions for active block connectivity when compared to the northern section.

Active Path Continuity

Observations:

- Segment number and coding: The figs in Annexes 5 shows that, the section has a large number of segments showing more path options for active travel users. When broken down in two zones, the northern zone has higher number of street segment when compared to the southern section. Looking into the type of street segment, it is clear from the map that the northern section of the radbahn has very good conditions for pedestrian commuting. However, it lacks roads with well-defined bike lanes. When seen for the southern section, majority of the streets have well defined biking and pedestrian environment, although there are streets with scope of further improvement. Overall, the section lacks sufficient provision for bike lanes to have a sound active environment ridership.

Vehicular Impact

Observations:

- Street Hierarchy and classification: As mentioned in the above section, the "Hotspot" section of radbahn has high number of segments implying good active travel conditions. When superimposed with the maps of land use type and the population density, it is seen that the Neighbourhood main street and Neighborhood street road type connect the highly populated residential setup to radbahn track with an exception of the boulevard leading towards the schliesisches Tor. (Fig (66) in Annexes)

- Number of blocks and segments: From the figs in Annexes 5 we can see that, the "Hotspot" section has large number of smaller grids on both the sides of the cycle track. This condition provides good active travel environment and in turn encourages

higher ridership. With high amount of connectivity in the grids around the radbahn, the active commuters have more path options with better vision as compared to the section of "Eye of the needle" which encounters large grids of plots with tall structures placed close proximity.

Section Report:

Factor: Vehicular Impact

Section Name	Factor	Vehicular Impact	
Hotspot	Sub Factor	Active User Friendly	Motorized User Friendly
		Good	Good

Table 39: Vehicular Impact (Hotspot)

Explanation: The section of "Hotspot" contains large number of street segments on either side of the track showing immense options for active commuters around the cycle track. Henceforth, the section is termed as a "Good" example for Active user-friendly environment.

Factor: Active Path Continuity

Section Name	Factor	Active Path continuity	
Hotspot	Sub Factor	Active User Friendly	Motorized User Friendly
		Poor	Good

Table 40: Active Path Continuity (Hotspot)

Explanation: The section of "Hotspot" lacks provision for bikers leading towards the cycle track. Only three out of sixteen roads joining the radbahn track possess bike tracks show poor conditions for the path continuity.

Factor: Active Path Connectivity

Section Name	Factor	Active Path Connectivity	
Hotspot	Sub Factor	Active User Friendly	Motorized User Friendly
		Average	Good

Table 41: Active Path Connectivity (Hotspot)

Explanation: The study finds the section of "Hotspot" rendering "Average" conditions for active commuter due to following reasons: a) nine out of sixteen intersections at the junction of radbahn we observe full intersections which provide good connectivity conditions, b) Large number of intersection in southern zone have marked intersections, However, c) The northern zone has large number of unmarked intersections and dead-end conditions towards the radbahn track.

6. Conclusion and Recommendation

Conclusion

The city centres are losing their attractiveness worldwide due to over congestion caused by increased traffic volumes. The demand for better mobility within the city, has been a new age issue for cities across the world. However, in many cases, enlarging and expanding the public transport network is not the answer as they are economically and environmentally not feasible. This issue can only be tackled by intelligent integration transportation system (Adamski. A, 2016). Many cities of Germany, Austria and Switzerland have successfully fulfilled the demands of integrating public transportation by resolving the issues of proper coordination of service levels, routes and time table, and a common fare system (Matas. A, 2004). However, Berlin, despite having a vibrant integrated public transport system, has failed to reduce the number of private trips made in recent past. This issue was tacked by the city administration in 2004 by adopting a bike strategy to integrate biking with the city's public transport system. Despite the promises, the city didn't see a momentous change in the ground results. Following which, the city administration adopted a new biking strategy in 2013. The reports of which suggested to exclusively promote biking in city to reach a modal share of 18-20% by the year 2025 (Senate department of Urban Development and the Environment, 2013). A goal which can only be achieved with the help of innovative ideas from the local biking community along with strong backing from the academics. This research was done on one of such innovative ideas put forward by a group of enthusiastic architects and urban planners of the paper planes e.V. organisation in the form of radbahn. In the quest to answering the major thesis question of: "How can implementation of radbahn help in integrating active and public mode of transportation in Berlin", the research followed a set of objectives.

The **first objective** of the research was to critically review the Macro level factors from the framework of Walkability for Health and determine the most suitable and least suitable sections of radbahn for active travel. Hence, when we look into the results mentioned in chapter 2, the framework of Walkability for Health had tabulated a wide range of factors pertaining to density and diversity. These factors helped in understanding the built environment conditions which in long run, would influence the ridership of the radbahn track. Interestingly, the study found a case of exception in the form of "In the park" section,

due to its built environment conditions, which were unique as compared to other sections of radbahn which fall in a general tissue of urban landscape. When we look into the outcomes of the tables, it was clear that the section "Hotspot" provided ideal active travel condition with its high population density, versatility in land use with a perfect mix of different kinds of economic and social service outlets located at a comfortable walkable distance from the nearest public transport outlets. On the other hand, the section "Eye of the Needle" was found as the 'least suitable' section of radbahn for active transport as it had irregularities in population density, unfavourable land use conditions with large blocks of land without public transport outlets. With these conditions prevailing in the section, the population around the track will not be able to take the advantage of a 'traffic-free' bike track running in the centre of the neighbourhood. Instead, the population will only benefit from a transport network when it helps in integrating different modes of transportation, improve health condition and mitigate congestion caused in the system (Kriezek. K.J, Stonebreaker. E.W, 2010).

The **second objective** of the research was to identify the streets with high scope of active travel activity and perform Meso-level factor study on them. Deriving from the theory of Integrating non-motorised transport with public transport, the research mapped the streets which were connecting the immediate neighbourhood to the nearest public transport outlet leading towards the radbahn track. The scope of study was narrowed down to the connecting streets to radbahn, as the area of research was restricted to one block on either side of the radbahn track. The second criteria used in mapping the streets was from a study done on the type of trip generating conditions prevailing around the radbahn track from trends of trip generation in Berlin. On the selected streets, the Meso-level factor study was done to check a) street hierarchy and classification, b) Intersection type), and c) Street segment type. When we look into the results from the table 34, it is clear that the intersection conditions around the radbahn track are far from ideal with large number of unmarked sections. The unmarked intersections render ideal conditions for accidents and congestions to both the biking and the pedestrian community. Looking into the observations of street coding and the results in table 35, we can observe that, the segment types around the radbahn track is ironically unfavourable for the biking community. While the pedestrians have a safe walking path in all the streets that join the radbahn track, only a handful of

connecting streets have a well-defined bike lane. Without addressing this basic issue of biking on the connecting streets of radbahn, it will be naïve to expect the cycle track to have high ridership.

The **third objective** of the research was to perform a detailed Meso-level factor study on the two-selected section from the Macro level study and check for the conditions of active path continuity and active block connectivity for active commuters. This study was extended to the roads and intersections joining the connecting roads of radbahn. For the least suitable section (Eye of the Needle), the study of active block connectivity revealed poor conditions of intersection marking on either side of the track. This was coupled with the presence of almost equal number of full and T- intersection, thereby rendering poor degree of mobility for active commuters (especially in southern section). However, the section of most suitable section (Hotspot) rendered average conditions for active block connectivity with considerable number of intersection playing in advantage for high mobility, and substantial number of unmarked intersection working against the safety levels of active commuters. The results from tables 36 and 39 depicted decent vehicular impact conditions on both the section barring the southern zone of "Eye of the needle" section, which had large plots of land without many mobility options. However, the active path continuity results showed poor conditions on both sections with handful of roads connecting radbahn track rendering safe commuting atmosphere for bikers. The results brought out by the study under the framework of Walkability for Health in each chapter, suggested substantial number of adverse conditions prevailing at the immediate environment of the radbahn track, which brings the study to the next section.

Recommendations

"How can implementation of Radbahn help in integrating Active and Public mode of transportation in Berlin?"

The radbahn project possess immense potential in encouraging citizens to use biking as an option of transportation or even as a part of their overall journey. The scope of generating interest in the forgotten space by using suitable locations along the track for open art gallery and recreation use fits the very ideology of creating demand on unused land. The concept of Mobility hubs to provide a platform for intermodal mobility will play a vital role in encouraging the pedestrians and bikers to choose different network of transportation and avoid using the personal motorized vehicles. In the longer run, these factors will play vital role in meeting the demand of egress trips from the public transport outlets on the radbahn tracks.

However, drawing from the observations of the Macro-level factor, the radbahn needs to identify the sections which lack mobility hub and provide a small-scale parking facility at the nearest U-Bahn station, to assure constant ridership in each section. For instance, the following U-Bahn stations which don't possess mobility hub due to infrastructural restrictions, also don't have the provision for parking bikes (U-Bullowstrasse, U-Prinzenstrasse, and U-Schlesisches Tor). This would adversely affect in generation of egress trips from the U-Bahn outlet. Further, this will impact the ridership of the radbahn around aforementioned U-Bahn stations. A small investment in creating sufficient bike parking space near the U-bahn stations will help to maintaining constant ridership throughout the bike track. Therefore, the first recommendation from the Macro-level study for the radbahn would be to <u>create minimum number of parking slots</u> in each section of the track to attain uniform ridership.

When checked for the conditions of the active commuters on the roads joining the radbahn in the analysis of Meso level study, the results showed overwhelmingly good conditions for the motorised vehicles, while the conditions for active travel were constantly moderate. The major drawbacks understood from the Meso-level study for active commuters were as follows: a) the lack of bike lanes on connecting streets and b) the lack of marked and pedestrianised intersection at major intersection. For the radbahn to attain a prominent

level of intermodal mobility, the track must be able to provide safe and congestion less travel experience along as well as towards the track. With handful of street sections having definite bike lanes and unmarked intersections at the junctions of radbahn, the project must focus on strengthening this aspect of the active travel. The figures in annexes 4 show that most of the joining streets fall under two categories, namely a) Pedestrian zone with buffer and b) Pedestrian Zone, which goes on to show that the condition of pedestrians is much better when compared to bikers. Hence, it is clear from the study that only one section of active travellers faces poor street segment conditions. To which the study gives the second recommendation to provide a on-street bike track, and further to improve the conditions of both bikers and pedestrians at the intersections, the radbahn needs to provide safe crossing zones in the form of fully marked intersections.

Further in the Detailed Meso level study, the factors of active path continuity and block connectivity were tested for two of the selected sections. Here, along with the consideration of street and intersection coding, the conditions of vehicular impact were also considered. The factors such as number of street segments and the number of blocks around the radbahn were seen to evaluate the active path mobility. The results of vehicular impacts were ideal for the "Hotspot" section while the section of "Eye of the needle" saw unfavourable mobility conditions due to the presence of long intersection less street segments. Due to the lack of mobility option, these types of sections tend to have poor rates of ridership along the radbahn. On these section, the radbahn can provide two kinds of solution; a) provide points of attraction (coffee shop or snack outlet) or b) provide green aesthetic (plant coverage) along with a provision to halt and gather. By doing this, we can play a section's weakness of lack of connectivity to its strength by making the long stretch of track a point of attraction and gathering.

The recommendations mentioned above, were given in consideration to have minimal infrastructural displacement, as it would make the section more congested with construction pertaining around the track. An additional factor of economic feasibility was also kept in mind while formulating the recommendations as the project is crowd funded. The track of radbahn has an enormous potential to become an ideal pilot project for future biking projects in Berlin or elsewhere. However, the project cannot ignore the pertaining

conditions which can hinder the efficiency of the track in integrating active commuters with the public transportation system.

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Annexes

Annex 1: Arguments for Biking

Following arguments were put by the Senate Department for Urban Development and the Environment to encourage people to use more bikes:

Biking

- Creates mobility. Biking can be used by majority of the population to travel short and medium long distance which also is inexpensive mode of transport. Further, when combined with public transport, it can also be used for long distance travel.
- Improves the quality of life in the city. With the least space occupancy, biking is more mobile with adding no air or noise pollution in the environment. This makes the city healthier to live in.
- Can replace part of motorized transport. According to the Senate Department for Urban Development and the Environment, almost half of the journeys are taken in less than 5km distance. But, one third of them are taken by car. This potential of replacing car by bikes needs to be tamped.
- Is fun and healthy. The Senate Department for Urban Development and the Environment also believes that biking half an hour each day will improve physical health of a person drastically.
- Contributes to traffic safety. By increasing the number of bikes on the road it makes all road users get accustomed and engaged in providing safe conditions on roads.
- Is easy on public purse. The Senate Department for Urban Development and the Environment believes that creating biking infrastructure is less expensive and easily repayable if used in large scale.
- Supports the economic development of Berlin. A city with healthier citizens and good environment with attractive public road design is always attractive to established and new inhabitants, for tourists and for business people (Senate department of Urban Development and the Environment, 2013).

Annex 2: Strategic goals to Integrate Biking

Following are the strategic goals that were put by the Senate Department for Urban Development and the Environment to integrate biking with the existing public modes of transportation:

- Increase in cycling's share of the overall number of journeys undertaken in the city.

The Senate Department for Urban Development and the Environment aim to reach 18-20% of total travel share in the city by biking with the new walking strategy. And also believe that it is possible to achieve the goal with the effective implementation of goals.

- Transferring longer journeys to bicycle.

According to the survey done by the Senate Department for Urban Development and the Environment, average length of the bike journey in Berlin is 3.7 km, and only 19% of the total journeys were more than 5 km. Henceforth, to decrease the negative effects of motorised transportation, the city administration is aiming to attain 4.6 km long average journey length by 2025. It is believed to impact the city in a positive way by reducing traffic jams caused by motorised vehicles.

- Combining the public transport with bicycle.

The cycling strategy has aimed to achieve 5% of combined journey in Berlin from the current figure of 3% by 2025. Studies show that combining biking with public transport increases the reach of public transport and also increase the radius of bicycle ridership. Further, it is believed to impact the ridership number and decrease the travel time in many routes.

- Reducing accident figure.

The accidents figures of bikers in Berlin is very high (2008-2010: 20.910 accidents). The cycling strategy aims to reduce the figures of "number of killed by 40% and number of injured by 30% by 2025.

- Appropriate financing.

Financing the biking cause is relatively inexpensive for the city administration, however it is the sustained availability of funds which is required for Berlin for long term security. The National Cycling Plan envisages a minimum investment of € 5 per inhabitant per year. The city of Berlin has an incremental approach to reach this figure.

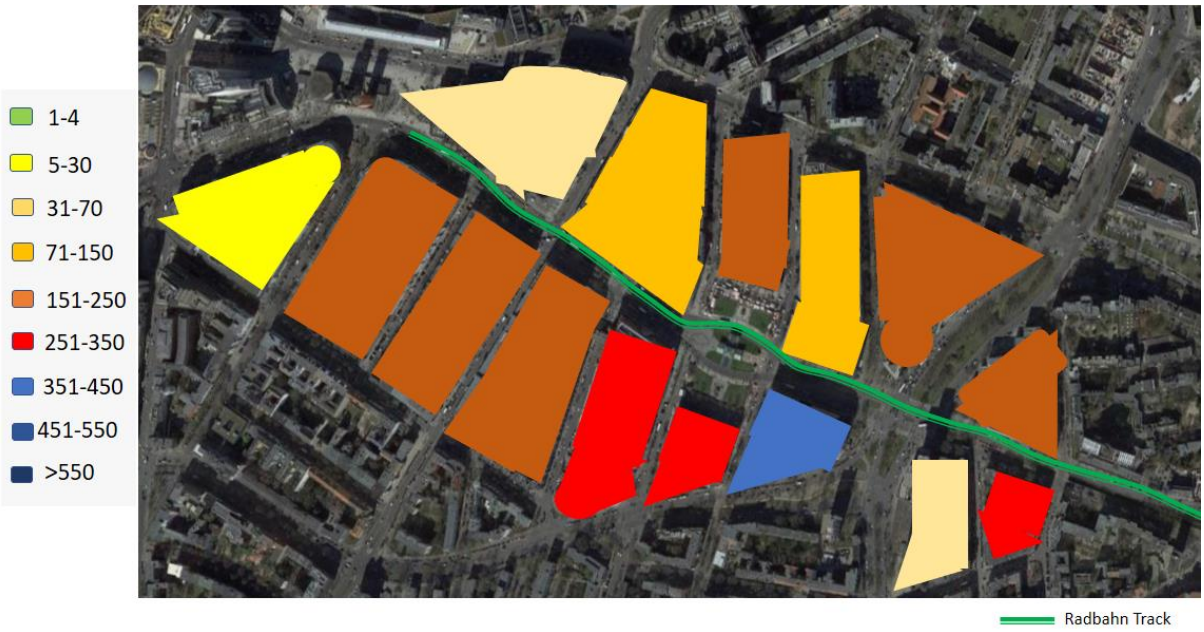
- Prompt completion of cycle route network.

The Senate Department for Urban Development and the Environment aimed to achieve completely covered, signposted and connected biking network in Berlin by 2017. In addition to the main network, the city administration aims to identify a subsidiary network in each borough of the city by 2013 and create these networks promptly (Senate department of Urban Development and the Environment, 2013).

Annex 3: Maps showing Macro-Level Factors

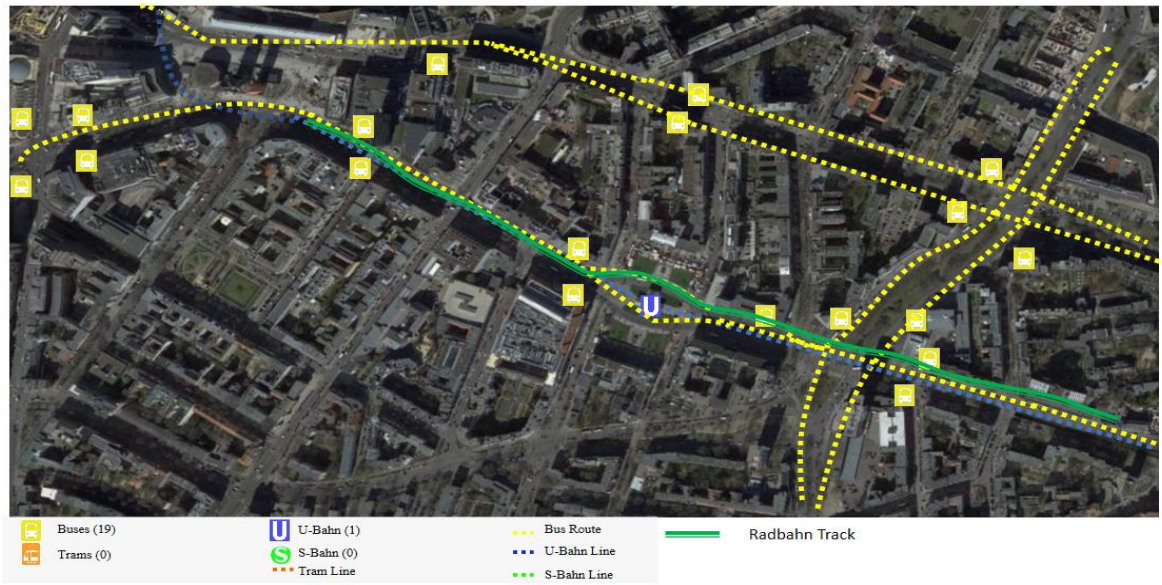
Promenade

Factor: Population Density

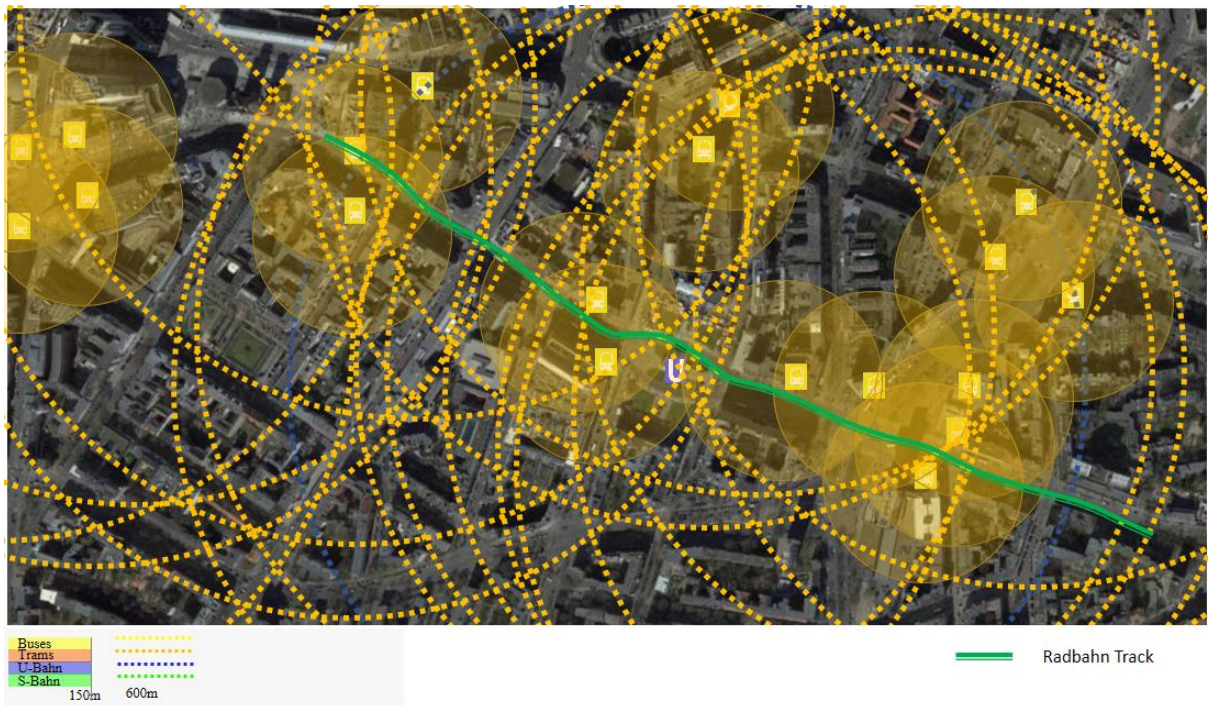


Factor: Land use

Factor: Transport Provision

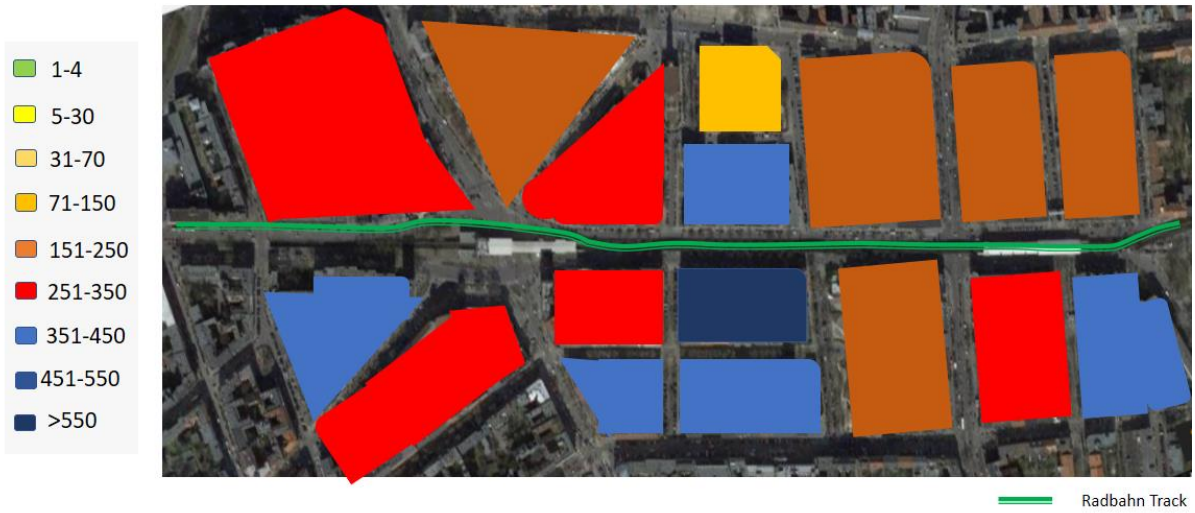


Factor: Transport Coverage



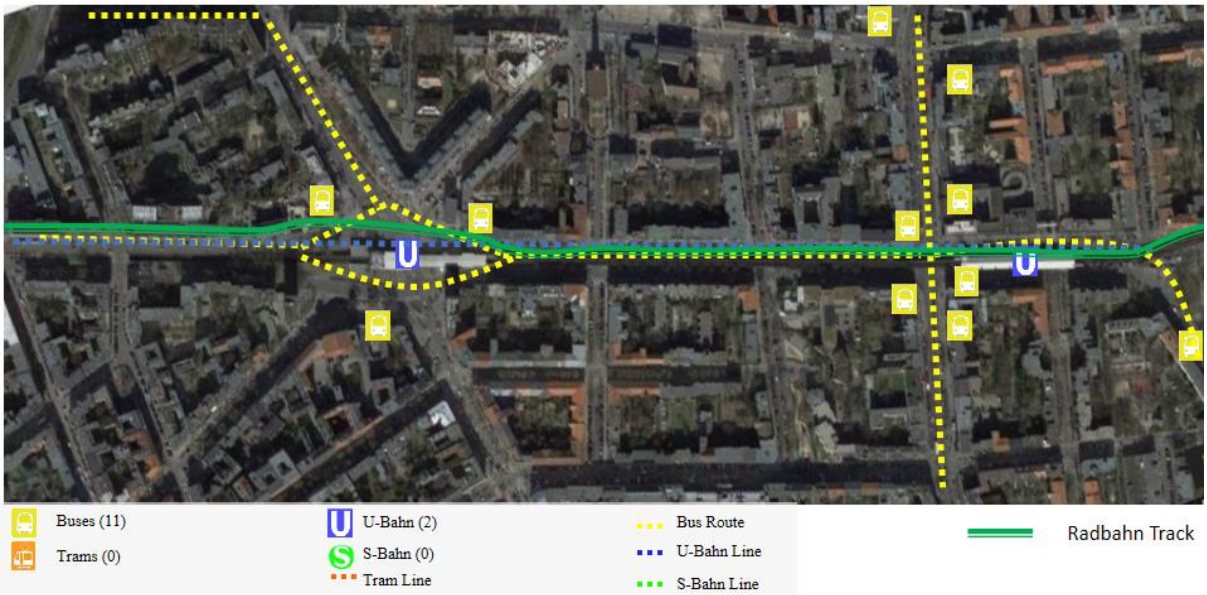
Under the Roof

Factor: Population Density

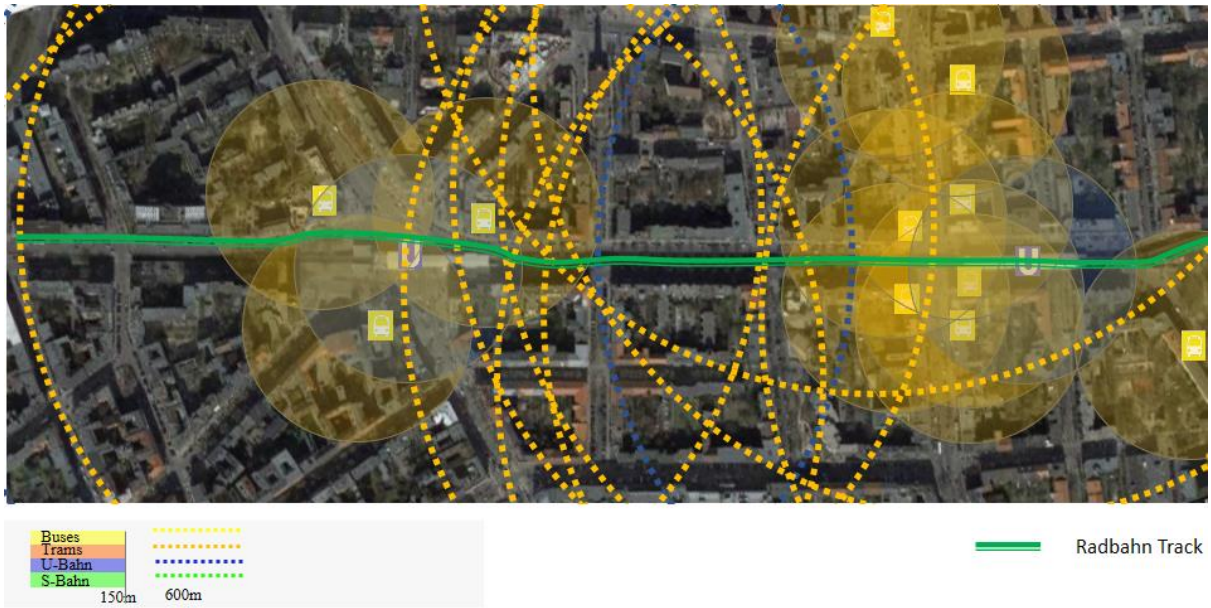


Factor: Land use

Factor: Transport Provision

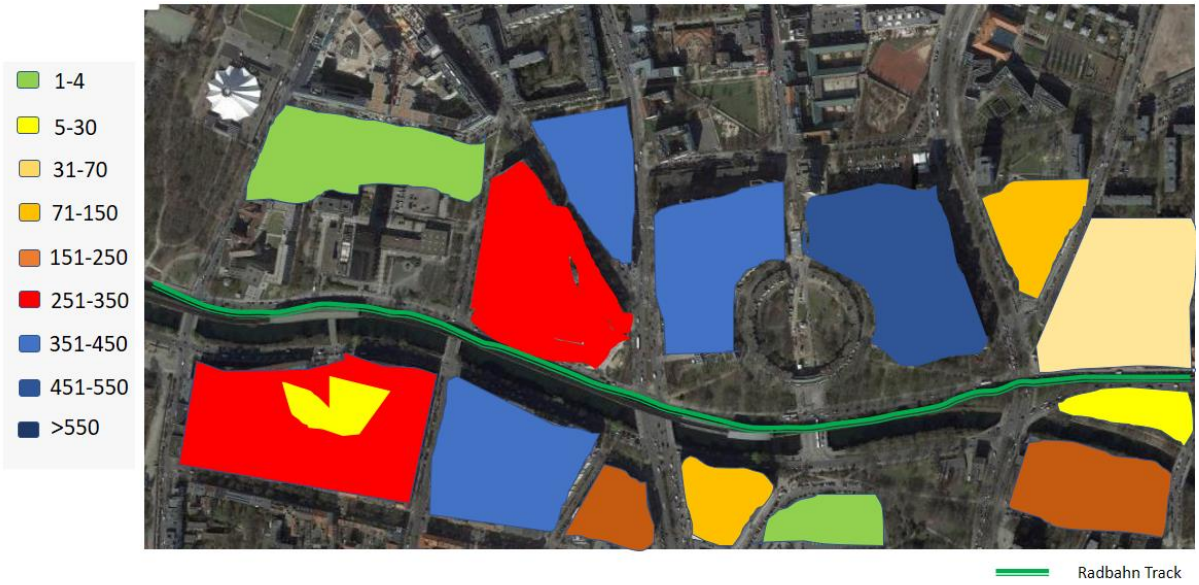


Factor: Transport Coverage

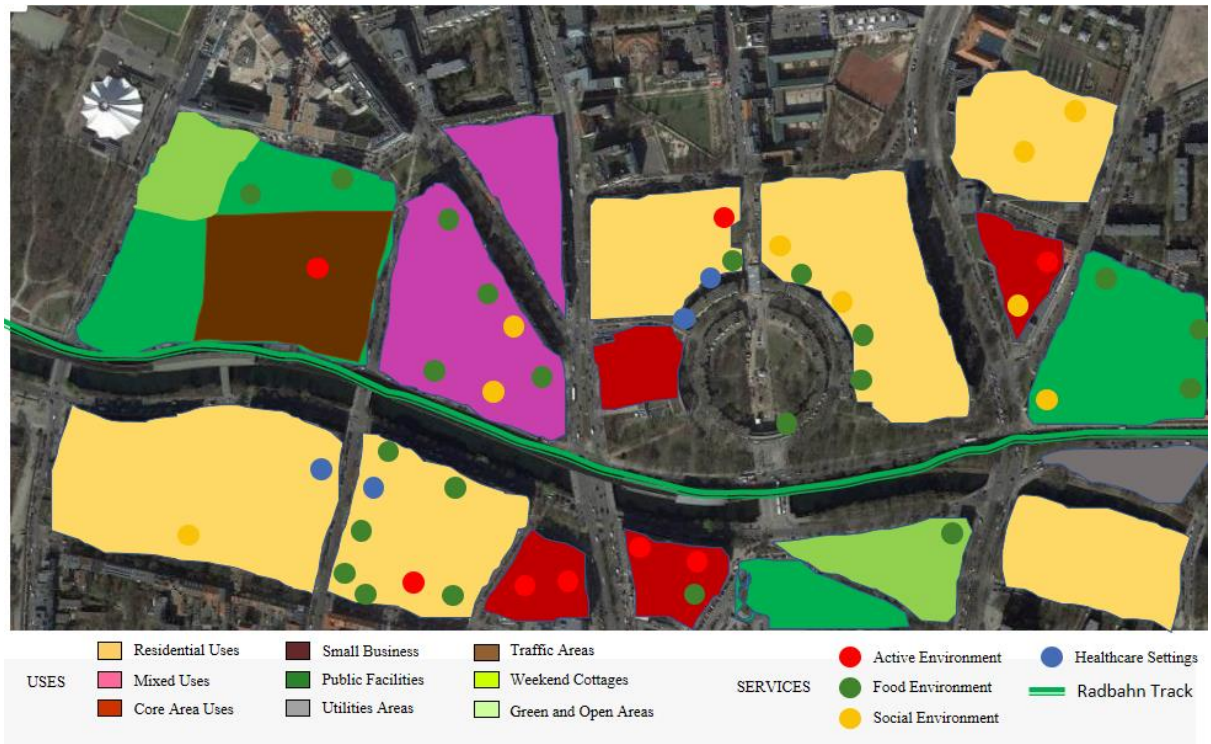


By the water

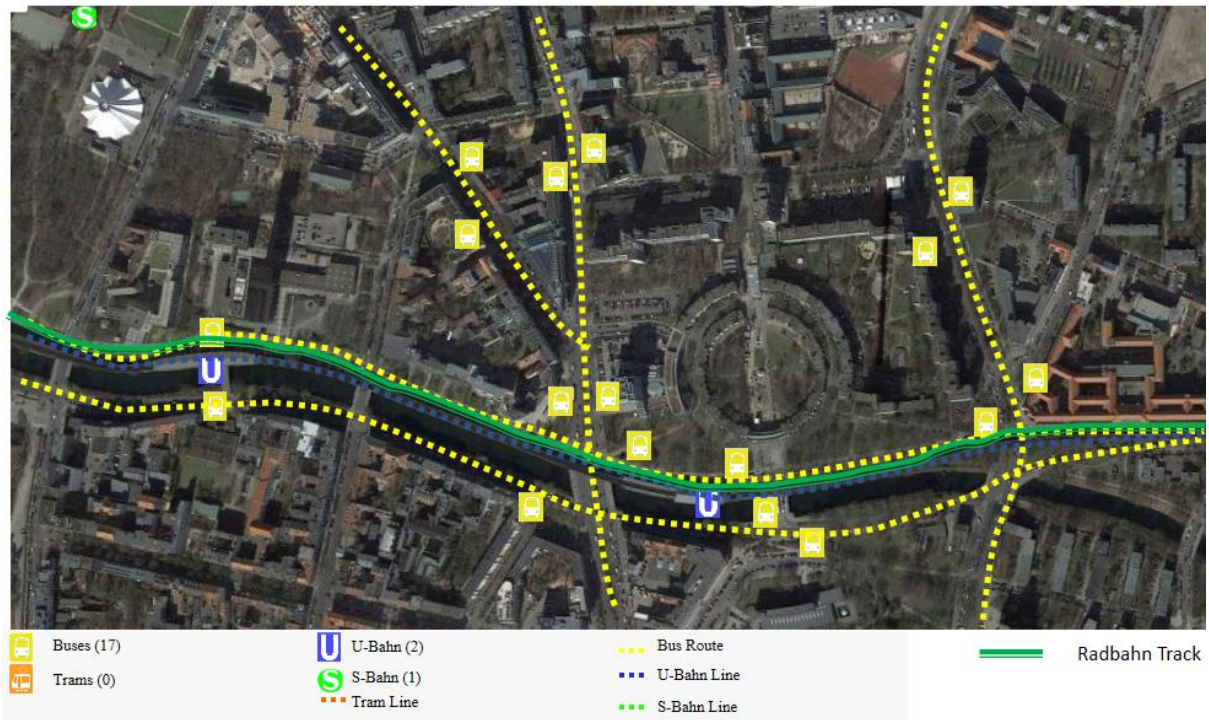
Factor: Population Density



Factor: Land use



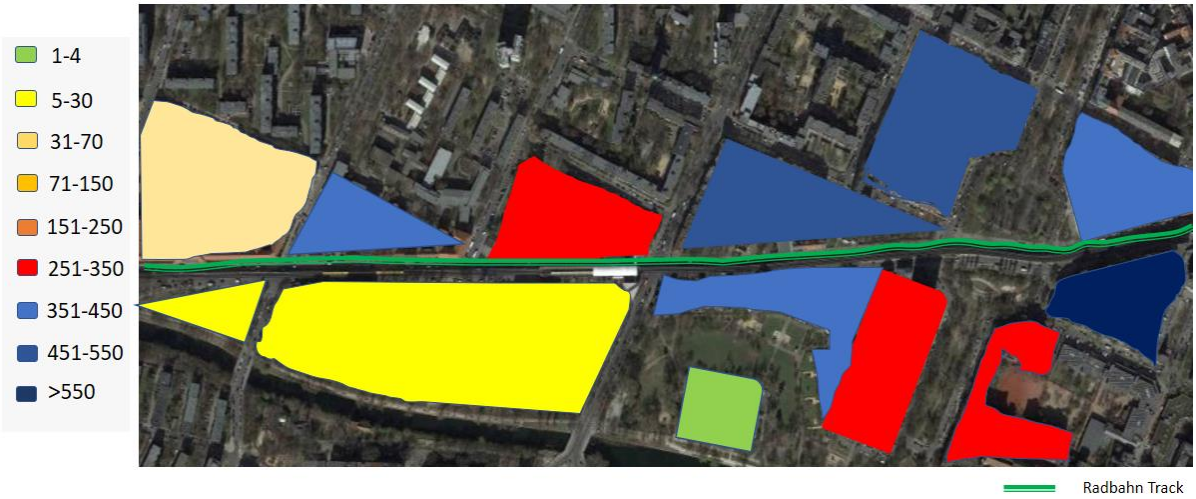
Factor: Transport Provision



Factor: Transport Coverage

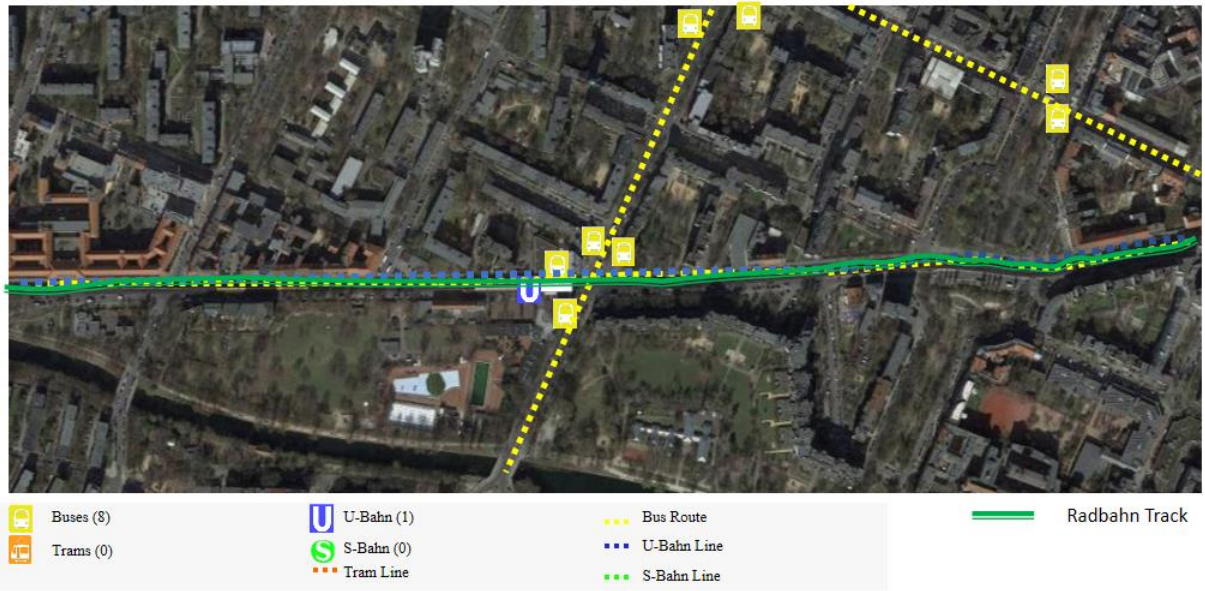
Eye of the Needle

Factor: Population Density

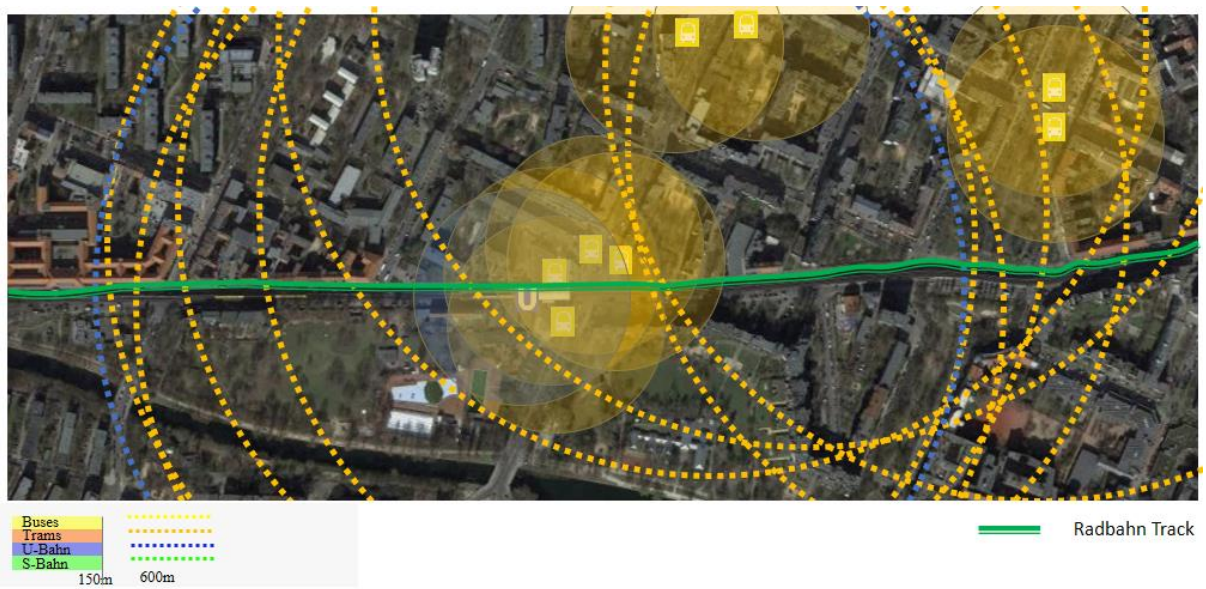


Factor: Land use

Factor: Transport Provision

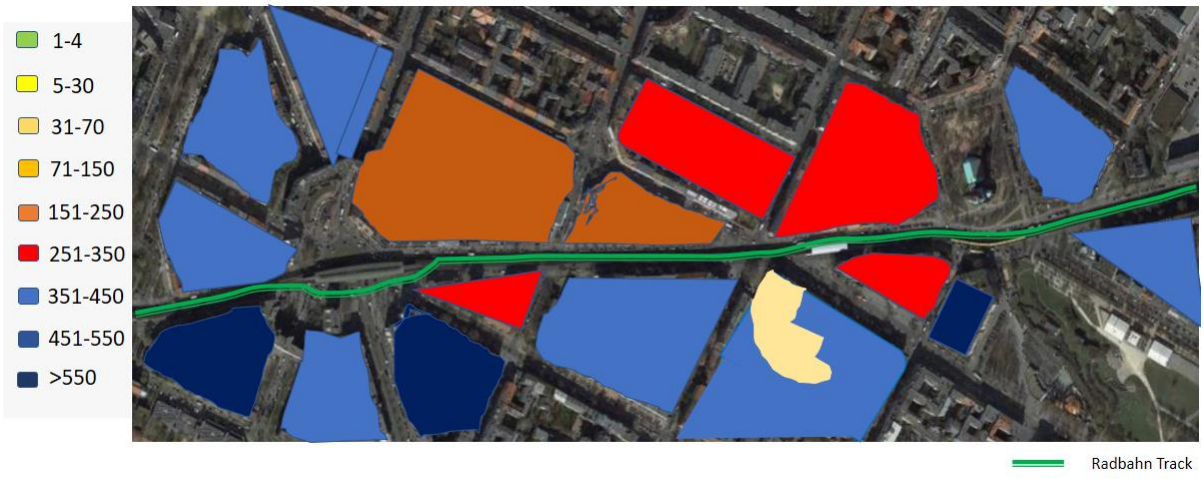


Factor: Transport Coverage



Hotspot

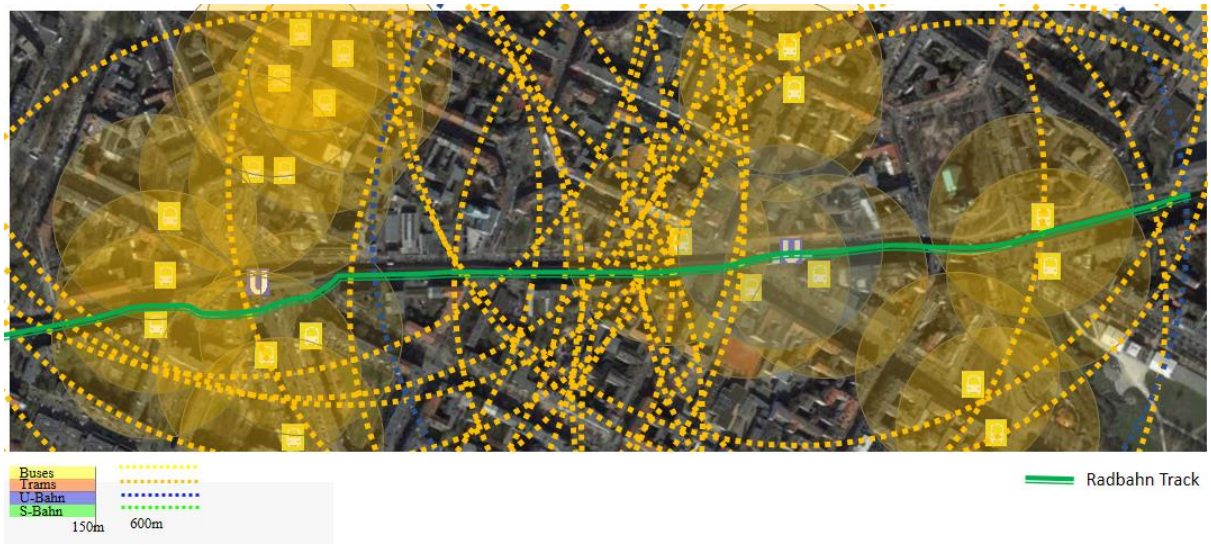
Factor: Population Density



Factor: Land use

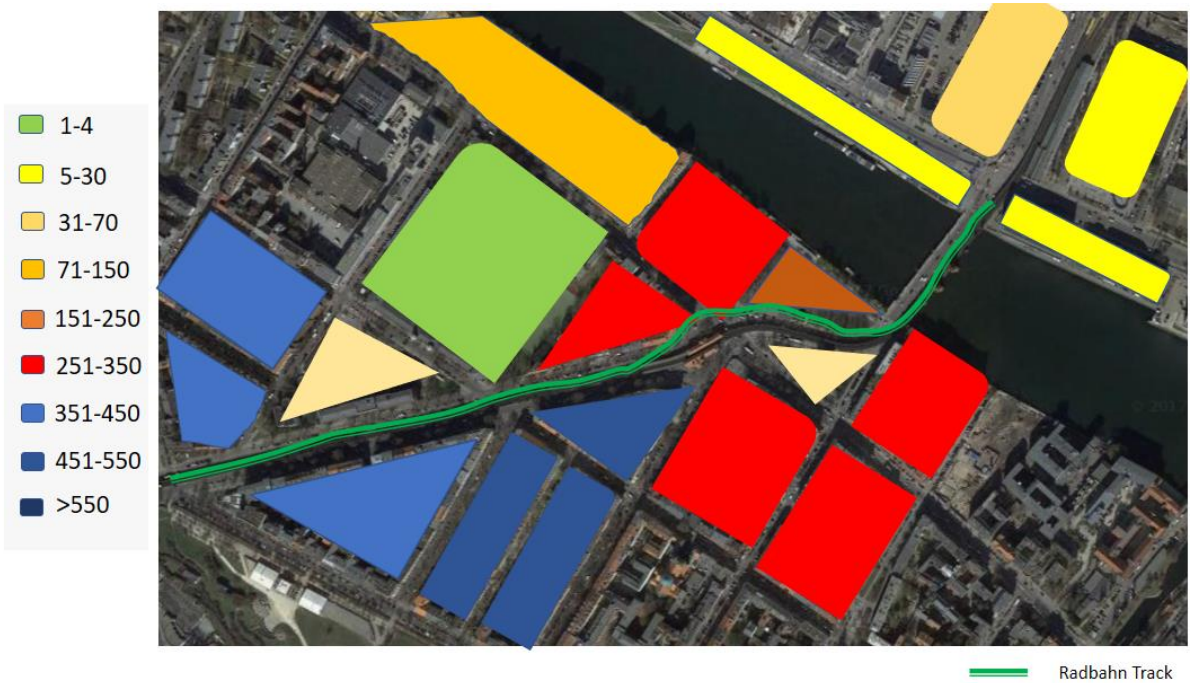
Factor: Transport Provision

Factor: Transport Coverage



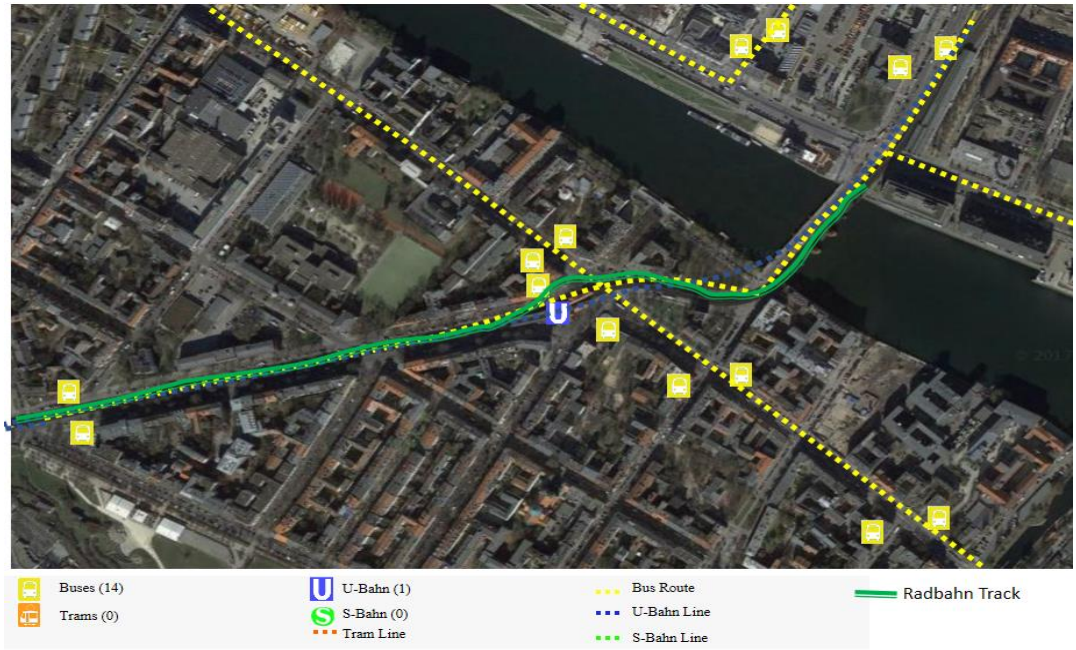
Spree Feeling

Factor: Population Density



Factor: Land use

Factor: Transport Provision



Factor: Transport Coverage

Annex 4: Maps showing Meso-Level Factors

Promenade

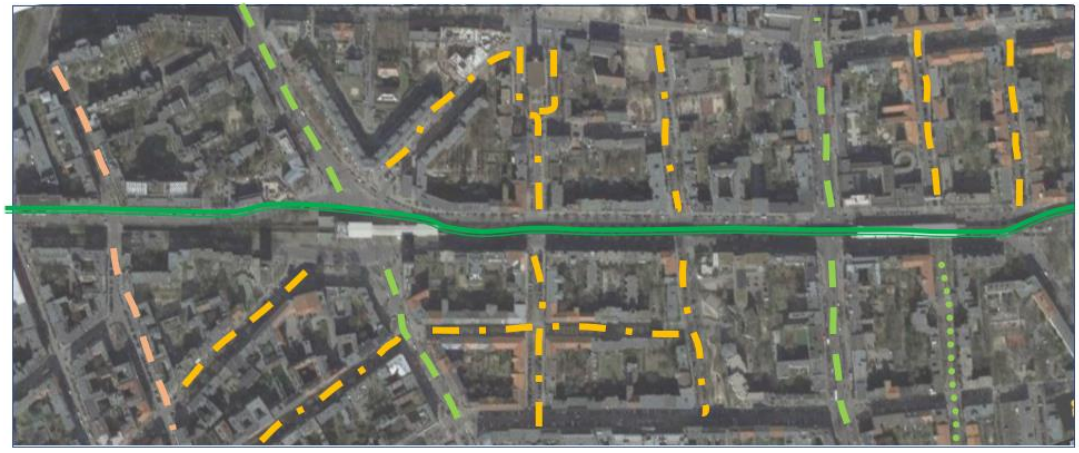
Factor: Street Hierarchy and Classification

Factor: Intersection type

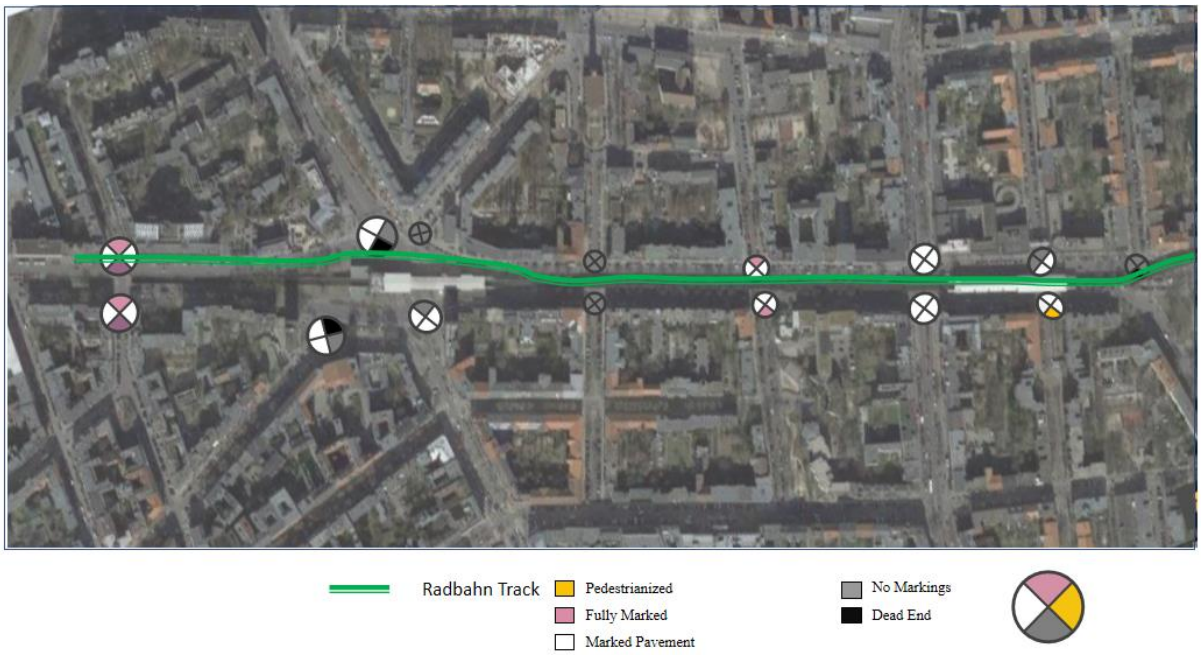
Factor: Segment type

Under the roof:

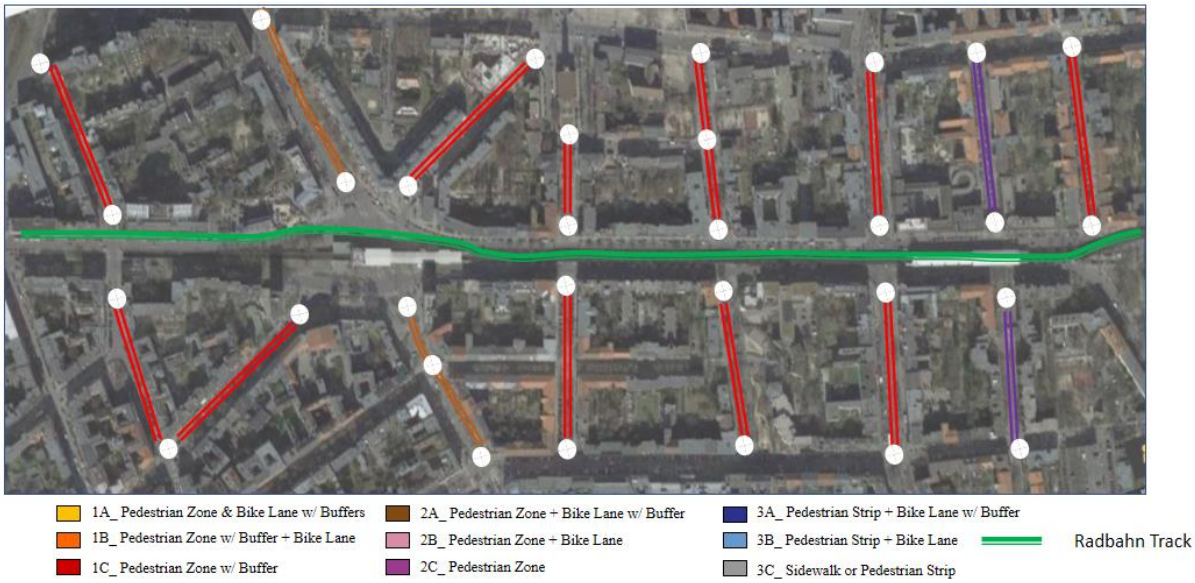
Factor: Street Hierarchy and Classification



Factor: Intersection type



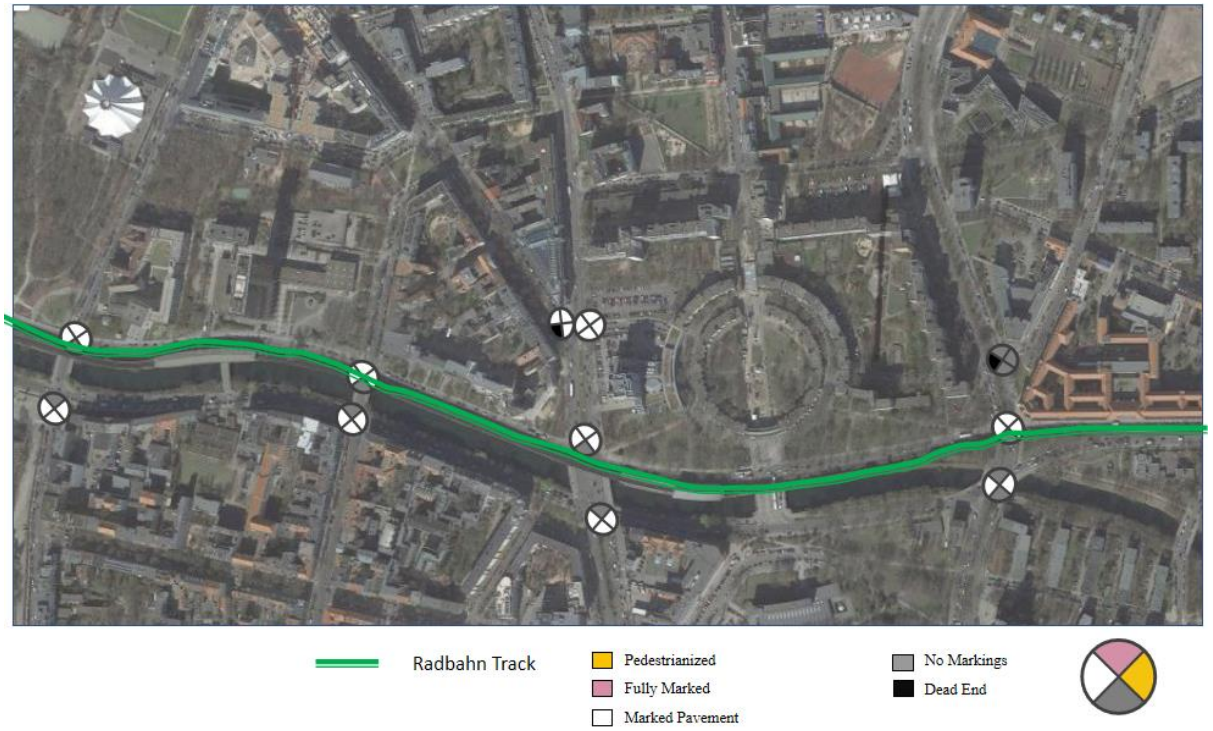
Factor: Segment type



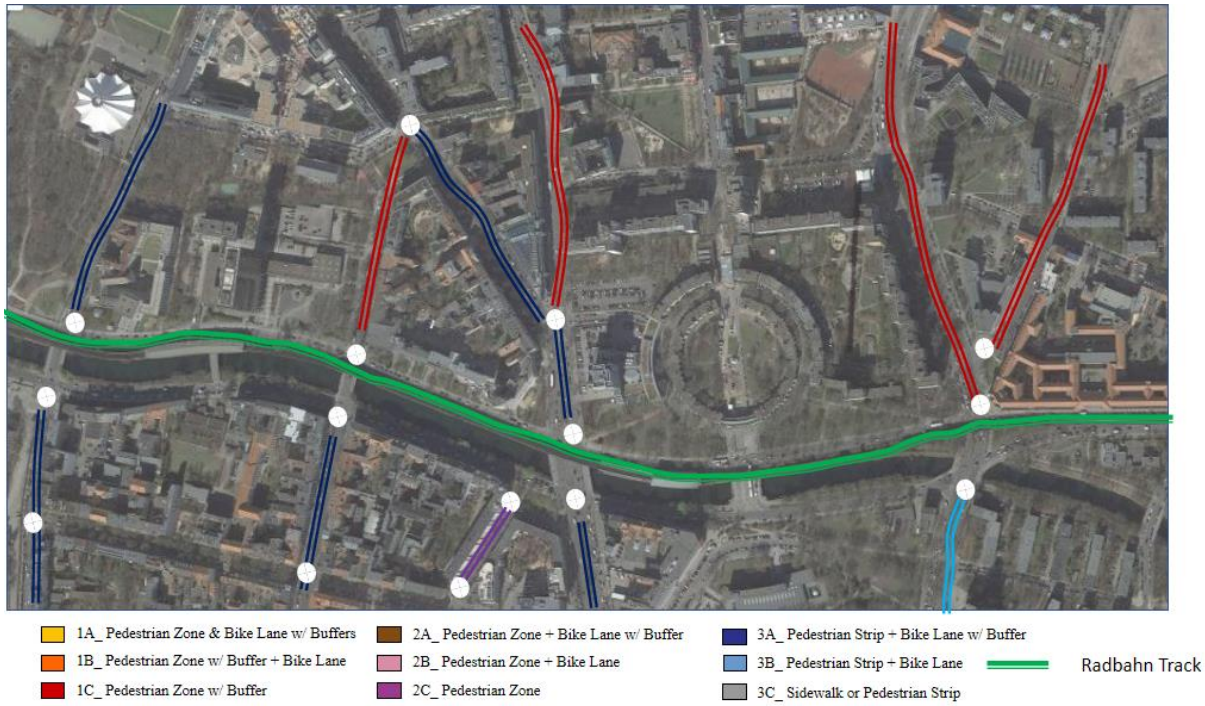
By the Water

Factor: Street Hierarchy and Classification

Factor: Intersection type



Factor: Segment type



Eye of the Needle

Factor: Street Hierarchy and Classification

Factor: Intersection type

Factor: Segment type

Hotspot

Factor: Street Hierarchy and Classification

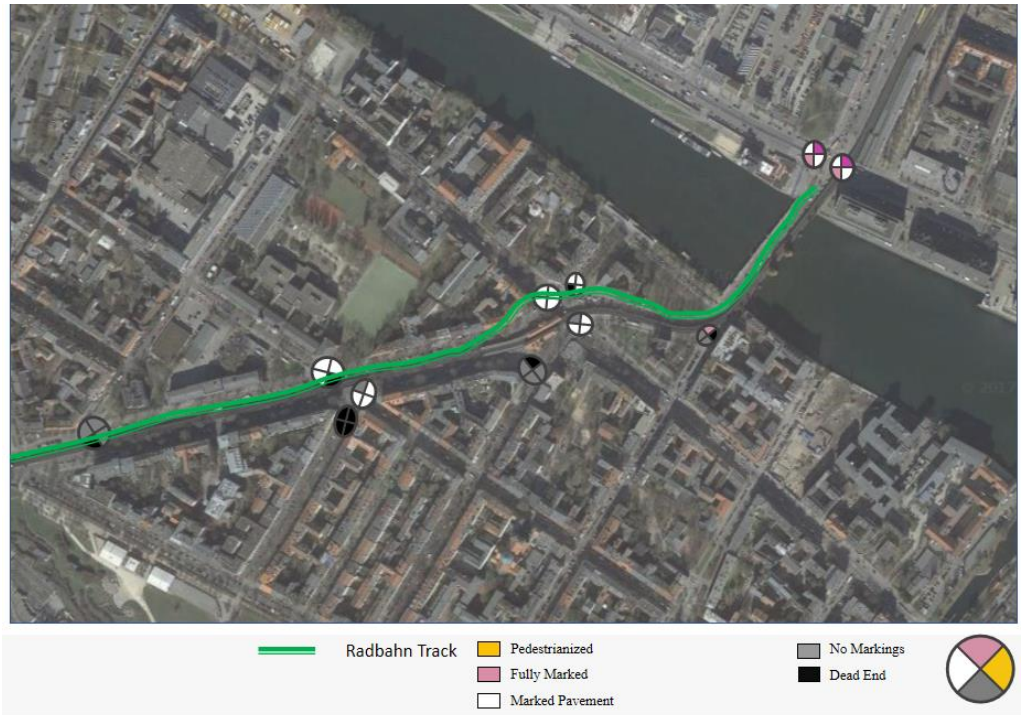
Factor: Intersection type

Factor: Segment type

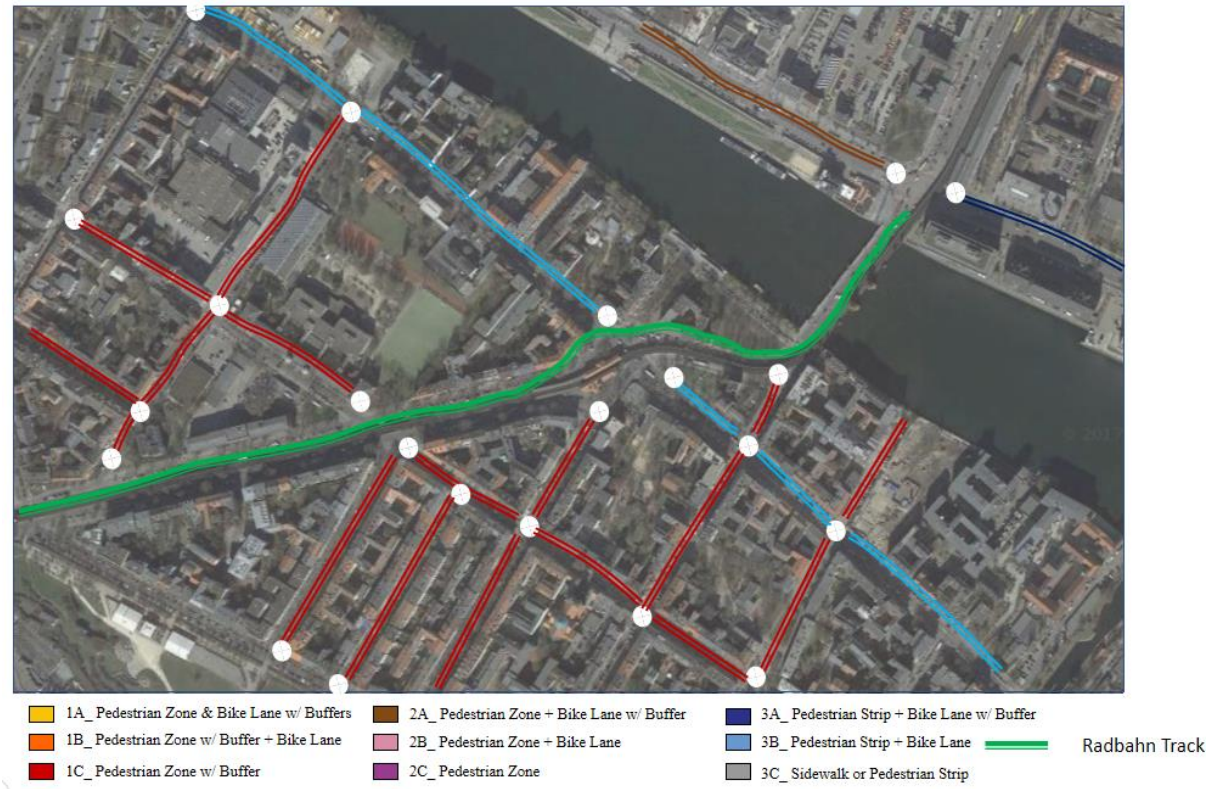
<u>Spree Feeling</u>

Factor: Street Hierarchy and Classification

Factor: Intersection type



Factor: Segment type

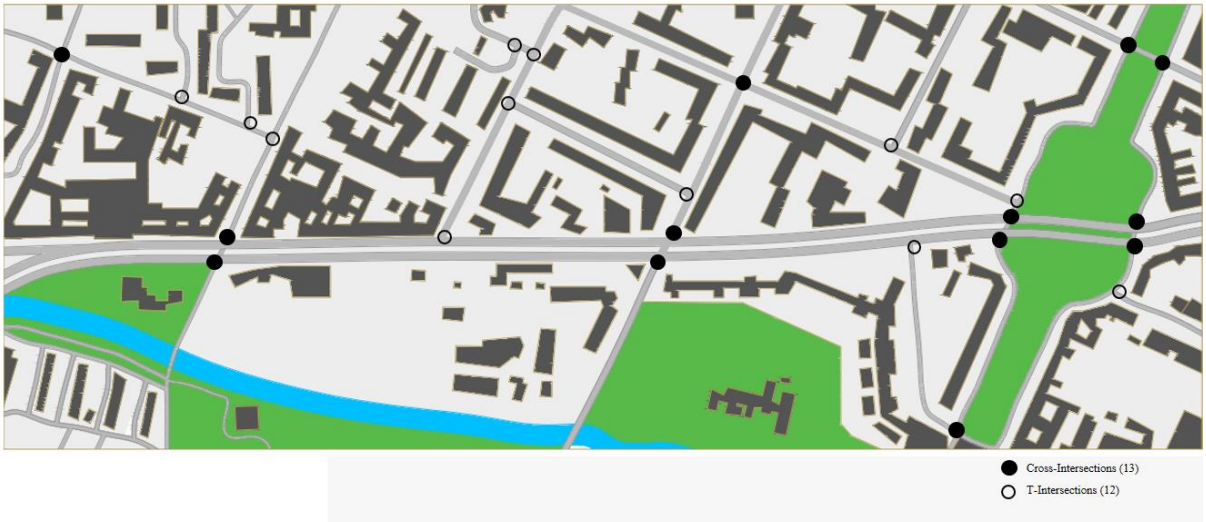


Annex 5: Maps showing detailed Meso level study

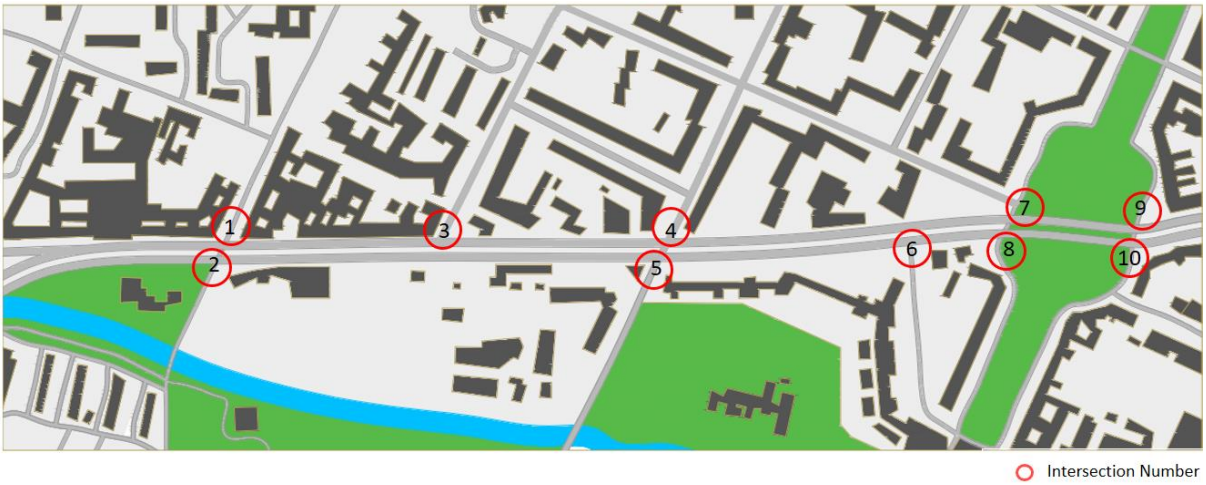
Least suitable section: Eye of the Needle

Active Block Connectivity

Factor: Intersection type



Factor: Intersections number



Factor: Intersection Coding

<u>Active Path Continuity</u>

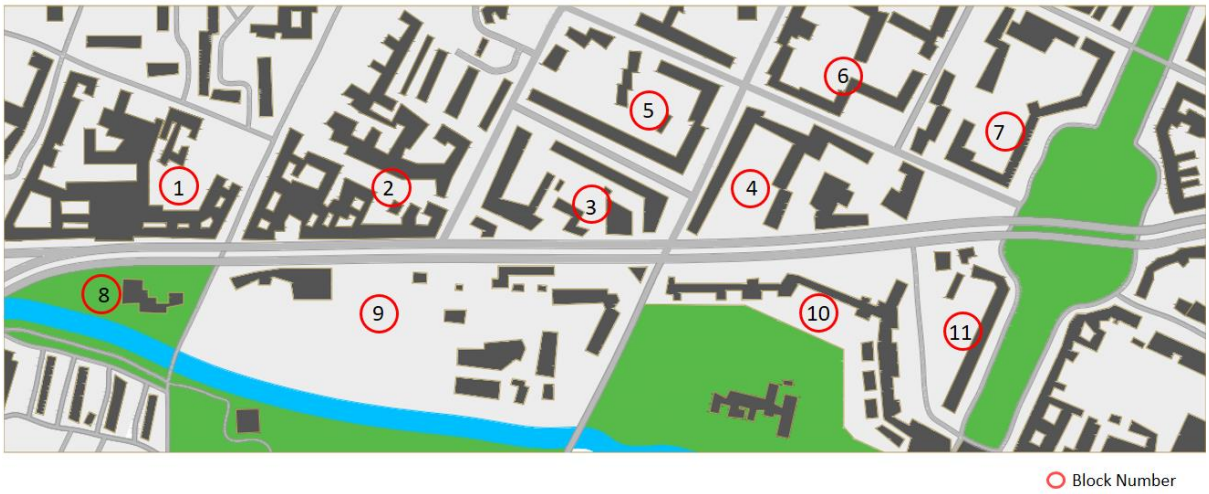
Factor: Street Segment numbers

Factor: Segment Coding

Vehicular Impact

Factor: Street Hierarchy & Street Classification

Factor: Street Grid

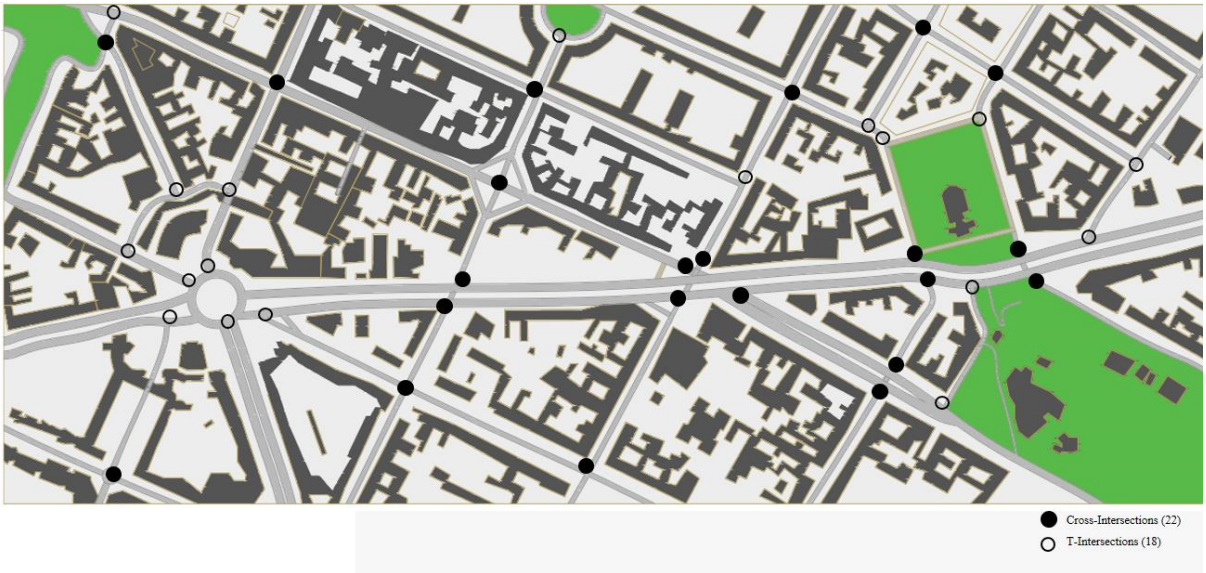


Factor: Street Segment numbers

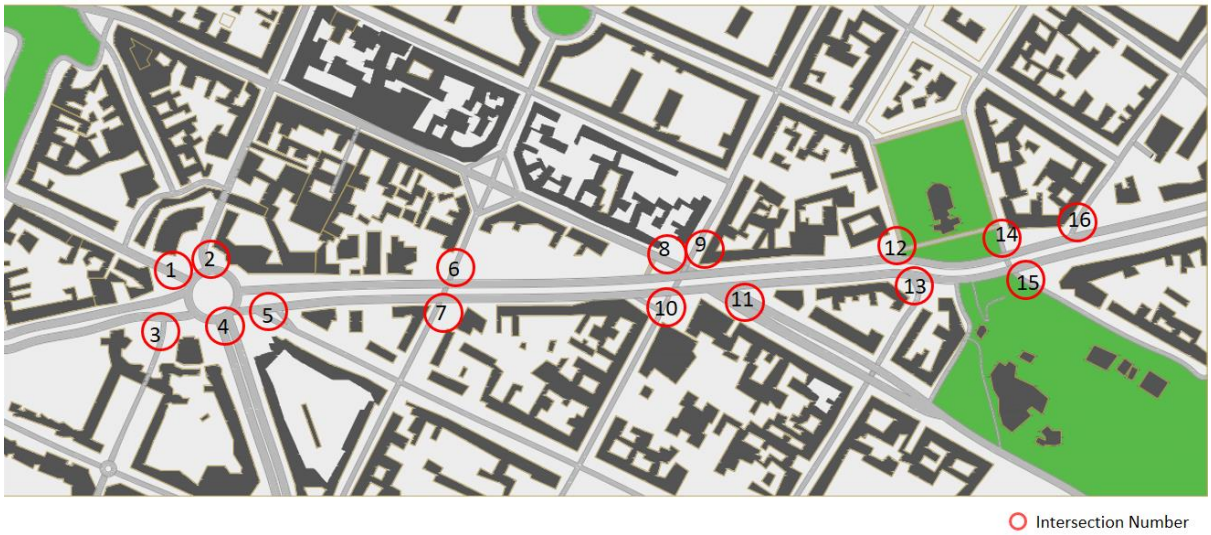
Most suitable section: Hotspot

Active Block Connectivity

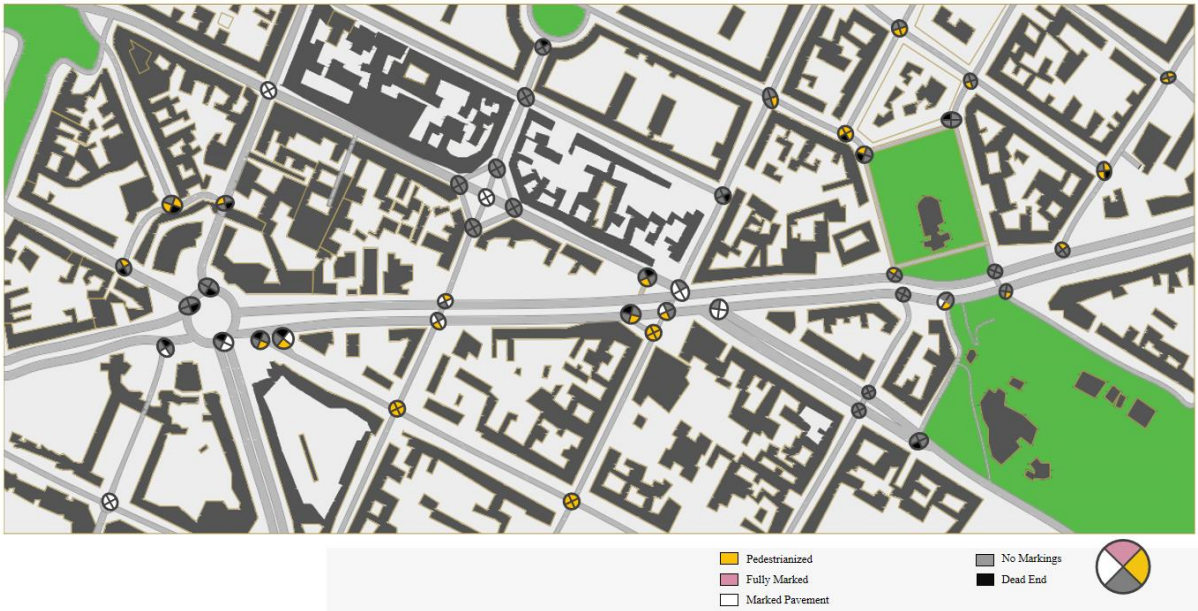
Factor: Intersection type



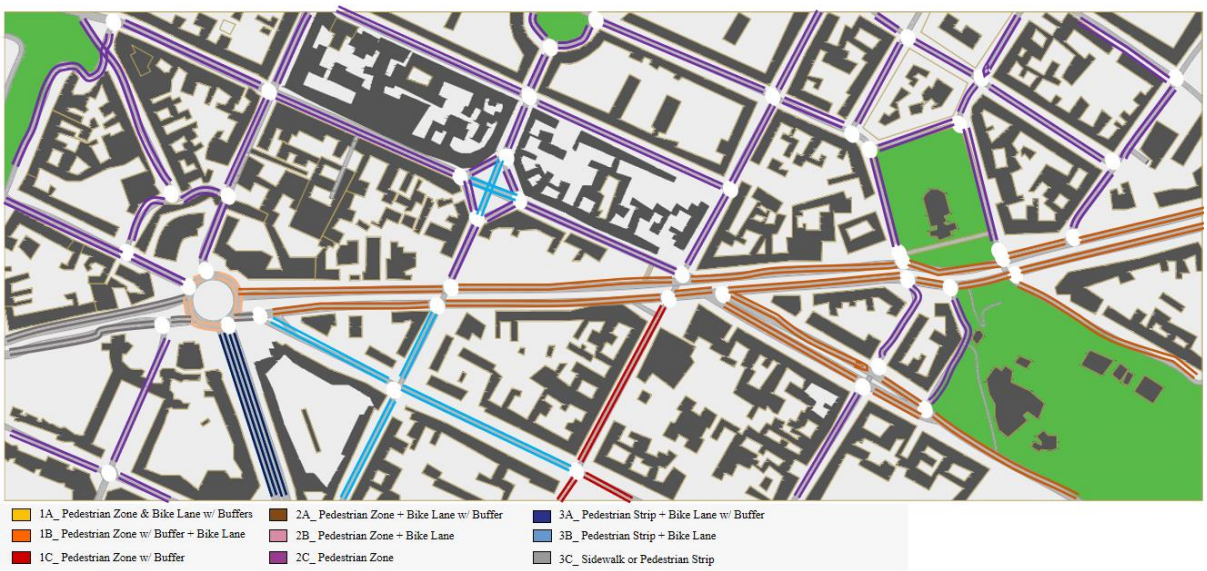
Factor: Intersection number



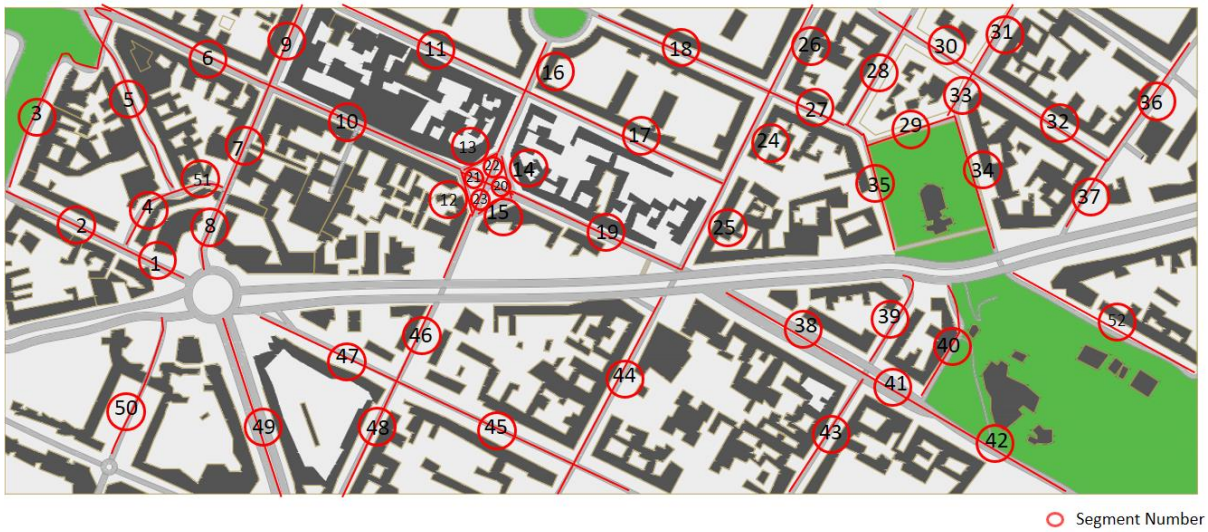
Factor: Intersection Coding



Factor: Street Coding



Factor: Street segment number

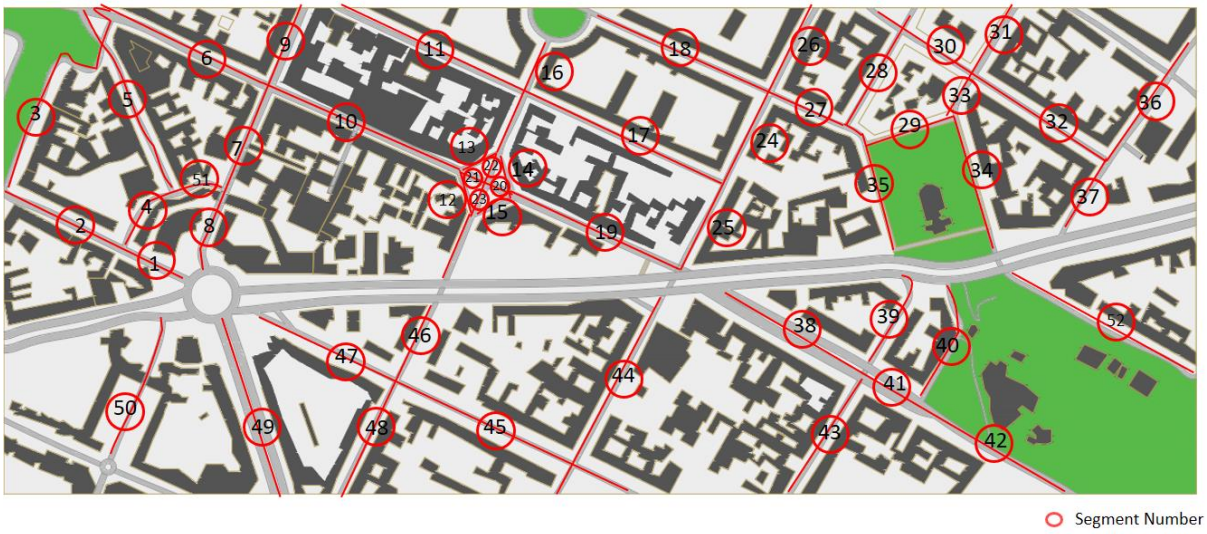


<u>Vehicular Impact:</u>

Factor: Street Hierarchy & Street Classification

Factor: Street Grid

Factor: Street segment



Annex 6: Micro level study Factors:

The Micro-level factors can be tested at two sections of the connecting road, which are a) Pedestrian crossings and b) Along the street segment (for footways and bikeways). Under the a) pedestrian crossings, the study will focus on detailing the following indicators:

1.1. Assess pavement: change in level, curbs with obstacles and holes, uneven road surface, dangerous interruptions in the path of travel and gratings on the road surface.

1.2. Access pathway navigation: marking for crossing, public lighting, signage visibility, signage legibility, guide strips, tactile marking and path guards.

1.3. Verify Obstruction: horizontal-minimum of 90 cm width path clearance and existing construction.

Thereafter, the study will concentrate on examining the following factors b) along the street segment for the safety of active travel network.

1.4. Estimate space allocation: Width and length of street segments.

1.5. Assess pavement: uneven road surface, dangerous interruptions in the path of travel and gratings on the road surface.

1.6. Rate navigation levels: public lighting, signage visibility.

1.7. Verify signage legibility: guide strips, tactile marking and path guards.

1.8. Indicate street provision and location: Resting facilities, Public transportation stops, Newspaper kiosks, Public communication booths, mailboxes, Ticket vending machines, water fountains, garbage bins.

1.9. Verify Obstruction: horizontal- minimum 90 cm width path clearance, Vertical: minimum 2 metre path clearance.