Technische Universität München

Examination of the influence of environmental quality on mobility behaviour
-
The case studies of Munich - Maxvorstadt and municipality of Maisach

Master Thesis

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ABSTRACT

The research done the last decades has shown that transport sector has both direct and indirect impacts on the environment. Although the direct impacts are generally clear and well understood, the indirect impacts are still vaguely examined. A factor that contributes to the indirect impacts is mobility behaviour and thus it has been tried from many researchers to investigate the different characteristics that have an influence on it. A literature review showed that several factors, such as sociodemographic aspects or spatial structure, affect mobility behaviour at a high degree. However, there is not sufficient literature which examines whether and to which extent environmental quality may have an influence on mobility behaviour. This thesis tried to overcome this gap of information, by examining the above relationship in two different spatial settlements. The municipality of Maisach was chosen as an example of a rural settlement and the district of Munich, Maxvorstadt, as an example for an urban settlement. The methodology that was implemented in the two study areas included both a qualitative and a quantitative analysis. As far as the qualitative analysis is concerned, an online survey was carried out in the two chosen areas, which gathered data regarding information about availability of different transport modes, sociodemographic aspects, as well as the attitude of the responders towards different environmental quality factors in correlation to specific mobility decisions. Furthermore, the participants were asked to input in an innovative way the most frequent trip, which they take under the week, and to evaluate air quality, noise and availability of green spaces along it. In parallel to the survey, an environmental assessment of the two study areas was carried out. Data considering air quality, noise and green spaces' availability, was either gathered or estimated, in order to calculate the actual levels of environmental quality in the two areas. This process was however not unproblematic, since for some cases there was no available data and conclusions from different neighbour areas had to be extrapolated. By conducting this quantitative analysis, it was possible to compare the perceived environmental quality, as given by the responders, to the actual environmental quality. The results showed that in both study areas, air quality and availability of green spaces were more precisely perceived, while noise seemed to be a more subjective matter. Regarding the cases that no coincidence between the perceived and actual environmental quality was met, the responders from the rural area appeared to perceive environmental quality more positive than it actually was, whereas in the urban study area the responders evaluated environmental quality more negative. This observed difference suggests that spatial structure can also play a role in the perception of environmental quality. Furthermore, air quality and noise seem to not have a straightforward influence on transport mode choice. On the other hand, green elements along a route seem to play a significant role in both transport mode and route choice. Finally, provision of information regarding environmental quality, is expected to not be able to trigger behavioural changes.

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Abbreviations

BAYSIS	Bavarian Street Information System (Bayerisches Straßeninformationssystem)
CAQI	Common Air Quality Index
DNRGPS	Department of Natural Resources of Minnesota GPS Application
EEA	European Environment Agency
END	Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise - Declaration by the Commission in the Conciliation Committee on the Directive relating to the assessment and management of environmental noise.
EPA	US Environmental Protection Agency
ETC/CDS	European Topic Centre on Catalogue of Data Sources
FFB	Fürstenfeldbruck
GEMET	General Multilingual Environmental Thesaurus
GeoJSON	Geospatial JavaScript Object Notation
GHG	Greenhouse Gases
GIS	Geographic Information System
GPX	GPS Exchange Format
Infas	Institute for Applied Sciences (Institut für angewandte Sozialwissenschaft)
JSON	JavaScript Object Notation
KML	Google Keyhole Markup Language
LfU	Bavarian State Office for the Environment (Bayerisches Landesamt für Umwelt)
LÜB	Air hygiene monitoring system of Bavaria (Lufthygienisches Landesüberwachungssystem Bayern)
MySQL	Structured Query Language (open-source relational database management system)
MVV	Münchner Verkehrs- und Tarifverbund GmbH
PHP	Hypertext Preprocessor (a popular general-purpose scripting language that is especially suited to web development)
PSU	Prof. Schaller UmweltConsult GmbH
RLS-90	Guideline for street noise protection (Richtlinien für den Lärmschutz an Straßen)
S-Bahn	suburban railway

TUM	Technical University of Munich
UBA	Federal Environment Agency of Germany (Umweltbundesamt)
U-Bahn	metro
WHO	World Health Organization

1. Introduction

In the last century environmental awareness has increased all over the world and has become a major subject for many organisations and political authorities across the globe. A common goal of the authorities is to maintain and improve the environmental quality of different urban and rural areas. However, it is widely known that land use and transportation decisions can either support or interfere with environmental protection and quality of life (EPA, 2013, p. 1). Regarding the alarming issue of climate change for example, it is considered that transportation plays a major role, due to its high greenhouse gas emissions. According to the European Environment Agency (EEA), transport in the EU-27 has the second highest share in GHG emissions among all sectors, with 19.7%:

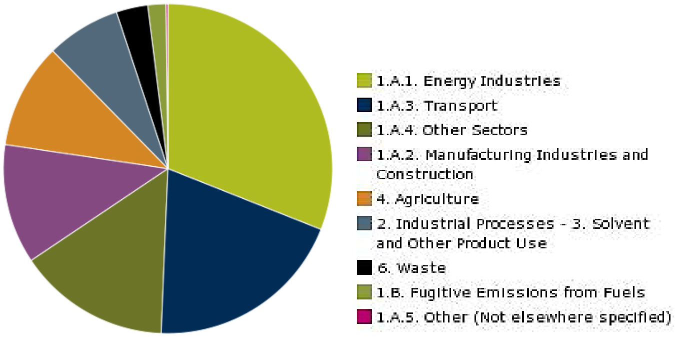


Figure 1.1: Emission share in EU per main sectors in 2012 (EEA, 2014)

To achieve a sustainable low carbon economy by 2050, Europe needs to cut emissions from transport by at least 60% compared to 1990: that's a cut of 70% compared to today's emissions. (Transport & Environment, 2014)

This thesis aims to contribute to the wider research done worldwide for achieving sustainability in the future. The focus is given on sustainable mobility, and specifically this study investigates the topic of mobility behaviour, in order to offer a further understanding of the factors that influence it.

This thesis is held under the supervision of the Chair of Urban Structure and Transport Planning of the Technical University of Munich (TUM) and Prof. Schaller UmweltConsult GmbH.

1.1. Problem Definition

An overview of the existing literature implies that the transport sector has both direct and indirect impacts on the environment. The direct impacts are generally clear and well understood (EPA, 2013, pp. 2-3; Rodrigue, 2013, p. 255). However, the secondary effects of transport activities on environmental systems are often of higher consequence than direct impacts, but the involved relationships are often misunderstood and difficult to establish (Rodrigue, 2013, p. 255). A factor that highly contributes to the indirect impacts of transportation is definitely the mobility behaviour of each individual. (EPA, 2013, p. 2)

There is a variety of studies which examine the influence that mobility behaviour has on the environment. It is safe to say, that our mobility decisions play a major role on air pollution, noise and other aspects of environmental quality. Many mitigation measures are also proposed, mainly focusing on three directions. First, a redesign of our cities in a more compact way and with increased land-use mix can be a strong instrument in achieving sustainable mobility. Moreover, it is a common goal for many authorities and experts to achieve a modal shift to more environmental friendly transport modes, such as public transport, cycling or walking. Finally, there is a lot of effort put into developing new technologies regarding the energy efficiency and examining whether post fossil mobility can become a reality. (UBA, 2010; European Commission, 2001; 2003; 2009; Coppola & Papa, 2013; Eriksson, 2008)

It is obvious that mobility is a high priority topic with such a complexity that requires an extended analysis on all the different factors that may have an influence on it. The research that is made so far shows that spatial structure, transport supply, as well as socio-economic factors can affect mobility decisions, which respectively can affect environmental quality (Curtis & Perkins, 2006). A more analytical overview of the factors that influence mobility behaviour is presented in the following figure.

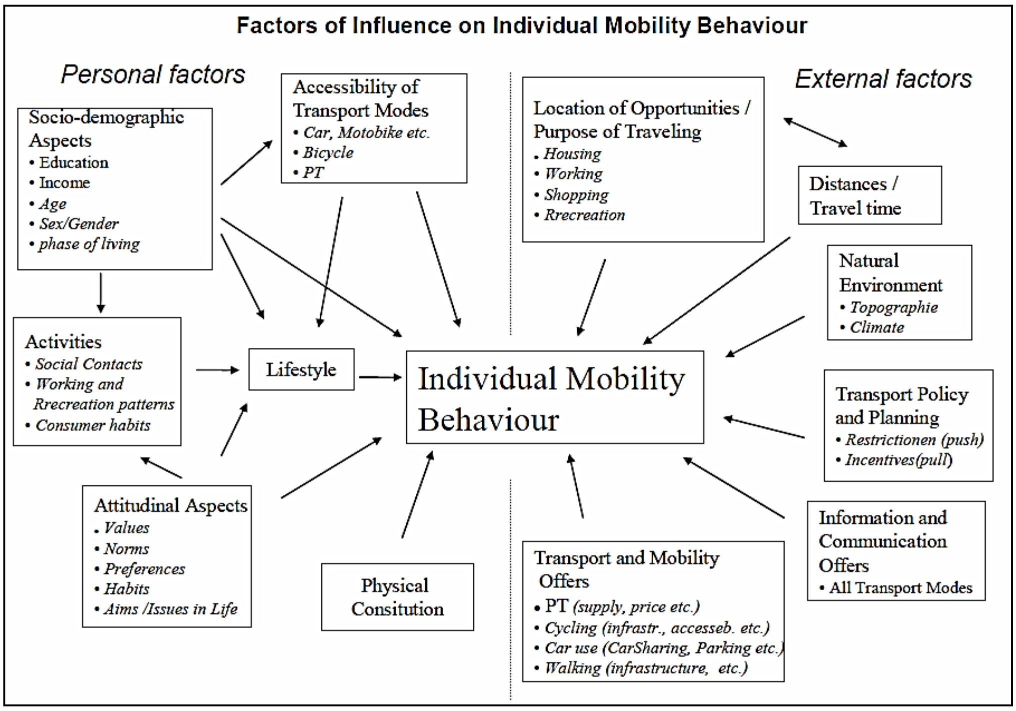


Figure 1.2: Factors of Influence on Individual Mobility Behaviour (EU Project: Add Home, 2009)

As presented in Figure 1.2, there are numerous factors, as well as many interactions between them, which play a role on mobility behaviour. In addition, the impacts that travel behaviour has onto the environment have become the last years better understood and more extensively examined. However, there is little research made on the opposite direction of the question. Is there an influence of environmental quality on mobility behaviour and if yes, to which extent?

1.2. Objective of the thesis

The aim of this Master's Thesis is to examine whether and to which extent environmental quality can play a role into making a mobility decision. It is also interesting to examine whether any dissimilarities are met between different spatial structures and thus, this relationship is investigated for both a rural and an urban area. The municipality of Maisach is used as an example for rural settlements and the city part of Munich, Maxvorstadt, as an example for dense urban settlements.

The results of this thesis should provide information necessary to understand the influence that environmental quality has on mobility decisions. Particular attention is also given into policy proposals and recommendations to the authorities, in order to enable the latter to offer people a higher level of 'quality of life', but also push them towards more sustainable mobility behaviours.

1.3. Structure of the thesis

This thesis begins by giving in Chapter 2 an overview of the definitions that are found in the literature regarding the two main components of the topic, mobility behaviour and environmental quality. In the next step, a literature review of studies related to the topic was carried out and the main findings are presented. At first, there is a presentation of the main factors that influence mobility behaviour as well as the more specific effects that these factors have on it, as found in numerous studies across the world. In addition, different characteristics of environmental quality, such as air quality, noise and green spaces, are discussed and the status quo of them in Europe and in Germany is outlined. Finally, an overview of studies that have tried to examine the subject under a similar scope to the objectives of this thesis is given, in order to first enable the author develop a suitable methodology, but also help the reader better understand the subject and the developing procedure of the topic.

In Chapter 3, the methodology of this thesis is discussed. The initial point of the methodology was to define the overall system boundaries. After defining what this thesis considers environmental quality and mobility behaviour, the geographical boundaries, and namely the two study areas that the investigation of the topic took place, are presented. Finally, the chosen methodology that was followed to answer the research question, is outlined.

Chapter 3 continues with the presentation of the qualitative methodology that was carried out and gives in detail the steps that were followed in order to develop the survey that was carried out, as well as the procedures that were undertaken for analysing the results of the survey. In parallel to the survey, an environmental assessment of the two study areas took place and is presented after the qualitative analysis.

Chapter 4 presents the results of the survey, as well as a discussion. Finally, Chapter 5 gives the conclusions that were drawn from this thesis and furthermore suggestions for further research on the topic.

2. Literature Review

This chapter initiates by giving the definition of the terms mobility behaviour and environmental quality. Furthermore, it includes an extensive literature review on mobility behaviour and factors that affect it, environmental quality and its status quo in Europe and in Germany, as well as an overview of studies that have tried to examine the subject under a similar scope to the objectives of this thesis. Finally, it presents the existing methods for conducting a qualitative analysis, in order to evaluate them and choose a suitable methodology for this thesis.

2.1. Definitions

This section gives an overview of the existing definitions found in the literature, regarding the two main terms this thesis is built upon, mobility behaviour and environmental quality.

2.1.1. Mobility Behaviour

According to the GEneral Multilingual Environmental Thesaurus, which has been developed as an indexing, retrieval and control tool for the European Topic Centre on Catalogue of Data Sources (ETC/CDS) and the European Environment Agency (EEA), mobility is "*the ability of groups or individuals to relocate or change jobs, or to physically move from one place to another*" (GEMET, 2004). Mobility behaviour is a term that includes all possible parameters that are related with this ability of individuals and groups to move. Some of these are:

- Travel distances
- Travel times
- Number of trips per day
- Destination choices
- Transport mode choice
- Purpose of trip
- Planned or spontaneous trip
- Route choices
- Travel alone or accompanied by someone

These are only some of the parameters that determine mobility behaviour and its definition makes it obvious why mobility behaviour is such a complex issue and why numerous factors may have an influence on it.

In general, mobility behaviour can be considered the group of decisions that each individual takes, such as which transport mode will he use or which route will he take, in order to move physically from one place to another.

2.1.2. Environmental Quality

Environmental quality as a concept is difficult to define; it is multidimensional, multi-faceted and multi-disciplinary in its nature (Moore, et al., 2006). Definitions of "environmental quality" are as for example:

"*Properties and characteristics of the environment, either generalized or local, as they impinge on human beings and other organisms. Environmental quality is a general term which can refer to: varied characteristics such as air and water purity or pollution, noise, access to open space, and the visual effects of buildings, and the potential effects which such characteristics may have on physical and mental health (caused by human activities)*" (GEMET, 2004)

"*An environment of high quality conveys a sense of well-being and satisfaction to its population through characteristics that may be physical, social or symbolic*" (Lansing & Marans, 1969)

"*Environmental quality is a complex issue involving subjective perceptions, attitudes and values which vary among groups and individuals*" (Porteous, 1971)

"*Environmental quality can be defined as an essential part of the broader concept of 'quality of life', the basic qualities such as health and safety in combination with aspects such as cosiness and attractiveness*" (RIVM 2002, cited by van Kamp, et al., 2003)

"*Environmental quality is the resultant of the quality of composing parts of a given region but yet more than the sum of parts, it is the perception of a location as a whole*" (RMB 1996, cited by van Kamp, et al., 2003)

The complexity of the term is obvious by the different definitions. As Moore et al. mention (2006), "*any assessment of the environment requires an intense investigation of different parameters, and thus one indicator alone cannot measure environmental quality*".

The most important outcome that we can get from the numerous definitions is that environmental quality can be both objective and subjective and therefore, despite the quantitative and objective indicators than can be measured and assessed to define environmental quality, it is vital to take into consideration also the perceived environmental quality of individuals. This is also mentioned by Bush, et al. (2001, p. 226) who state that "*experiences of air pollution can vary dramatically at local levels therefore it is particularly important to acknowledge and respond to local knowledge*".

Other aspects that are included in environmental quality definitions are soil quality, biodiversity and land take (Rodrigue, 2013). However, this thesis examines the influence that environmental quality has on mobility behaviour, and aspects such as soil and water quality are not expected to have a strong impact on mobility behaviour. Therefore, the focus is given on air quality, noise and availability of green spaces.

Through the above definitions, the complexity of both terms, mobility behaviour and environmental quality, is highlighted and the importance of further examination of this topic is made clearer. The following sections give an overview of the main findings in the existing literature regarding these two terms, as well as their interrelation, as investigated so far.

2.2. Factors influencing mobility behaviour

As presented in Chapter 1, there are numerous factors that influence mobility behaviour. A recent review of the existing literature showed that there are two key questions included in the majority of the papers that investigate this subject. The first one is whether urban structure, infrastructure and land-use patterns can influence travel behaviour and the second key question concerns which socio-demographic factors appear to influence travel behaviour. (Curtis & Perkins, 2006)

2.2.1. Influence of spatial structure on mobility behaviour

Regarding the first question, Cervero (2002) analysed the impact that compact, mixed-use and pedestrian-friendly urban developments can have on travel behaviour. The analysis reveals that "*intensities and mixtures of land-use significantly influence decisions to drive-alone, share a ride, or patronize transit, while the influences of urban design tend to be more modest*". What is more, he found that workplace destinations with a higher land-use mix produced a higher level of public transport use and that the sidewalk ratio is the most statistically significant built-environment variable. On the other hand, neighbourhoods with fairly well developed sidewalk infrastructure appeared also to have influenced mode choice to some degree, by providing more attractive settings for taking a bus.

Another study found that low-density, single use, large area zoning, usually found in conventional suburbs, limited the ability of participants to walk or cycle for their daily travel requirements. Moreover, this study suggests that proximity to shopping places encourages choices of sustainable modes of travel whereas suburban development away from major activity centres results in higher private car use, thus decreasing the use of other modes. (Soltani & Primerano, 2005, pp. 8-9)

Obviously, a really important factor that influences mobility behaviour is the built environment. Where and how we build is associated with beneficial environmental results. For example, encouraging compactness through infill or brownfields redevelopment often facilitates mixed-use development and creates the type of environment that makes transit use, walking, and cycling easier and more appealing (EPA, 2013, pp. 76-77). Moreover, it is considered that higher residential densities lead to shorter trips and lower levels of car use, higher employment density leads to greater public transport use, but often over longer distances, mixed development leads to shorter trips and lower levels of car use and "traditional" neighbourhoods have shorter trips and lower levels of car use than car oriented suburbs. (European Commission, 2003, p. 8)

Many researchers have also tried to examine the effect of induced travel, a term used for traffic growth due to additional road capacity. In other words, adding road capacity (supply) will reduce the cost of vehicle travel by reducing the costs associated with travel time. As a consequence, privatized motor transport becomes more attractive, which has both short-term and long-term effects. In the short term, additional road capacity can lead to more trips, increased trip lengths, or switch from public transport and car-pooling schemes to driving alone because the traffic situation is better. In long term, that could encourage more disperse land use patterns, which respectively will lead to longer trip distances and higher vehicle dependency and eventually permanently higher travel demand. (EPA, 2013, pp. 27-28)

2.2.2. Influence of socio-demographic variables on mobility behaviour

A strong relationship between travel behaviour and socio-demographic variables such as age, gender, household composition, car ownership and income is also found throughout the literature. All of these factors are significant but gender and household composition appear to be of particular significance in influencing travel behaviours. (Curtis & Perkins, 2006, p. 17)

According to Polk (2003, p. 75), while in general there are not large differences between men and women and their attitudes towards auto-mobility, women consistently show more support for ecological issues and are more positive towards measures which lead to reductions in car use, such as improving and expanding public transportation. Women are furthermore more prepared to participate in ecological-friendly activities to a greater extent than men, activities which also include reducing car use.

A research study in Edinburgh showed that households with children have distinct travel behaviour characteristics. Usually they are highly dependent on cars as their primary source of travel mode, own but do not often use bicycles, and favour cycle trips mostly for leisure rather than work journeys. Moreover, households consisting of students, unemployed and part-time workers without children are most likely to use non-motorised forms of transport; while on the other hand, families consisting of retirees and high-income owners are least likely to use non-motorised forms of transport. (Ryley, 2005, pp. 17-19)

Another study was conducted in the West of Scotland, in order to examine the significance of the car as providing protection, autonomy and prestige compared to public transport. The results showed that there were some psycho-social benefits to car users. For example, many responders answered that their car provided them with protection from ‘undesirable’ people, autonomy, convenience and greater access to a greater range of destinations than public transport. Socially desirable attributes such as competence, skill and ‘masculinity’ were also perceived to be derived from car ownership. People who didn’t own cars were felt to be eccentric, particularly those who chose to travel by bicycle. (Hiscock, et al., 2002)

A study conducted in Sydney showed that travel cost is also a factor that highly influence travel behaviour. The participants of the study were asked to evaluate six alternative scenarios regarding park and ride facility, switch to public transport and continue the whole trip to the Central Business area with their car. The outcome of this study was that 97% of the participants mentioned parking pricing as the most significant factor for choosing their transport mode. (Hensher & King, 2001, p. 193)

In 2007, a study in Germany examined the relationship between psychological, sociodemographic, and infrastructural variables and the ecological impact of mobility behaviour. The results showed that mobility behaviour is not only affected by infrastructural factors or unchangeable sociodemographic characteristics, but also by mobility-related attitudinal variables, including values, norms and attitudes, which affect preferences for specific mobility decisions. Thus, it is implied that these variables should be also taken into account in soft-measure policies. However, the authors explain that an attitude-based strategy is more promising in achieving a change in travel mode choice than in achieving a reduction of travelled distances. "*Measures to reduce travelled distances are more difficult to design on the basis of psychological variables, because just the appeal for travelling less will not be a very successful intervention strategy to support sustainable mobility behaviour*". For the case of travel mode choice, the study suggests that providing information can help users realize existing mobility services in public transport that offer better or comparable opportunities to travelling by private motorized modes. Finally, another significant psychological attitude regarding mobility behaviour was weather resistance: The higher the sensitivity to bad weather conditions the more often motorized private transport was used. (Hunecke, et al., 2007)

Finally, the University of Exeter made an extensive review of the existing literature in order to determine the existing barriers and people' motives to adopt more sustainable mobility behaviours. The habitual character of daily mobility is seen to be a major barrier for changes towards a more sustainable behaviour. Other predictors for mobility-related decisions are attitudes towards certain modes of transport and the individual importance of environmental beliefs and moral norms. Moreover, the study found out that concerns about convenience and flexibility, personal limitations (such as health and physiological problems), and different perceptions of relevant conditions (like weather or topography) are also working as barriers. For tourist travel decisions, the writers imply an important influence from socioeconomic driving factors, while environmental values and attitudes do not seem to play a major role. To conclude, the authors mention that "*there is also a lack of information about sustainability-related effects, which in addition to the existing perception of necessary changes to stop climate change and the unsustainable behaviour, create a psychological gap, where people don't draw consequences for themselves, but wait for others to act*". (Prillwitz & Barr, 2009)

The above literature review showed that different factors are influencing mobility behaviour, with spatial structure and sociodemographic aspects appearing to be the most significant of them. Mixed-use land developments and socio-economic parameters, such as travel costs, attitudes, household composition, gender and age, seem to influence in particular mobility behaviour. However, the literature review showed a lack of available information, regarding the influence that environmental quality has on mobility behaviour. As a consequence, this thesis tried to further contribute to the existing research, by covering this gap. The next pages present information found about environmental quality in Europe and in Germany.

2.3. Environmental quality in Europe and in Germany

Environmental quality is a wide term that includes various factors and characteristics, such as air and water purity or pollution, soil quality, noise levels, biodiversity, accessibility to open spaces and other composing parts of a given region. It was also highlighted throughout the different definitions that it must be always taken into consideration that environmental quality is also subjective, because each individual perceives the level and the importance of environmental quality of an area in a different way.

This chapter presents the characteristics of environmental quality that are expected to have a stronger influence on mobility behaviour, as well as the monitoring of them in Europe and in Germany. The focus was given on air quality, noise levels and open spaces. Finally, an overview on how Europeans perceive these environmental quality factors is presented.

2.3.1. Air Quality

"*There are still major challenges to human health from poor air quality. We are still far from our objective to achieve levels of air quality that do not give rise to significant negative impacts on human health and the environment*." Janez Potočnik, European Commissioner for the Environment. (EU, 2013)

Air quality is a vital issue for public health, environment and economy. In the last decades, Europe has truly tried to reduce emissions of several air pollutants by applying environmental policies and by establishing thresholds for air pollution (EU, 2008; WHO, 2008). However, as Potočnik also mentioned, we are still far away from our objectives.

Ozone, airborne particulate matter (PM) and lead are the transport-related pollutants that create the most concerns, but SO_2, NO_x, CO, lead scavengers and various carcinogens are also notable (WHO, 2008, p. 27). For example, 5% of the EU urban population lives in areas where the annual EU limit value and the WHO Air Quality Guidelines for NO_2 were exceeded in 2011 (EEA, 2013a, p. 7). Figure 2.1 presents the percentage of the urban population in EEA countries that are exposed to air pollution above the respective thresholds.

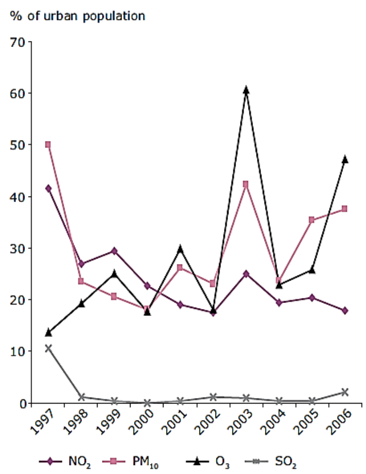


Figure 2.1: Percentage of the urban population in EEA member countries (except Turkey) exposed to air pollution above the limit and target values (EEA, 2009)

However, it is not only the pollutants that harm the environment, but also the greenhouse gases. GHG, with CO_2 the main contributor, despite that are not directly harmful for public health, are very important to monitor because they are responsible for global warming and climate change. "*Their increase caused by human activities build them up in the atmosphere, causing an increase of the average global temperature. That can have both positive and negative effects on people, society, and the environment—including plants and animals. Because many of the major greenhouse gases stay in the atmosphere for tens to hundreds of years after being released, their warming effects on the climate persist over a long time and can therefore affect both present and future generations*" (EPA, 2014a). As described in the first chapter, transport sector highly contributes to GHG's emissions and as a consequence to the magnification of the impacts of global warming. This is also a reason why so much effort is put by the authorities to achieve a modal shift to more environment-friendly transport modes.

In Germany, throughout the last decades, there is a trend in reduction of air pollutants' concentrations. Nevertheless, there is still much to be done for clean air in all sectors. For instance, more than half of the monitoring stations near traffic axes measured exceedances of the allowable annual mean of 40 $\mu g/m^3$ nitrogen dioxide (NO_2) in the previous years. Particulates also continued to exceed limit values. Compared to earlier years, 2013 was nevertheless a year which registered some of the lowest levels of pollution. "*However, this is no reason for an all clear signal*", says Thomas Holzmann, Vice-President of the Federal Environment Agency of Germany (UBA). "*The particulate limit value was only exceeded at about three per cent of all measuring stations, which although it may seem low does not accurately reflect the health impact of particulates on public health, especially in consideration of the much stricter air quality guidelines recommended by the World Health Organization*". (UBA, 2014a)

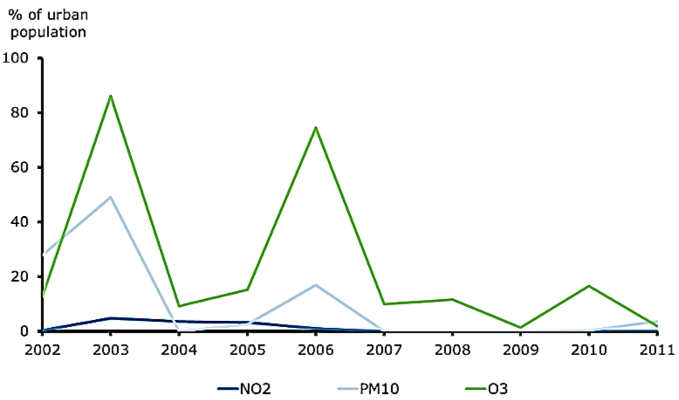


Figure 2.2: Percentage of the urban population in Germany potentially exposed to air pollution exceeding EU air quality objectives (EEA, 2013b)

2.3.2. Noise

In general noise is considered to be amongst the most relevant environment & health problems, just behind the impact of air quality, but potentially becoming more relevant, if no action will be taken. (European Commision, 2014)

Excessive noise seriously harms human health and interferes with people's daily activities. It can disturb sleep, cause cardiovascular and psychophysiological effects, reduce performance and provoke annoyance responses and changes in social behaviour. Furthermore, it has various effects on animals and ecosystems. Regarding the animals for example, an animal's respond may range from mild annoyance to panic and escape behaviour. (den Boer & Schroten, 2007, p. 19)

According to the EU Green Paper on Future Noise Policy "*around 20 percent of the Union's population or close to 80 million people suffer from noise levels that scientists and health experts consider to be unacceptable. An additional of 170 million citizens is living in so-called "grey areas", where the noise levels are such to cause serious annoyance during the daytime*" (European Commission, 1996, p. 1). What is more, the WHO estimates that about 40% of the population in the EU is exposed to road traffic noise at levels exceeding the limit value of 55 dB(A), and that more than 30% is exposed to levels exceeding the interim target value of 55 dB(A) during the night (WHO, 2014). Figure 2.3 provides information on the percentage of people in some European cities exposed to noise levels from road transport above the WHO threshold.

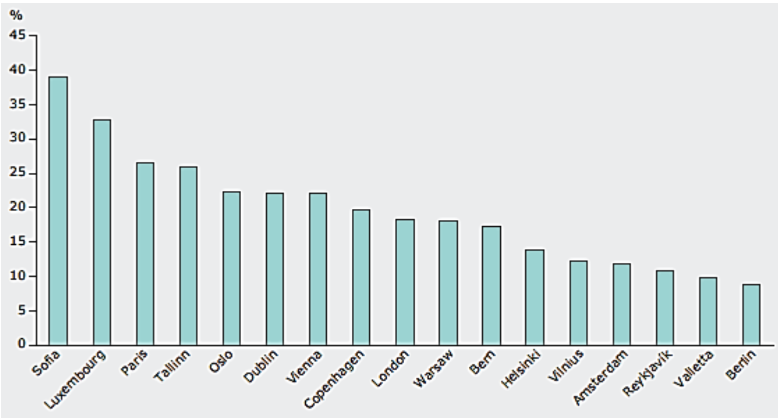


Figure 2.3: Percentage of people exposed to levels above the WHO interim target for night-time noise in Europe from road transport in 2012 (> 55 dB Lnight) (EEA, 2013a)

The main legislative instrument for assessing exposure to noise in the EU is the Directive 2002/49/EC, known as "END". The END aims to "*define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to the exposure to environmental noise*". However, the present Directive does not set binding limit values, nor does it prescribe the measures to be included in the action plans thus leaving those issues at the discretion of the competent authorities. (European Commission, 2002)

In Germany the situation is not much better than in the rest of Europe. According to the Federal Environment Agency, traffic noise is a serious problem in Germany, where surveys show that traffic-noise pollution has declined only marginally over the past decade (UBA, 2012). In a survey done in 2010, 55% of the Germans claimed to feel disturbed or annoyed by road traffic noise in their living environment, with 11% even ranking disturbance "extremely" or "very". Aircraft noise ranks second after road traffic noise as the greatest transport-related source of noise annoyance in Germany. Moreover, rail noise causes annoyance in a little more than 20% of the population, while nearly one third of the population is disturbed by industrial and commercial noise. (UBA, 2011, pp. 25,80)

2.3.3. Open / Green spaces

According to the EPA, "*open space is any open piece of land that is undeveloped (has no buildings or other built structures) and is accessible to the public*". Open space can include green space (land that is partly or completely covered with grass, trees, shrubs, or other vegetation), such as parks, community gardens and cemeteries, schoolyards, playgrounds, public seating areas and vacant lots. Furthermore, it normally provides recreational areas for residents and helps to enhance the beauty and environmental quality of neighbourhoods. (EPA, 2014b)

Nearly 75% of European citizens live in urban areas, and this is expected to increase to 80% by 2020. As a result, it is vital to improve urban environments and make them healthier to live. Green urban areas can play an important role in this context. A multifunctional network of green urban areas is capable of delivering many environmental, social, and economic benefits (EEA, 2010b, p. 108). For example, a study in Sweden showed that the perceived availability of green urban areas can reduce annoyance due to noise (Gidlöf-Gunnarsson & Öhrström, 2007, p. 122). Another study concluded that individuals are happier when living in urban areas with greater amounts of green space. (White, et al., 2013, p. 926)

Regarding transportation, green urban spaces are vital for promoting non-motorised trips. Better facilities for walking and cycling in combination to accessible, well maintained green spaces can encourage physical activity and contribute to the accomplishment of modern transport systems and safe walkable neighbourhoods, both key elements of high urban quality of life (EEA, 2009, p. 13). Figure 2.4 shows the percentage of green urban areas in core cities across Europe. The percentage for the city of Munich accounts to 10-20%.

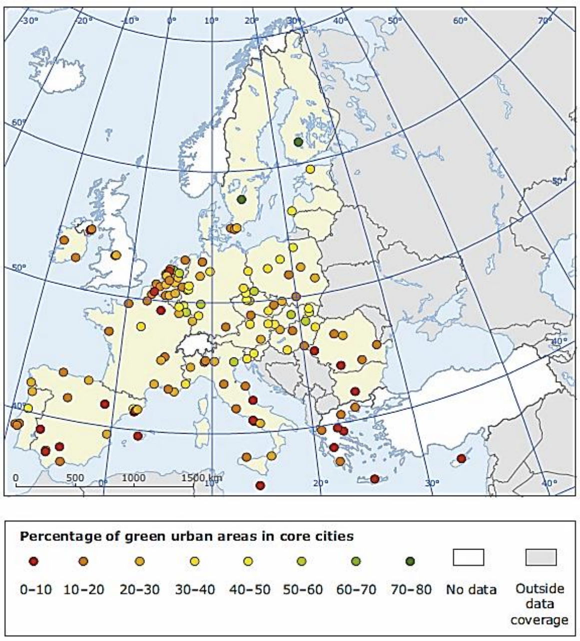


Figure 2.4: Percentage of green urban areas in core cities, Munich: 10-20% (EEA, 2010a)

2.3.4. Perceived Environmental Quality

The approach of this thesis considers as a core aspect that environmental quality is not only objective and measurable, but also subjective for each individual. Each one of us perceives the environmental quality of an area in a different way, depending on many factors such as our social background, age or even our mood. This sub-chapter presents how Europeans perceive environmental quality in their cities.

In 2010, the European Commission published a report, examining the perception on quality of life in European Cities. The report contains the results of a survey that was carried out in 75 cities of the EU, Croatia and Turkey in November 2009. The survey contained questions for a variety of topics related to quality of life, such as health care, jobs, economic situation, pollution, safety, city infrastructure, public transport and administrative services. The selected results presented in this thesis are related to the environmental quality of the cities. Furthermore, because it was not convenient to present the results for all the 75 cities in each category, the following graphs show only the highest and the lowest ranking cities.

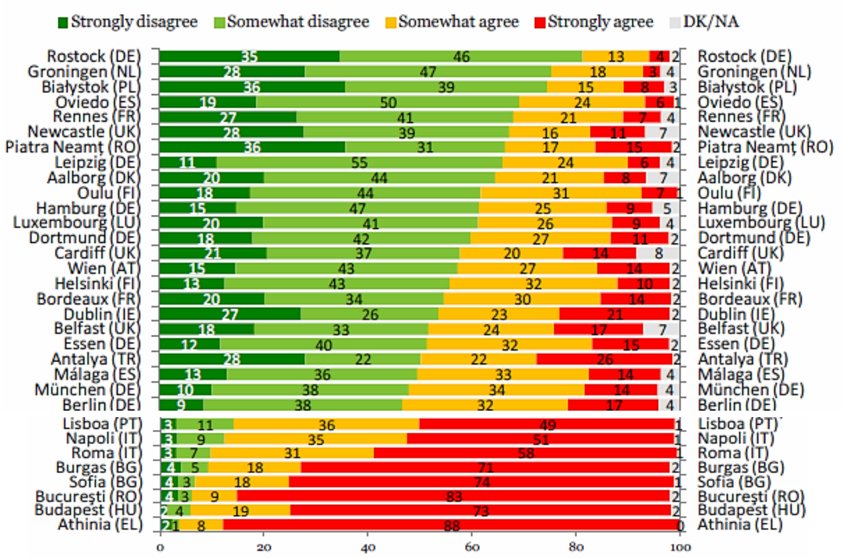


Figure 2.5: Air Pollution is a major problem (European Commission, 2010)

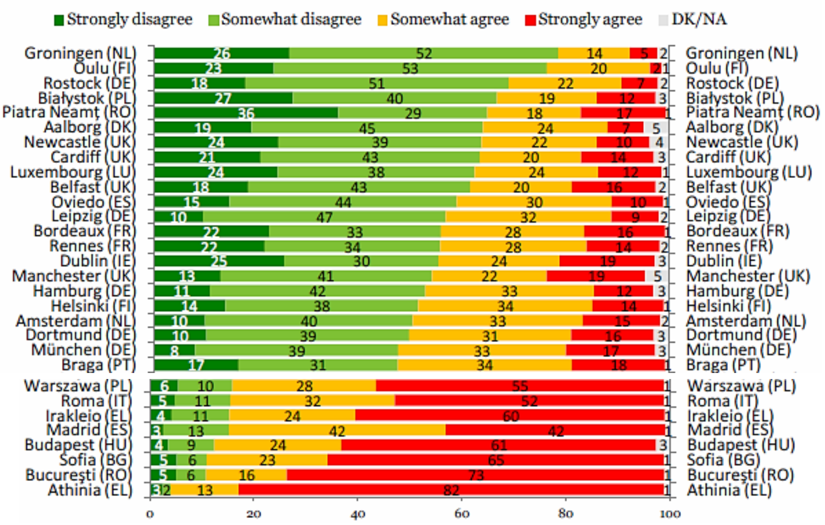


Figure 2.6: Noise is a major problem (European Commission, 2010)

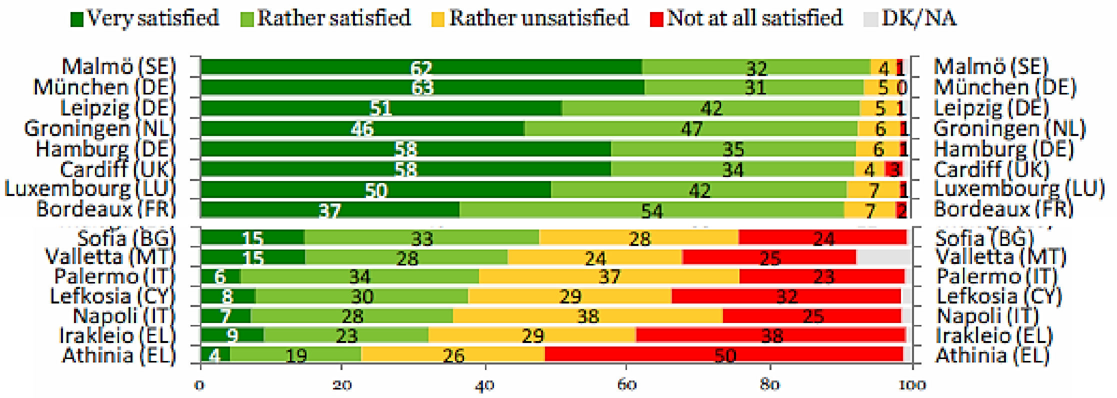


Figure 2.7: Satisfaction with green spaces (e.g. parks and gardens) (European Commission, 2010)

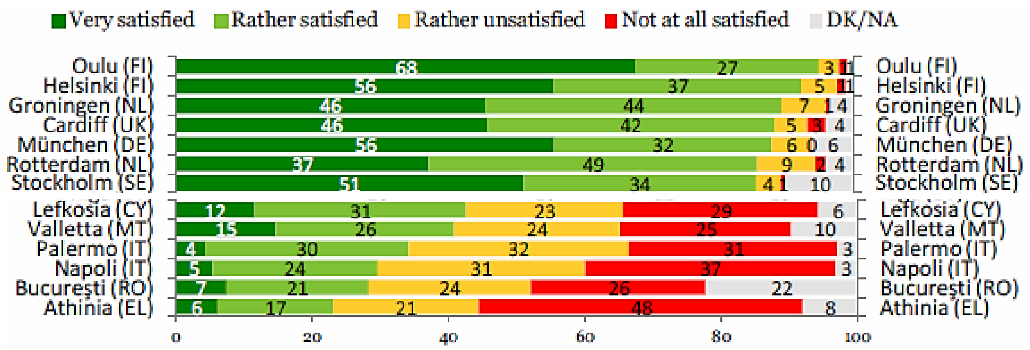


Figure 2.8: Satisfaction with outdoor recreation (e.g. walking or cycling) (European Commission, 2010)

The main findings from this survey were that air pollution appeared among the three most important problems in 21 cities. More than half of respondents agreed that noise was also a major problem in their city. Moreover, there was a strong correlation between the perceived levels of air pollution and perceptions about whether a city was healthy to live in or not - the same cities appeared at the higher and lower ends of the rankings. Finally, a majority of citizens was satisfied with parks and gardens in their cities except for 7 of the 75 listed cities. (European Commission, 2010)

As far as Germany is concerned, results for some cities can be seen in the above figures. Half of the citizens of Munich for example, consider that air pollution and noise are major problems in their city. On the contrary, approximately 90% of the responders agree that outdoor recreation, such as walking and cycling, is satisfactory in Munich. The same amount of responders are also satisfied with green spaces, which is interesting, considering that according to Figure 2.4 the amount of green spaces in Munich accounts to 10-20%.

In addition, every two years the Federal Environment Agency conducts a survey about environmental awareness in Germany. The last one took place in 2012, where 84% of the participants said that environmental quality in their area is ‘very good’ or ‘good’ and 69% believe that this is also true for whole Germany (UBA, 2013, p. 23). However, regarding the global environmental quality only 21% believes it is good. Comparing to the results from the survey in 2010 (UBA, 2011, p. 28), we can see that perception of the local environmental quality is slightly worse in 2012 but the overall perception of environmental quality in whole Germany and globally has increased.

The literature review that was carried out, regarding the different factors of environmental quality, showed that authorities and scientists have become the last decades more aware about the interplay between human activities and the environment. Human activities have strong impacts on the environment, such as the cause of higher air pollutants concentrations or noise levels, which respectively affect human beings and ecosystems. Authorities have set up also legislative directives and guide values, in an effort to protect humans and the environment from the negative impacts of pollution. These thresholds were taken into consideration during the analysis conducted by this thesis' methodology.

Moreover, the fact that half of the responders of the European Commission's survey recognise air pollution and noise as a major problem for the city of Munich, while in the meanwhile are satisfied with the amount of green spaces, makes it interesting to further examine how this perception affect their mobility behaviour.

As far as the topic of this thesis is concerned, the mobility behaviour, as part of a human activity, impacts the environment. However, the counteraction of the influence of the environment on the mobility behaviour is vaguely examined so far. Literature suggests that open green spaces can promote non-motorised trips, but the rest of the factors of environmental quality are not clearly examined for influencing modern transport systems.

2.4. Overview of studies with comparable objectives to this thesis

In the beginning of this thesis, a literature review was carried out in order to find similar studies, with the same research question to this thesis: if and how environmental quality affects mobility behaviour. However, it was not possible to find one single study with precisely that objective. Therefore, this chapter presents a literature review of studies with a relatively close subject to the topic of this thesis or studies that simply contributed and helped in better developing this topic.

In 2013, a study in Belgium tried to uncover the factors that influence the choice of transport mode for short distance travel to various destinations in older adolescents. The researchers used thirty two focus group volunteers to conduct a qualitative analysis. First, the participants were asked to answer a questionnaire collecting sociodemographic data, data about transport modes, transportation preferences and travel distances. Then five focus groups meetings took place, in which the discussion lasted approximately 50 minutes.

The analysis showed three main themes that affected choice of transport mode: personal, social and physical environmental factors. The most important reasons for older adolescents to choose a transport mode were short travel times, high autonomy, good social support, low costs, good accessibility to transport modes and good weather. On the contrary, safety, ecology and health reasons seemed not to have a big influence on their transport mode choice. Regarding ecology for instance, the participants thought that is indeed a disadvantage that a car is bad for the environment and an advantage that walking and cycling is good, but still that would not be a factor in making a transport mode choice. (Simons, et al., 2013)

The study mentioned above tried to find out the most important factors influencing the choice of transport mode. The results showed that environment is not important for taking this mobility decision. However, this study cannot be considered exhaustive. The main reason is that the participants were adolescents, between 16-18 years old. As a result, none of them owned a car, a fact that definitely influences mobility behaviour. Furthermore, usually adolescents are not so much environmentally aware and informed about the consequences that their behaviour may have on the environment. These aspects could also be a reason for the findings that ecology does not play an important role in their mobility decisions.

Transport for London (2012) conducted a survey, in order to investigate the decisions that cyclists make when deciding which route to take. Among other results, the survey showed that half of the responders would change their route in order to travel through parks and/or green spaces, with around 15% saying that they would be prepared to use a significantly longer route. Furthermore, there was much greater willingness to change route for parks and green spaces amongst the over 55s.

A study in Sweden examined whether environmental concerns can influence travel behaviour. More specifically, the study investigated the impact of attitudes and environmental knowledge on driving distance, travel behaviour and acceptance of various traffic restrictions. The research was made with the help of surveys and it implies that environmental-friendly attitudes can play a role in travel behaviour. It also suggests that local implementation of new strategies to reduce private car driving might benefit from a better understanding of what will be accepted among the public. Moreover, the authors suggest that in promoting pro-environmental travel behaviour it may be important to focus on basic attitudes, rather than to rely solely on factual information. (Nilsson & Küller, 2000)

Another study, made by the University of Bath, examined the pedestrians' perception of environmental stimuli through a field survey. Microclimate, noise and PM were monitored during 260 guided-interviews at two study sites. In general, higher PM concentrations were connected to perception of bad air quality. The authors suggested that understanding the human assessment of environmental stimuli could inform the design and development of urban spaces, in relation to the allocation of uses and activities, along with air quality management schemes. (Nikolopoulou, et al., 2011)

The importance of perception of air quality was also pointed out by Semenza et al. (2008), who tried to investigate the public perception and behaviour change in relationship to hot weather and air pollution. His outcome was that air quality advisories for the public were not effective in changing individuals' behaviour, even in severe air quality episodes. Behaviour change, such as driving less or postponed refuelling, was predominantly motivated by perception of the environmental conditions and not the advisory system.

In addition, a study in UK, based on semi-structured in-depth interviews, suggested that the public does not receive air quality information in a passive way, but actively negotiates and critically evaluates such information on the basis of a range of cultural resources, including experiential and local knowledge (Bush, et al., 2001, p. 225). From the above studies, it can be concluded that perception of environmental quality is really important and has a strong influence on human behaviours.

Another interesting study comes from UK and presents an overview of environmental quality, looking at both the quantitative environmental conditions and in addition the opinions and experiences of people who live in three of the UK's major cities: London, Sheffield and Manchester. The researchers used a multi-method approach combining qualitative and quantitative data collection techniques, in order to examine outdoor, indoor and perceived environmental quality. The outdoor environmental monitoring involved the intensive monitoring of an urban road system, where noise levels, some air pollutants and temperature were monitored. In order to examine the perceived environmental quality, the researchers used a variety of qualitative methods. At first, participants answered a short questionnaire (on personal data, household characteristics, etc.). Then they were asked to take photographs of their local area, that record both the positive and negative aspects of it. Finally, a semi-structured interview was given by each participant. After collecting all the data, the researchers created local environmental quality maps using GIS, indicating the areas with better assessments. According to the authors, "*the findings of this study help to understand the influence environmental quality has on quality of life, which in turn can aid urban policy, planning and design*" (Moore, et al., 2006). This thesis has a similar aim with that study, with the difference that instead of the influence of environmental quality on quality of life, it is intended to examine the more specific influence on mobility behaviour.

Silva et al. (2012, pp. 6,30) examined the correlation between environmental quality and life satisfaction. The writers suggest that there is no one-to-one relationship between actual pollution concentrations and reported satisfaction with environmental quality. The main findings of this report are that there is a clear positive relationship between PM_{10} concentrations measured in urban areas and the proportions of urban residents declaring that they are dissatisfied with air quality and that the effect of environmental quality on life satisfaction is much lower than the corresponding effect of health status.

Finally, the Federal Environment Agency of Germany presents some useful information regarding people's behaviours and opinions in the study about environmental awareness in Germany (UBA, 2013), which are also interesting for the scope of this thesis and therefore some of its results are presented here. The topics covered in the survey include new mobility concepts, such as electromobility and car-sharing, travel behaviour, acceptance of transport-related measures to improve the environment and assessment of noise pollution.

The researchers tried to understand whether environmental friendly alternatives to private car use, such as electric vehicles and car sharing, are known and also their rating for their potential for innovative change in mobility practices. Electric mobility is known for 68% of citizens and 39% have heard of the possibility of car sharing. A large majority of those who know electric mobility is convinced that it is an environmentally friendly alternative to conventional car, but only about two-thirds of them can imagine trying an electric vehicle even once. Practically interested in electric vehicles are mainly young people up to 29 years and men.

The vast majority of those who know car sharing is convinced that these offers are environmental friendly and 36% of them find car-sharing an attractive alternative.

In addition to the alternative transport concepts, also traffic calming measures with environmentally positive effects were assessed. A clear majority of citizens is in favour of reduced-traffic residential areas and see very positively urban development, ensuring that the individual is less dependent on the car. However, the creation of traffic-calmed residential areas is slightly less favoured than in the study of 2010.

Overall, despite that citizens are aware of the problems that car traffic causes in the environment, this hardly makes them more inclined to turn to environment-friendly alternatives. The dominant pattern of individual mobility proves to be a difficult issue for environmental policy. The ideas about the value of the car as a status symbol, but also its importance in managing the family everyday life with children, suggest that alternative offers will require a massive development in order to persuade habitual car users.

People were also asked to assess noise pollution in their residential area. The interviewees said that their neighbourhoods were mostly affected by noise caused by road traffic. However, the annoyance due to noise does not seem to be perceived as very strong. Those who were strongly impacted were people older than 65 years and women, while people younger than 29 years old believe that such environmental problems in their neighbourhood do not affect their health.

The above literature review tried to find the extent that this topic is already analysed. An interesting outcome is that green spaces seem to have an important influence on route choice. Furthermore, a careful examination of the existing studies showed that perception of environmental quality has a strong influence on human behaviours, as well as it contributes to the general 'quality of life' or 'life satisfaction'. However, studies with a straightforward examination of the influence that the perceived and actual environmental quality has on mobility behaviour are still missing. What is more, the review of the above studies contributed to the development of this topic, by examining the ways that other researchers studied and assessed actual and perceived environmental quality of their study areas, a knowledge that was required for developing the methodology of this thesis.

2.5. Methods for qualitative analysis

The majority of the studies presented above, chose to conduct a qualitative analysis, usually by gathering primary data with the use of surveys, personal interviews, or focus-group discussions. Such qualitative methods are used increasingly in research and policy studies and can help fill the gaps left by quantitative techniques. Qualitative research is vital to understand the complexity of traveller perceptions, attitudes and behaviour, which rests upon the subjective beliefs and behaviours of the individual person (Clifton & Handy, 2001, pp. 3-4; Grosvenor, 2000). The main methods to collect primary data for a qualitative analysis are presented in this section.

2.5.1. Questionnaires

The Federal Statistical Office of Germany has published a manual for the creation of survey documents of official statistics (Statistische Ämter des Bundes und der Länder, 2011). According to this manual, a common method to carry out surveys is a questionnaire in written form. Depending on the type of distribution they can be further divided into paper surveys and online surveys. In both cases the participants are not under the pressure of time and their answers are not biased by the behaviour of the interviewer. These are the main advantages of this methodology, which however lead to two main drawbacks. Low return rates and the possibility of incomplete or incorrectly filled questionnaires can be the main problems that the researchers may meet.

As far as the paper surveys are concerned, the printing and mailing process as well as the manual evaluation of the answers afterwards results in considerably high costs and time efforts. In order to lower these costs, many researchers choose to conduct an online survey. This can save money and usually has a better return rate. Other advantages of the online surveys are the easier distribution and automated retrieval of the answers. However, the technology needed for an online survey may overwhelm specific social groups, such as elderly people or low-income households without access to a computer, which leads to a lower representation of these groups. Finally, both paper and online surveys include the risk that the participants may misunderstand the instructions or the questions and thus this can lead to an incorrectly fill of the survey.

2.5.2. Focus Groups

Focus groups are another way of collecting data for qualitative analysis. Clifton and Handy (2001) published a report that present different qualitative methods in travel behaviour research. Among the different methods, they give useful information about focus groups. Generally, in a focus group setting, a small number of people, usually between six and twelve, are recruited based on a specific set of criteria. The participants exchange their ideas, experiences, and attitudes about a particular subject in a guided discussion facilitated by a moderator. Nevertheless, the small sample size does not allow for statistical testing or broad generalizations, but it does allow for in-depth exploration of selected issues. On the other hand, focus groups have also their disadvantages. Like any survey, "*focus groups may produce halo effects and strategic response effects*". (Clifton & Handy, 2001, p. 8)

Focus groups have been often used in studies to understand more about the factors that influence decision making. The concept has been adopted also by the transportation field to identify mobility needs, evaluate programs, identify preferences and attitudes and assess reactions to different service or policy scenarios. Moreover, focus groups are also being used by academic researchers to better understand the factors behind observed travel behaviour and the implications of travel choices for the household.

2.5.3. Personal Interviews

"*Personal interviews can provide the same rich, situational response as focus groups. However, due to the fact that the interviewees are asked individually, the confidentiality issues and normative pressures that often plague focus groups are not as problematic*" (Clifton & Handy, 2001, p. 8). During personal interviews, the contact to the participants is direct and the interviewees have the possibility of communicating with the interviewer.

There are two ways to conduct personal interviews, face-to-face or interviews done by telephone. The advantage for both methods is that questions can be answered right away and the direct contact can motivate people to participate more easily in the survey. These two aspects can guarantee a high data quality and higher return rates. On the contrary, the drawbacks of these methods are not few. Like focus groups, conducting interviews contain the risk of receiving biased answers from the respondents due to their contact with the interviewer. In addition, the methodology of the interviews is quite costly and time consuming. The telephone interviews can reduce the cost, but when the questions of the survey are too complicated, a face-to-face interview is mandatory. However, considering the large amount of time necessary for the interviews and the travelling, this method is very costly. (Statistische Ämter des Bundes und der Länder, 2011; Clifton & Handy, 2001)

2.5.4. Participant-Observer Method

At a participant-observer method, the researcher has the chance to observe the daily life of the participants and share their experiences. Problems such as self-selection bias, recall and memory issues, and behaviour modification do not interfere with the investigation, due to the fact that participants are observed in the context of their daily lives. Moreover, this method allows the researcher to develop a better understanding of how people behave and how they respond in particular situations. One drawback of this method is that it often takes time to enter a community and gain its acceptance. In addition, the technique of the participant observation requires normally a considerable time and emotional investment from the researcher. (Clifton & Handy, 2001, pp. 10-11)

Participant observation is a technique that is perhaps not used as extensively as it could be in the transport sector. A good implementation of this methodology was made by David Hollings, a leading consultant in the UK, who pioneered the use of this method in the transport sector. He used this methodology in order to examine passenger behaviour and attitudes toward transport information provision. The particular value of this technique lies in the opportunity to link actual behaviour with attitudinal questioning. (Grosvenor, 2000, p. 8)

2.5.5. Issues regarding the qualitative methods

The main pros and cons of each method were described above. However, there are some main issues regarding all the qualitative methods that are important to be mentioned. According to Clifton and Handy (2001, pp. 12-13), for a successful qualitative analysis it is important that researchers have the required theoretical background to deliver the right questions with the right methodology. Moreover, the authors of this report imply that it is difficult to find persons qualified to conduct data collection, because "*qualitative investigators must be able to secure the trust of informants, develop a rapport with them, engage them in discussion, and guide them through the interview or focus group*".

Another important problem of conducting a qualitative analysis is the low response rates in all the available methodologies. It is noticed that response rates have been declining in postal questionnaires since 1992 and this trend may well be apparent for the other data collection methods. Some of the factors that may improve response rates in the methodology of questionnaires include (Curtis & Perkins, 2006, p. 25):

- well-designed questionnaires
- avoiding overt references to government involvement
- inclusion of stamped, addressed envelopes
- providing a deadline for questionnaire return and
- avoiding requests for sensitive personal and financial information

On the other hand, there are two key advantages found in the use of qualitative approaches. First and most important, the entire approach triggers and encourages creativity in research design and in the conduction of the research. A second advantage is that the results obtained from qualitative approaches tend to have high level of realism (Grosvenor, 2000, p. 19). To conclude, it is outlined in the literature that qualitative analysis is a really important and useful tool for researchers who want to examine mobility behaviours. Nevertheless, researchers need more data to work with, thus it is strongly promoted the undertaking of more qualitative analyses. However, it is really important a qualitative analysis to be carefully designed and conducted by appropriate researchers, in order the outcome to be useful.

2.6. Summary of the literature review

The literature review presented in this chapter gave an overview of the definitions of mobility behaviour and environmental quality. In general, mobility behaviour is the decisions that someone takes in order to physically move from one place to another. Environmental quality however is more complicated to be defined. It involves a variety of characteristics, such as air, water and soil quality, and its subjective perception from individuals plays a vital role in defining it.

Moreover, the literature review examined several factors that influence mobility behaviour. The effects of these factors were presented by different studies found in the literature, in order to help the readers of this thesis better understand the multivariate nature of the term mobility behaviour. In addition, the extensive examination of different factors was made in order to help us better realize where environment stand as an influential factor. The research made so far, showed that spatial structure and socio-economic aspects play a major role in taking a mobility decision, whereas environment is not a highly influential parameter for mobility behaviour and it mostly plays a role to people with pro-environmental behaviour and beliefs.

This chapter also provided information related to environmental quality and its status quo in Europe and in Germany. The focus was given on air quality, noise levels and green spaces, since these aspects have possibly a more blatant impact on mobility behaviour, than aspects such as soil quality or water purity. The importance of perception of environmental quality was also highlighted and an overview of this perception was given for cities across Europe. The outcome showed that air pollution appeared among the three most important problems in 21 cities, whilst more than half of the respondents agreed that noise was also a major problem in their city. Regarding Munich, half of the responders considered that noise and air pollution is a major problem for the city, whilst almost all of them were satisfied with the city's green spaces and opportunities for cycling and walking.

What is more, studies with a similar scope to this thesis, conducted across the world, were analysed in order to help the author better understand and develop the topic of this thesis. The literature review showed that studies with a straightforward examination of the influence that environmental quality has on mobility behaviour are still missing. Literature implies that green spaces have an influence on route choice and can promote non-motorised trips, but the other factors of environmental quality are not examined for influencing mobility behaviour.

The majority of the reviewed studies used a qualitative methodology to acquire primary data. As a result, this chapter presented also the different qualitative methods that are commonly followed by researchers, as well as their advantages and disadvantages, in order to evaluate them and choose one suitable methodology for this thesis. The chosen methodology of this thesis includes a conduction of an online survey and is presented in the next chapters.

3. Methodology

This chapter discuss the methodology that was followed for this thesis. The initial point of the methodology was to define the overall system boundaries. Firstly, a definition of what this thesis considers environmental quality and mobility behaviour is given, and then the geographical boundaries, and namely the two study areas that the investigation of the topic took place, are presented.

The methodology included both a qualitative and a quantitative analysis. As a result, this chapter presents the qualitative methodology and gives in detail the steps that were followed in order to develop the survey that was carried out, as well as the procedures that were undertaken for analysing the results of the survey. Finally, the chapter continues with the presentation of the quantitative analysis, and namely the environmental assessment of the two study areas.

3.1. System Boundaries

In Chapter 2, the definitions of mobility behaviour and environmental quality presented the complexity of the terms, while the literature review showed that the interrelationship between them is still vaguely examined. To adjust this wide topic to a manageable frame for a master thesis, some boundaries had to be set. This section clarifies the parameters of the two terms that were examined, the geographical boundaries where the examination took place, as well as an overview of the methodology that was followed.

3.1.1. Environmental Quality

It is important to have a clear definition of what we consider environmental quality of an area. For the scope of this study, environmental quality is considered to include the following characteristics:

- Air Quality
- Noise
- Spatial Quality (supply of green spaces, access to open spaces)

The above three characteristics were chosen among the different aspects of environmental quality, because they possibly have the highest correlation to mobility behaviour. Aspects, such as water purity, soil quality or the visual effects of buildings, would perhaps have a more vague relation to mobility behaviour and it was chosen to not be examined.

3.1.2. Mobility Behaviour

Mobility behaviour includes a variety of parameters, some of which were presented in the previous chapter. This thesis is focusing on the parameters of:

- Transport mode choice
- Route choice

- Travel distance
- Travel time
- Purpose of trip

This thesis tried to investigate the extent to which the above defined environmental quality factors influence transport mode and route choice. However, the aspects of travel distance, travel time and trip purpose were also analysed within the methodology. Nevertheless, the focus was given on transport mode and route choice, because these are the aspects of mobility behaviour, on which it is more possible that environmental quality has a stronger impact.

3.1.3. Geographical Scope

The definition of the geographical boundaries was really important for the selected topic. The influence that environmental quality may have on mobility behaviour would be obviously different in environmentally-friendly cities like Copenhagen to cities with strong problems of pollution like Beijing. It is logical that in places with strong pollution, the latter can be more easily perceived and possibly can affect human behaviours to a greater extent than in areas with really low pollution, in which the citizens probably do not consider environmental quality as a major issue.

In this thesis, the focus was given on areas in Germany and more specifically, there was a special interest to examine and compare different spatial structures. As a result, within the frame of this thesis, both a rural and an urban area were chosen to be examined. The municipality of Maisach was used as an example of a rural area, whereas the district of Munich, Maxvorstadt, consisted the urban study area.

The reason for choosing specific areas and not the wider area of a region, was to assure that the participants of each area would have a specific and similar background (regarding their perception for mobility and environmental quality of the area) and therefore more homogeneity in the results could be achieved. Some information about the two study areas are presented in the next pages.

3.1.3.1. Maisach

Maisach is a municipality, which belongs to the county of Fürstenfeldbruck (FFB), in Bavaria. It consists of different districts, with Maisach, Gernlinden and Überacker being the primary and main areas of the municipality. The last census on 09.04.2014 counted a population of 13.485 people in total, from which 5.574 and 4.637 live in Maisach and Gernlinden respectively. Regarding the wider region of Fürstenfeldbruck and as far as the population is concerned, the municipality of Maisach consists the 6th biggest district of FFB. Moreover, the municipality of Maisach has a total area of 53.45 km², leading to a density of 240p/km². (Gemeinde Maisach, 2014; WestAllianz München GbR, n.d.)

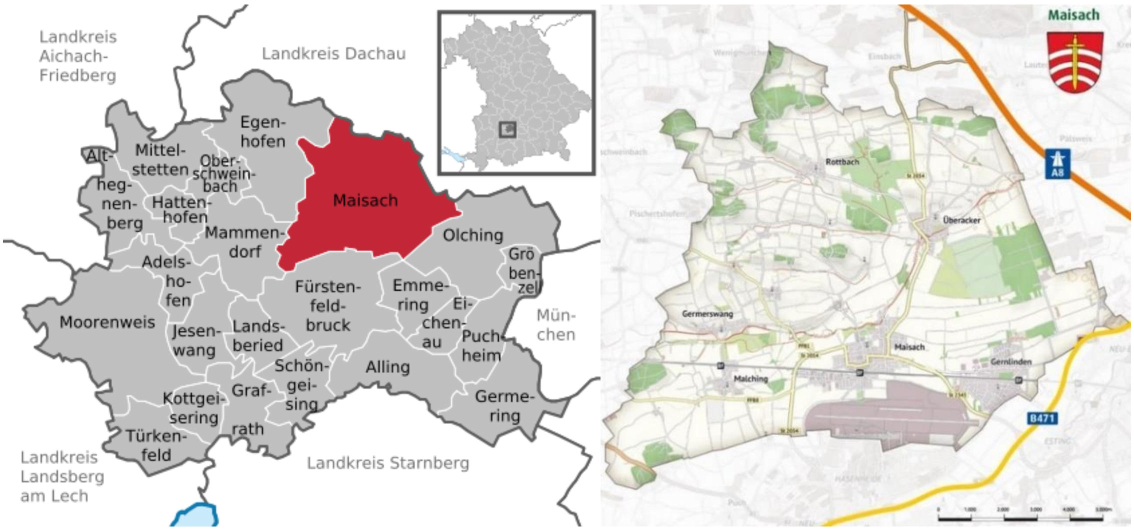


Figure 3.1: Municipality of Maisach (Wikipedia, 2010a; WestAllianz München GbR, n.d.)

It is also important to present some information about the transport supply in the municipality of Maisach. As shown in Figure 3.1, along the northern borders of the municipality, there is the A8 national motorway (Munich-Augsburg-Stuttgart) and the B471 federal highway, which connects A8 with the A96 national motorway (Munich-Lindau). The S3 suburban railway and buses 870, 871, 872, 873 represent the public transport of the municipality. Finally, the concepts of “Park+Ride” and “Bike+Ride” are promoted in the municipality. Table 3.1 presents the P+R and B+R supply and demand in the municipality (MVV, 2010, p. 15):

Station	P+R Supply	P+R Demand	B+R Supply	B+R Demand
Gernlinden	55	60	270	290
Maisach	264	265	236	220
Malching	26	20	80	50

Table 3.1: Park + Ride and Bike + Ride supply and demand in municipality of Maisach

Considering the mobility behaviour in Maisach, a high usage of individual motorised transport is noticed. The car ownership ratio is 551cars /1000 residents, which means that more than half of the population owns a private car. In addition, the modal share in the community of Maisach shows that only 16.1% uses public transport (TUM-PSU, 2012; MVV, 2010). More detailed mobility data for the municipality of Maisach are unfortunately not published. However, there are some rather detailed mobility-data reports for the county of Fürstenfeldbruck, where Maisach belongs to. According to them, the average trip length is 9.9 Km and the average travel time is 23 min. In overall during a day, the average distance travelled is 34.9 Km and the time spent for travelling 85 min. Furthermore, 34% of the trips are made for leisure purposes, while 22% of them are made for shopping. The percentage of the trips, with work or education as the main purpose, is 20%. (Infas, 2009)

3.1.3.2. Maxvorstadt

Maxvorstadt is a district in the centre of Munich, with a population of 51.642 people and a space of 4.3 km². It is a very dense neighbourhood, with 12.000 p/km² and hosts 4% of the total population of Munich (Statistisches Amt München, 2014). Beside the residents, Maxvorstadt attracts also a high amount of visitors every day. The two biggest universities of Munich, Technische Universität München and Ludwig-Maximilian Universität, as well as a lot of cultural sightseeing, such as art galleries, museums, theatres and cinemas are located inside this district. Figure 3.2 presents the location of Maxvorstadt, in correlation to the city of Munich.

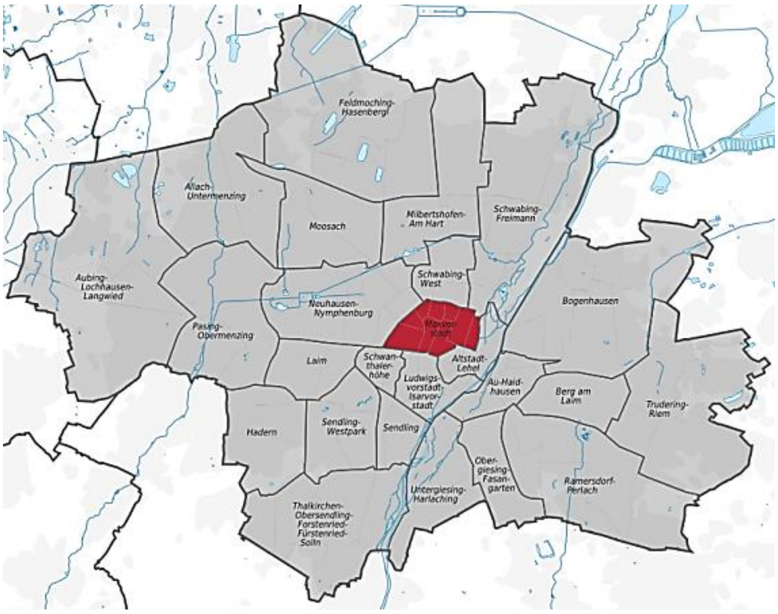


Figure 3.2: Location of Maxvorstadt within Munich (Wikipedia, 2010b)

Figure 3.3: Maxvorstadt (Zinemedia Agentur, 2014)

As observed in Figure 3.3, the core area of Maxvorstadt can be defined from the quadratic grid, formed by Schleißheimer Straße, Ludwigstraße, Georgenstraße and Elisenstraße. Between these axes there are parallel vertical and horizontal one-way streets. Maxvorstadt has a good public transport connection, with 4 underground lines and 5 metro stations, 6 Tram lines and several bus lines running along the district. In addition, there is a good cycle path network in the area, connecting Maxvorstadt with a large number of other districts of Munich.

Regarding the mobility behaviour of the area, the last big survey that took place in Germany showed that there is a high share for walking and cycling in the modal split of Maxvorstadt (39% and 24% respectively), while 15% of the residents is using the public transport. That leads to the rather small share for car use of 22%. The same survey shows that in Munich, the average trip length is 10 km and the average travel time 27 min. Finally, 33% of the trips are made for leisure purposes and approximately 20% of the trips are made for educational or work purposes. (Infas, 2009)

3.1.4. Choice of the methodology

It was made clear from the literature review that the majority of the existing studies on the subject conducted a qualitative analysis, usually by gathering primary data. Furthermore, since environmental quality can also be a matter of individual perception, it only makes sense the chosen methodology to be able to include this aspect of subjectivity. As a result, an effective methodology to successfully meet the goals of this thesis was to conduct a qualitative analysis. In the previous chapter there was an overview of the different methods a researcher may use in order to conduct a qualitative analysis. Regarding the scope of this thesis, the limited time frame and the restrained budget, as well as the geographical boundaries of this study, the method that seemed to be more appropriate for this thesis was the development of an online survey. The main advantage of this method was the easiness of the distribution of the survey as well as the fact that the answers could be automatically retrieved, which proved very useful within the limited time frame.

However, in order to examine and compare the perceived environmental quality to reality, a quantitative analysis was also necessary to be conducted. Thus, the methodology of this thesis includes furthermore an environmental assessment of the two study areas. Data about air quality, noise levels and the availability of green spaces within the two chosen study areas, were gathered and used to document the actual environmental. Then, the results from this assessment were compared to the evaluation of the environmental quality that the participants of the survey gave. This comparison was made in order to examine the coincidence of actual and perceived data about environmental quality.

3.1.5. Summary of the system boundaries

This section gave an overview of the system boundaries that were set for this thesis. At first, it was defined what is considered environmental quality and mobility behaviour within the frame of this thesis. Furthermore, the geographical boundaries were set and information about the two chosen study areas was presented. Finally, a description of the chosen methodology, as well as the reasons for making this choice was given. The next section presents the procedures that were followed to conduct the qualitative analysis.

3.2. Qualitative Analysis

This section describes the qualitative analysis that was carried out during this thesis. The first part holds information regarding the development of the online survey. It describes both the content of the questionnaire, as well as the technical information needed for developing it. In addition, it presents the means that were used to attract responders for the survey. The second part of the section, describes the methods used to process and analyse the answers of the survey.

3.2.1. Development of the survey

Surveys are a really important and useful tool for transport researchers and have already highly contributed to a better understanding of mobility behaviour. However, in order a survey to be successful, it is vital that it has been carefully designed to ask the appropriate questions and get the adequate responses, which answer its objective. As a result, and since the online survey is a core part of this thesis, the design of this questionnaire was fundamental.

The first step was to identify the answers needed to solve this thesis' research question. As explained in Chapter 1, the aim of this thesis is to understand if and to which degree environmental quality along our paths can play a role in our mobility decisions. Besides the general attitude that people have for environmental quality in correlation with mobility behaviour, it was also necessary to ask people to evaluate the environmental quality along their paths, in order to see how this perception may affect their mobility decisions. In addition, questions related to the responder's transport mode choice, as well as personal questions were added to the survey, leading to a questionnaire with four parts. Finally, an introductory text with information about the purpose of the survey, as well as the terms on privacy was added in the first page of the questionnaire. This chapter gives an analytical presentation of the questions asked. The complete questionnaire can be found in ANNEX 1.

3.2.1.1. Part 1 – Information about transport mode

In the first part of the questionnaire, the information that was gathered was related to the transport mode that the responders choose. Transport mode is one of the main parameters of mobility behaviour and it has one of the highest potential for contributing to sustainable mobility. This is the reason, why this questionnaire tried to examine thoroughly the actual situation of the responders, regarding their transport mode choice, as well as the reasons that lead them to choose this mode.

The questions of this part examined both long-term decisions, such as car and bike ownership and monthly public transport tickets possession, but also short-term decisions, by asking the responders to evaluate different factors for choosing a transport mode in their everyday trips. More specifically:

- This part started by asking the responders whether they have access to a personal car and bike or not.
- The next question asked if they are members of a car-sharing programme, and if the answer was positive, then they were asked to choose the car-sharing company that they were a

member of. The last years, car-sharing is becoming more and more popular in Munich and a lot of people are becoming members of such programmes and offers. However, car-sharing provides only limited accessibility to a car, comparing to owning an own vehicle. This is the reason why access to private cars or to car-sharing offers were separated into two different questions.

- The next question referred to public transport and more specifically asked the responders whether they own a monthly public transport ticket or not.
- The last question of this part contained a large number of factors, which the responders were asked to evaluate depending on the extent to which they influence their choice of transport mode. The scale of influence that was used was from 1 to 5, with 1 corresponding to ‘no influence at all’ and 5 to ‘fully’ influential factors. The factors that were examined were comfort, health, habit, travel costs, safety, environmental friendliness of the mode, time needed for the trip, trip purpose and weather.

3.2.1.2. Part 2 – Perceived environmental quality related to the most frequent trip

The purpose of the next part of the questionnaire was to examine how responders evaluate environmental quality. The first idea was to ask them to evaluate the air quality, the noise levels and the availability of green spaces in their neighbourhood or the study area they belong to in general. However, since the focus of this thesis is the correlation of these factors to mobility behaviour, it made more sense to ask them to evaluate environmental quality along their paths.

In Germany, 32% of the trips are made for leisure purposes, 21% of the trips are made for shopping and 20% are made for work-education purpose. The rest 27%, includes trips done due to private reasons or service purposes (Infas, 2009). However, rarely someone follows the exact same route for every leisure trip, because usually the destination is different. Most of the people choose to go on different bars, museums, etc. each time they decide to go out. On the other hand, the route someone takes to go to work or university is pretty much the same each day. As a result, since this trip is made almost every day, people are more aware of the environmental quality along this path. For that reason, the participants to the survey were urged to evaluate the environmental-related factors along their trip “work/university- home”.

The first question of the second part asked the responders to think of their most frequent path they do during the week and write down the purpose of this trip. Then, information about the route, as well as the evaluation of the environmental quality along it, was needed. This part was the most complicated of the questionnaire, because it was important to get this information in a detailed way. The first idea was to offer a table, where the responders would input the required information for each section of their path. However, the outcome would be some points along the path and not the exact route, which was the desired outcome. It was vital to get the exact route between the origin and destination points, because the perception of environmental quality may differ at a high degree, depending on whether a route passes by a park or a congested avenue.

After long research, it was found that there was no way so far that allowed researchers to get the exact route in a frame of a questionnaire. Similar results were acquired in projects were the participants had a GPS tracking device with them that was recording the exact coordinates along their trip. However, in the limits of an online survey with anonymous responses, this was not feasible. In addition, the research showed that a lot of transport researchers are interested in this possibility in the frame of an online survey, but nobody had managed to include it so far, or at least nobody had published a way to include this option into a survey.

For the reasons mentioned above, it was decided to create such an option from the beginning. The implementation involved the integration of Google Maps© and its option of routing in the questionnaire, so that responders were able to drag the route to the exact path they make. Google Maps© was selected instead of other map platforms, like Open Street Maps©, because most people are already familiar with it and because Google offers a very analytical documentation of its platform. In order to integrate Google Maps© in the survey, it was necessary to set it up in an environment that allows manipulating its scripts with programming. For that reason, Limesurvey© was chosen to be used for the survey. More information about the programme used for the development of the survey, as well as the online set up of it, is given in Chapter 3.2.2.

The code needed for including Google Maps© API to the questionnaire was written in JavaScript and JQuery. After reading the respective Google© documentation (Google Inc., 2014), the code was written and it was now possible to include this option to the survey. The services that were used from Google© for this application included, the autocomplete service, where google suggest places or addresses according to what the user input in the text box, geocoding service, which transforms the given addresses to coordinates and finally the directions service, including the different travel modes, waypoints and draggable extensions of it. Figure 3.4 shows how Google Maps© was integrated in the online questionnaire. In addition, a sample of the code written for this purpose is given in Figure 3.5. The complete code is available in ANNEX 2.

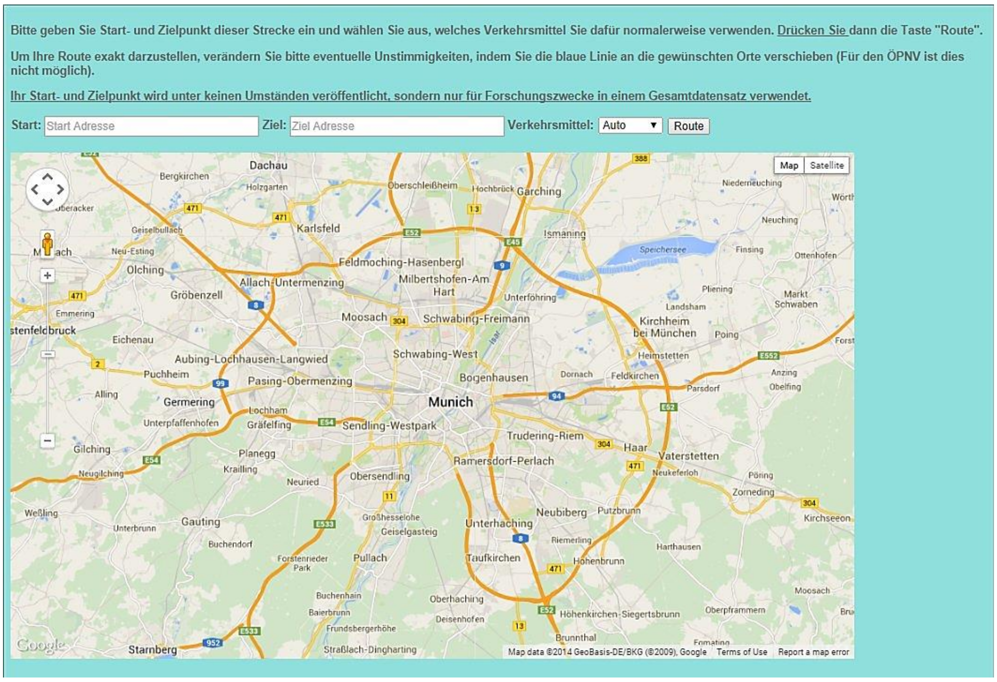


Figure 3.4: Integration of Google Maps in the survey

```
    function initialize() {
      var mapOptions = {
        zoom: 11,
        center: new google.maps.LatLng(48.1333, 11.5667)
      };
      map = new google.maps.Map(document.getElementById('map-canvas'),
          mapOptions);

    }
    google.maps.event.addDomListener(window, 'load', initialize);

});

function codeLatLng1() {
        geocoder = new google.maps.Geocoder();
        var address = document.getElementById("address1").value;
        geocoder.geocode({ 'address': address}, function(results, status) {
            if (status == google.maps.GeocoderStatus.OK)
            {
                if (results[0])
                {
                    var startCoords = results[0].geometry.location;
                    codeLatLng2(startCoords);
                    placeMarker(results[0].geometry.location);
                }
                else
                    alert("No results found");

            }
```

Figure 3.5: Sample code of Google Maps integration

After the participants inserted and adjusted their exact route, they were asked to fill in a table, where they had to evaluate air quality, noise levels and availability of green spaces along their route. The users inserted in this table each path of their route and evaluated environmental quality along it. In addition, they were given the option to omit their evaluation for parts of the route that were made with motorised transport modes. The reason for doing that was to avoid confusion of the responders, since evaluating air quality in the metro would make them consider probably the indoor air quality of the wagons and the stations, a factor that this thesis is not focusing on. Furthermore, it would not make sense to ask people to evaluate availability of green spaces along their trip with the underground. The following figures present the table, filled in for the trip 81539 (PLZ) – Technical University of Munich (TUM), with different transport modes.

	Strasse / PLZ / Ort / Haltestelle (Start)	Strasse / PLZ / Ort / Haltestelle (Ziel)	Verkehrsmittel	Zeit (min)	Luftqualität	Lärm	Grünflächen
1	81539	Giesing Bhf	Fahrrad	3	gut	mittel	mittel
2	Giesing Bhf	Theresienstrasse	U-Bahn	10	Bitte auswäh	Bitte auswäh	Bitte auswäh
3	Theresienstrasse	TUM	zu Fuß	5	mittel	laut	gar kein grür
4			Bitte auswäh		Bitte auswäh	Bitte auswäh	Bitte auswäh

	Strasse / PLZ / Ort / Haltestelle (Start)	Strasse / PLZ / Ort / Haltestelle (Ziel)	Verkehrsmittel	Zeit (min)	Luftqualität	Lärm	Grünflächen
1	81539	TUM	Fahrrad	26	gut	mittel	eher kein grü
2			Bitte auswäh		Bitte auswäh	Bitte auswäh	Bitte auswäh

	Strasse / PLZ / Ort / Haltestelle (Start)	Strasse / PLZ / Ort / Haltestelle (Ziel)	Verkehrsmittel	Zeit (min)	Luftqualität	Lärm	Grünflächen
1	81539	TUM	Auto (Fahrer	20	Bitte auswäh	Bitte auswäh	Bitte auswäh

Figure 3.6: Evaluation of environmental quality along a route

The levels of evaluation were five for each factor of environmental quality and are presented more specifically here, together with the available transport modes:

- Transport Mode: on foot (zu Fuß), bicycle (Fahrrad), bus (Bus), metro (U-Bahn), suburban railway (S-Bahn), trams (Tram), car (driver) (Auto (Fahrer)), car (passenger) (Auto (Mitfahrer))
- Air Quality: very good (sehr gut), good (gut), intermediate (mittel), bad (schlecht), very bad (sehr schlecht)
- Noise: very loud (sehr laut), loud (laut), intermediate (mittel), quiet (ruhig), very quiet (sehr ruhig)
- Green Spaces: very green (sehr Grün), rather green (eher Grün), intermediate (mittel), rather no green (eher kein Grün), no green at all (gar kein Grün)

3.2.1.3. Part 3 – Mobility Behaviour and Environmental Quality

The third part of the questionnaire aimed to answer the core objective of this thesis, and namely whether environmental quality affects in any way mobility decisions. People were asked to read five statements and tell how strong they agree or disagree to them. The five statements focused on the examined factors of environmental quality in correlation to mobility decisions and are presented analytically here:

- *When I perceive bad air quality*, I prefer to use public transport/car than walk/cycle.*
  **bad air quality: air pollution due to dust, exhaust fumes, etc.*

The first statement aimed to examine the influence of air quality on transport mode choice. There was the hypothesis for example that perception of bad air quality makes someone travel more with motorised transport modes, in order to protect himself from pollution. However it is also possible that it may not play a role in reducing non-motorised trips.

- *High noise levels along my way make me walk/cycle less.*

The second statement examines the influence of noise on transport mode choice and more specifically aims to answer whether high noise levels can be a constraining factor for walking and cycling.

- *I would stop using motorised transport in favour of cycling/walking, if there were more green spaces and cycle paths along my way.*

The third statement focuses on the effect of the available green spaces on walking and cycling and more specifically examines whether more green spaces can achieve a modal shift from motorised trips to non-motorised.

- *You read in the news that the thresholds for air pollution have been reached in your area. Therefore you change your mode of transport in a more environmental friendly one in order to help reducing pollution.*

The purpose of the fourth statement was to identify to which extent people are ready and willing to contribute themselves to sustainable mobility and to the protection of the environment and in addition to examine whether provision of information about environmental quality may have an influence in decision making.

- *When I walk/use the bicycle, I choose my route in such way, that I can pass through open green spaces.*

Finally, the last statement aimed to answer whether green spaces are important to pedestrians and cyclists for choosing a route.

The responders were asked to answer what best describes their attitude towards the above statements in a scale of 5: strongly agree (++), agree (+), neutral (+ -), disagree (-) and strongly disagree (--).

3.2.1.4. Part 4 – Personal Information

In the final part of the questionnaire, people were asked to answer questions regarding their age, sex, occupation and monthly net-income of their household. In order to have an easier separation of the two samples from the two study areas, a question was added where the responders chose to which study area they belong, Maisach or Maxvorstadt. Finally, since there was an incentive for filling the survey, an optional question regarding the participants' contact details was included, in order to be possible to inform the winners. More information about the incentive and the procedure followed to contact people are given in Chapter 3.2.3.

3.2.2. Online set-up of the questionnaire

In parallel to the development of the survey, a search for the appropriate platform to set it up online was undertaken. There are a lot of websites that offer hosting for online surveys. In most of them, someone can register for free and create short and limited surveys. However, for more complex questionnaires or for allowance for more participants to take part, usually a fee is required. Considering the restrained budget of this thesis, a free survey tool was needed. Limesurvey© is a free online software tool for creating surveys without limitations. In addition and as mentioned before, Limesurvey© offers the opportunity to parameterize its scripts using JavaScript, an option that was vital for integrating Google Maps© to the survey.

The only requirement that Limesurvey© has, is that an own webserver with PHP© and MySQL© database is needed. A webserver was offered by the "Leibniz-Rechenzentrum (LRZ) der Bayerischen Akademie der Wissenschaften" as a sub-domain of the Technical University of Munich and its Chair of Urban Structure and Transport Planning. After acquiring access to the server, Limesurvey© was installed on it and the questionnaire was available under the website www.umfrage.sv.bgu.tum.de.

3.2.3. Reaching responders to the survey

After setting up the survey online, the next step was to get participants from both study areas to answer the questionnaire. In order to attract people to answer the survey, an incentive was set up. In the end of the survey, two of the responders were selected after a lottery and were offered a price. It was considered necessary that the topic of "sustainable mobility" should be connected directly to the incentive. As a result, the incentive that was chosen was two coupons of 50 € value each, from the national trains of Germany (Deutsche Bahn).

The problem of contacting people was solved by creating a postcard, which informed people about the existence, the goal, the website and the incentive of the survey. 2500 postcards were printed and scattered around randomly in letter boxes of the two study areas. In the municipality of Maisach, the postcards were distributed in the three more dense neighbourhoods, Maisach, Gernlinden and Überacker. In the district of Maxvorstadt, the postcards were distributed randomly in buildings within its core area as well as at the Technical University of Munich and Ludwig-Maximilian University. Figure 3.7 presents the postcard that was created for this purpose, while Figure 3.8 shows the areas that the latter was distributed to.

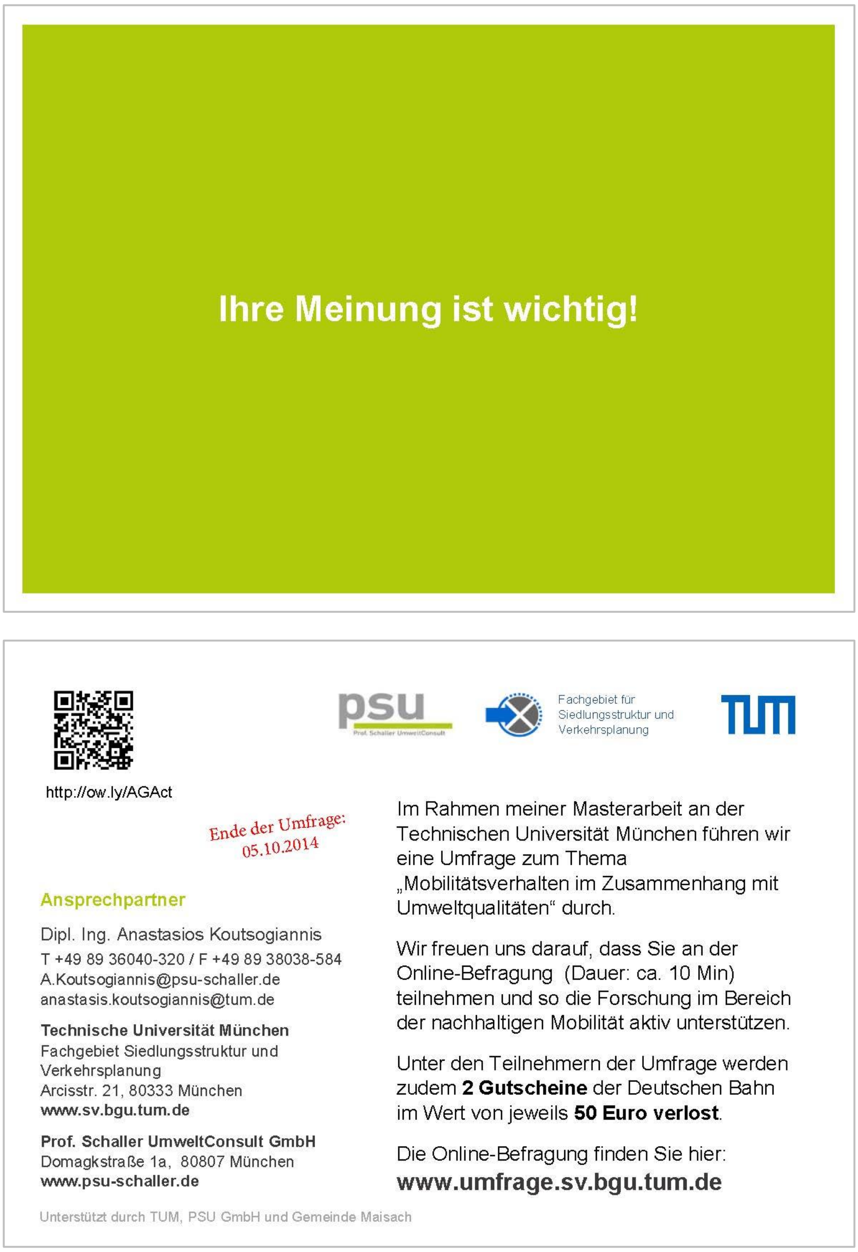


Figure 3.7: Postcard used for inviting people to the survey

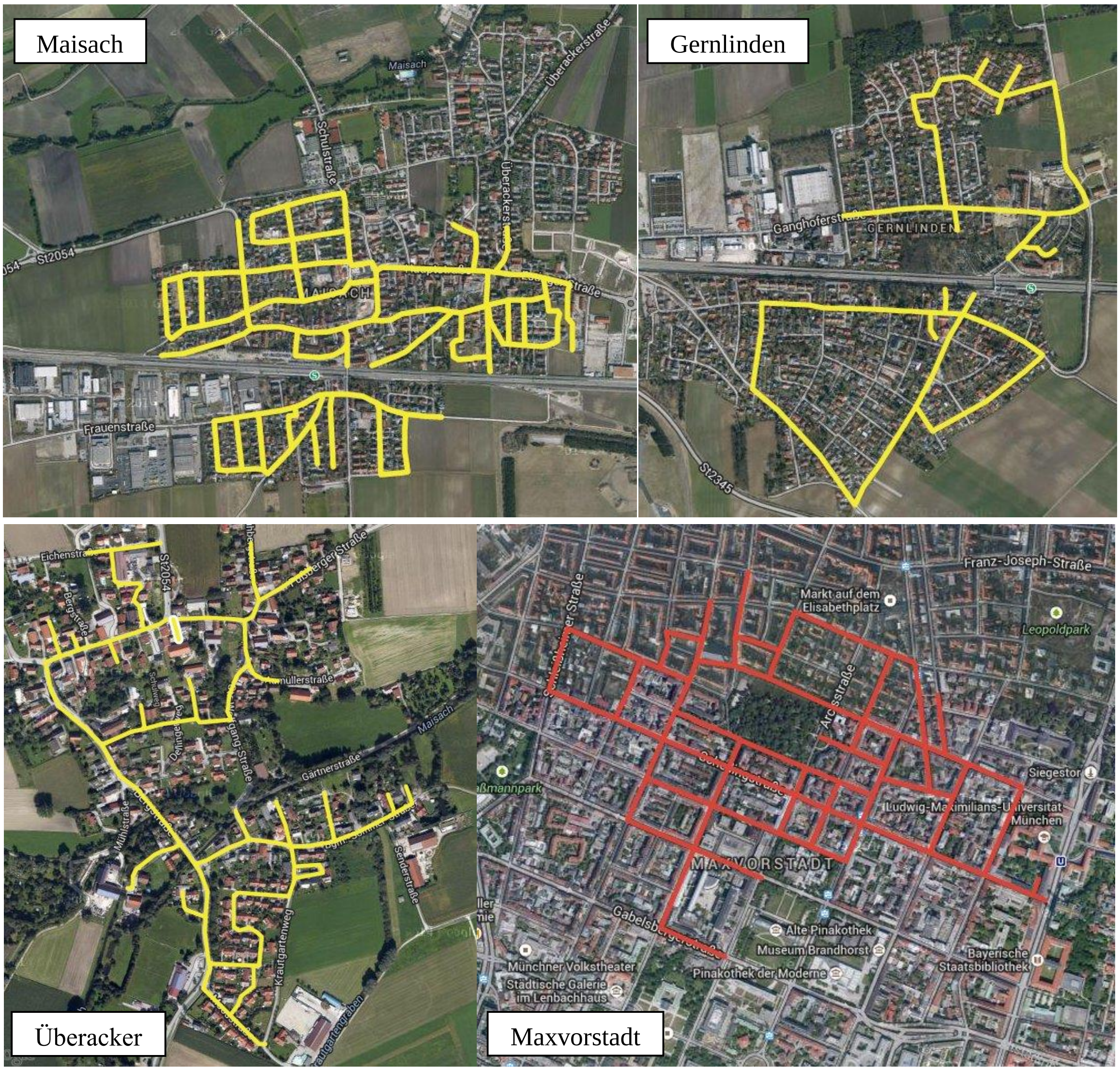


Figure 3.8: Distribution of the postcards in Gemeinde Maisach (yellow) and Maxvorstadt (red)

3.2.4. Processing of the data retrieved from the answers of the survey

The duration of the survey was 5 weeks and lasted from the 5th of September 2014, when the first postcards were distributed, until the 10th of October 2014, when the questionnaire was taken offline. The final analysis of the survey started after the latter had ended. However, during the period of the 5 weeks, there was a preparation of the data received from the participants' answers related to their most frequent trips, since this procedure was time-consuming.

3.2.4.1. Trip data

All the information of the responders' trips, such as transport mode and coordinates of their path, was taken from Google Maps© API as a data object and was saved in a JSON format. JSON (JavaScript Object Notation) is a lightweight data-interchange format which is easy for humans to read and write and easy for machines to parse and generate (ECMA International, 2013). An example of a trip in JSON format is given in Figure 3.9.

{"travelMode":[["TRANSIT"],["WALKING"],["TRANSIT"],["WALKING"]],"startLat":48.151655,"startLng":
11.570871000000011,"endLat":48.138457,"endLng":11.520749000000023,"waypoints":[],"paths":[[[{"k
":48.15166000000001,"B":11.570870000000001},{"k":48.15169,"B":11.57089},{"k":48.15138,"B":11.5
71980000000002},{"k":48.151070000000004,"B":11.57309},{"k":48.15093,"B":11.573580000000002},
{"k":48.150650000000006,"B":11.574560000000002},{"k":48.150310000000005,"B":11.57577},{"k":48
.15019,"B":11.57618},{"k":48.149930000000005,"B":11.57712},{"k":48.14972,"B":11.5778500000000
02},{"k":48.14931000000001,"B":11.579320000000001},{"k":48.149060000000006,"B":11.580190000
000002},{"k":48.14904000000001,"B":11.580240000000002},{"k":48.14902000000001,"B":11.58031},

Figure 3.9: Trip information in JSON format

However it is obvious that the information was not usable in such a format. The final goal was to transform the above JSONs to an ESRI-shapefile, in order to input the trips in a Geographic-Information-System (ArcGIS). There is no direct way to do such a conversion and therefore a multiple transformation took place. At first, a code was written in Matlab that converted the JSONs into GeoJSONs©. GeoJSON© is a geospatial data interchange format based on JavaScript Object Notation (JSON) and encodes a variety of geographic data structures (Butler, et al., 2008). It is basically again a JSON format, but parsed in such a way that can be read from many geo-information platforms. A sample of the Matlab code and the transformed JSON of the previous figure in a GeoJSON© format are presented in Figure 3.10.

```
function [ result ] = Geojson( json, antwort_id )
%Transformation of JSON to Geojson

    field1 = 'type';  value1 = {'Feature'};
    field2 = 'geometry';
    value2_2='LineString';
    field2_2 = 'coordinates';

    Coordinates = [];
    Coordinates(1,1) = json{1,1}.startLng;
    Coordinates(1,2) = json{1,1}.startLat;
    m = 2;
    for i=1:length(json{1,1}.paths)
        for j=1:length(json{1,1}.paths{1,i})
            for l=1:length(json{1,1}.paths{1,i}{1,j})
                for h=1:length(json{1,1}.paths{1,i}{1,j}{1,l})
                    Coordinates(m,1) = json{1,1}.paths{1,i}{1,j}{1,l}.B;
                    Coordinates(m,2) = json{1,1}.paths{1,i}{1,j}{1,l}.k;
                    m = m+1;
                end
            end
        end
    end
    Coordinates(m,1) = json{1,1}.endLng;
    Coordinates(m,2) = json{1,1}.endLat;

    value2_1 = Coordinates;
    field4 = 'properties';
    fieldMode = 'travel_Mode';
    a = [json{1,1}.travelMode{:}];
    valueMode = sprintf('%s %s ',a{:});
    value3 = struct(fieldMode,valueMode);
    field5 = 'type2';
    geometry = struct(field5,value2_2,field2_2,value2_1);
    s = struct(field1,value1,field2,geometry, field4,value3);
```

```
{
    "type": "Feature",
    "geometry": {
        "type": "LineString",
        "coordinates": [
            [11.570871,48.151655],
            [11.57087,48.15166],
            [11.57089,48.15169],
            [11.57198,48.15138],
            [11.57309,48.15107],
            [11.57358,48.15093],
            [11.57456,48.15065],
            [11.57577,48.15031],
            [11.57618,48.15019],
            [11.57712,48.14993],
                    .
                    .
                    .
            [11.52142,48.13796],
            [11.52121,48.1381],
            [11.52109,48.13819],
            [11.52099,48.13827],
            [11.52093,48.13831],
            [11.52085,48.13838],
            [11.52075,48.13846],
            [11.520749,48.138457]
        ]
    },
    "properties": {
        "travel_Mode": "TRANSIT WALKING TRANSIT WALKING "
    }
}
```

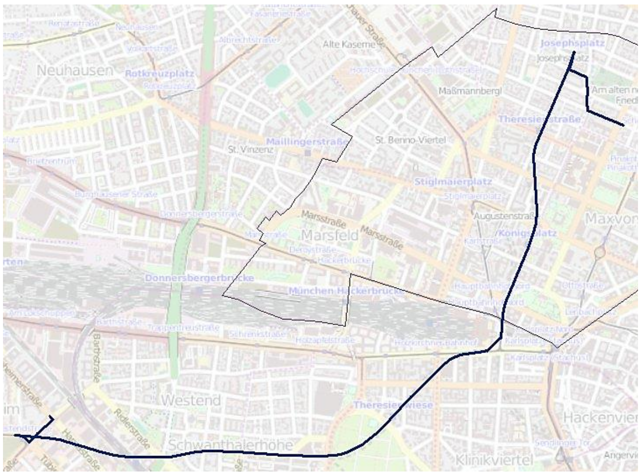
Figure 3.10: Sample of Matlab code for converting JSON to GeoJSON© and trip information example in GeoJSON© format.

After converting the trips into GeoJSON© objects, the DNRGPS Application was used to convert them to ESRI-shapefiles. DNRGPS is an open source software tool, developed by the Department of Natural Resources of Minnesota, which was built to transfer data between Garmin handheld GPS receivers and GIS software (Minnesota Department of Natural Resources, 2014). This software allows you to input geographical information in different formats, such as GPS Exchange Format (.gpx), Google Keyhole Markup Language (.kml) or GeoJSONs© and save them in another format, including ESRI-shapefiles. One drawback of this tool is that it does not allow multiple conversions at the same time and as a result all the

164 trips, which were gathered throughout the survey, had to be input manually in GeoJSONs© one-by-one and to be converted into shapefiles.

After having all the trips in an ESRI-shapefile format, they were inserted and edited in ArcGIS. The DNRGPS tool exported each trip into one continuous route, and therefore the first task was to split the trips at the points of transport mode change and input the respective transport mode as an attribute field to each section. What is more, the id of the trip was inserted each time, in order to be able to correlate the trip with the environmental quality evaluation. Finally, six more attribute fields were created which allowed to add information to each trip about the perceived air quality, noise and availability of green spaces along the trip, as well as the trip purpose, time travelled with each mode and study area that the responder belongs to.

After creating these attribute fields, the respective information were added from the answers of the survey. The environmental quality indicators were asked in the survey in a qualitative way (“very loud”, “quiet”, etc.). However, they were inserted into the attribute fields in a quantitative scale of 1 to 5, with 1 describing the best evaluation of the indicator (“very quiet”) and 5 the worst (“very loud”). That was necessary in order to calculate later the statistical mean values of environmental quality for each section of the street network. An example of a trip with its attribute table is presented in the following figure.



FID	Shape *	type	tident	ident	Air_Qualit	Noise	Green_spac	Min	Gebiet	Zweck
3	Polyline	TRACK	U-Bahn	287	3	4	5	10	Munchen	Ausbildungsplatz
2	Polyline	TRACK	on foot	287	1	3	3	2	Munchen	Ausbildungsplatz
1	Polyline	TRACK	U-Bahn	287	3	4	5	10	Munchen	Ausbildungsplatz
0	Polyline	TRACK	on foot	287	1	2	2	5	Munchen	Ausbildungsplatz

Figure 3.11: Representation of a trip in GIS with its attributes table

The above procedure was followed manually for each trip. During this procedure it was noticed that not all trips were represented in accordance to the information that the users had given in the table, in which they evaluated environmental quality. For instance, there were mismatches of trips done by public transport and given by Google Maps© with the trips that the participants actually had made and evaluated. That was a case for example when someone travels with the metro and then changes to a bus, but Google Maps shows the trip done by a metro line and then change again to another metro line, because it is faster. However, the user had evaluated the environmental quality along the route that he actually takes and not the one that is suggested by Google©.

In order to overcome this problem, the trips that had this error were created from the beginning. Using Google Maps©, each leg of the trip was accurately represented based on the separation of the segments that the responder had given at the table of the questionnaire. Then, using the online platform GPS Visualizer© (Schneider, 2005), which allows you to input the link of a map made with Google Maps© and to export it in several data types, the routes were exported into GPS Exchange Format. Then these files were converted again with the help of DNRGPS to shapefiles and were inputted and edited in ArcGIS, following the procedure described previously.

The above described procedure that was followed in order to create the shapefiles of each trip, is summarized in the following diagram.

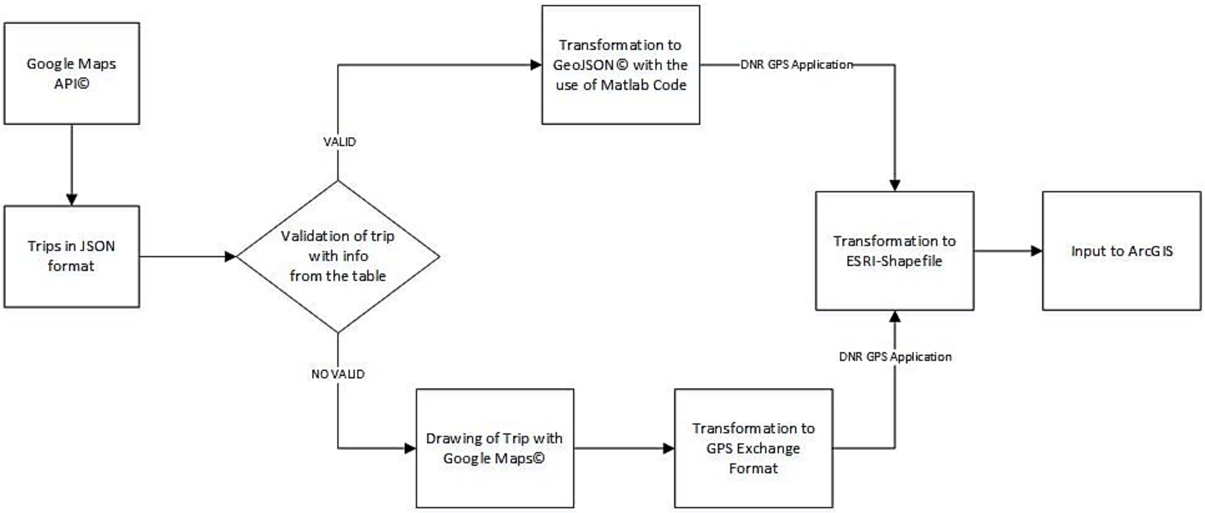


Figure 3.12: Procedure for transforming trip information from Google Maps API© to shapefile

When finally all the trips were inputted correctly in ArcGIS and the respective attribute fields were created, the analysis of the perception of environmental quality was to be done. The next difficulty occurred when all the trips were inputted into the map. The trips were overlapping each other, but they did not have a common id at the segments of overlapping, making it impossible to analyse them.

For that reason, a new shapefile was created with just the geometry of the network of the two study areas. The network shapefile was acquired by the open source data library of Geofabrik (2014). This shapefile contained the whole transport network of Oberbayern and thus it was necessary to clear it up. Firstly, the only parts that were kept from the network, were those that belong to the two study areas and the rest of the network was deleted. In addition, wherever there was a footway or cycleway next to the street, this was represented by a different line. However, the evaluation was made for the street in general and it was not important to differentiate the exact points of the routes within the width of a street. As a result, the remaining network was furthermore cleared, leaving only one central line for each segment. Moreover, smaller paths, like pathways which pass through buildings' backyards, were also deleted from the network.

Figure 3.13: Creation of a base network shapefile

While creating the base network, an id was given to each segment of the street. Then, each trip was split at each segment of the street network that was passing through and for each sub-leg of the trip the respective id was assigned. That resulted into trips separated into many parts, but with a characteristic id at each part, which later was used to calculate the mean average quality for each street section. Having done the above procedure for each trip, the attribute tables looked like the one in Figure 3.14.

FID	Shape *	type	tident	ident	Air_Qualit	Noise	Green_spac	Min	Gebiet	Zweck	Buff_id
0	Polyline	TRAC	on foot	287	1	2	2	5	Mónche	Ausbildungsplatz	361
1	Polyline	TRAC	U-Bahn	287	3	4	5	10	Mónche	Ausbildungsplatz	0
2	Polyline	TRAC	on foot	287	1	3	3	2	Mónche	Ausbildungsplatz	0
3	Polyline	TRAC	U-Bahn	287	3	4	5	10	Mónche	Ausbildungsplatz	0
4	Polyline	TRAC	on foot	287	1	2	2	5	Mónche	Ausbildungsplatz	403
5	Polyline	TRAC	on foot	287	1	2	2	5	Mónche	Ausbildungsplatz	395
6	Polyline	TRAC	on foot	287	1	2	2	5	Mónche	Ausbildungsplatz	383
7	Polyline	TRAC	on foot	287	1	2	2	5	Mónche	Ausbildungsplatz	374
8	Polyline	TRAC	on foot	287	1	2	2	5	Mónche	Ausbildungsplatz	345

Figure 3.14: Trip that has been split at each segment of the street

Finally, the lines of the trips were converted to polygons in order to be able to use the Dissolve toolbox of ArcGIS. The Dissolve toolbox aggregates features based on specified attributes and gives the opportunity to summarize the aggregated fields using a variety of statistics. So, after merging all the trips into one shapefile, the lines were converted to polygons, using the Buffer toolbox and then these polygons were dissolved, with dissolved field the “Buff_id”. It was also selected to calculate the mean values of air quality, noise and green space availability for each segment, as well as to count the amount of evaluations that were available for each segment (Buff_id). After acquiring this information, it was now possible to represent the perceived environmental quality by the responders, using the mean values for the parts of the streets that more than one evaluation existed. Furthermore, although it was given to the participants of the survey the option to not evaluate motorised trips, like trips made by the metro, most of them did. However, the evaluation of the environmental quality along the trips that were made by metro was omitted, since the given level of green spaces was always “no green at all” and the level of air quality and noise described rather the indoor quality of the underground, a factor that this thesis does not examine.

Having now the above evaluation for each segment, it was able to visualize the perceived environmental quality in the two study areas. The values were now converted again to the qualitative scale and the classification that was followed is shown in the following table. The final maps with the perceived environmental quality are presented in Chapter 4, with the rest of the results.

Quantitative Value	Qualitative Value
1 - 1.5	very good
1.5 - 2.5	good
2.5 - 3.5	ok
3.5 - 4.5	bad
4.5 - 5	very bad

Table 3.2: Correlation between quantitative and qualitative values

3.2.4.2. Descriptive Statistics

The rest of the data that was gathered during the survey was communicated with the public through descriptive statistics. Microsoft Excel was used to analyse the answers from the rest of the questions and to create the respective informative graphs, which are presented in Chapter 4 with the remaining results. A more detailed explanation of how the analysis of the rest of the data was undertaken is not given, since it only required basic knowledge of the spreadsheet tool MS Excel.

3.2.5. Summary of the qualitative methodology

This section gave analytical information regarding the core part of this thesis, and namely the survey that was carried out. At first, the steps that were followed in order to develop the online questionnaire were described. Furthermore, the chapter gave an overview of the tools and methods used to process the data that was received from the responders’ answers. Among other information, this qualitative method gathered all the available data needed to examine and visualise the perception of the environmental quality of the responders. In order to compare this perceptions to reality, a quantitative analysis was also carried out and is presented in the following sub-chapter.

3.3. Quantitative Analysis

As already mentioned in the previous chapters, a part of the methodology followed for this thesis was the development of an environmental assessment for the two study areas. This section presents the data that was gathered and used in order to assess the environmental quality in the municipality of Maisach and the district of Maxvorstadt.

3.3.1. Assessment of air quality

The chapter of the literature review gave information about the different air pollutants, their effects on human health and ecosystems as well as the exiting respective thresholds for air pollution. The main pollutants that are monitored across Europe are particulate matter for certain sizes (PM), ozone (O_3), sulphur dioxide (SO_2), nitrogen oxides (NO_x) and carbon monoxide (CO). In Germany there are approximately 400 stations for monitoring air pollution, from which around 60 stations are placed in Bavaria. The measured values for the different pollutants are published daily from the Federal Environment Agency of Germany (UBA) and the Bavarian State Office for the Environment (Bayerisches Landesamt für Umwelt). (UBA, 2014b; LfU, 2014a)

In order to evaluate air quality, measured values for different pollutants were retrieved from monitoring stations near the two study areas. The time interval of the measured air pollution data that was used was from 23.07.2014 until 10.10.2014, when the survey went offline. Initially it was intended to use data for the exact time period that the survey took place. However, it is highly possible that when the participants were asked to think of their most frequent trip and to evaluate environmental quality along it, the perceived air quality that was given, was not necessarily the air quality of the exact day they answered the survey, but rather a general feeling the responders have in mind about the air quality along this trip. For this reason, the time interval that was chosen included the last 3 months before the end of the survey. The required data for this analysis was obtained by the Federal Environment Agency of Germany. (UBA, 2014b)

Regarding Maxvorstadt, the data that was used came from the monitoring station of München/Lothstrasse, since that station is placed within the borders of Maxvorstadt (see Figure 3.15). The pollutants that this station measures are ozone, particulate matters, carbon monoxide, nitrogen dioxide and sulphur dioxide and the measured meteorological data are air pressure, wind speed and direction, air temperature and relative humidity. The type of this station is "background urban station". (LÜB, 2014)

As far as Maisach is concerned, it was more difficult to find accurate data, since none of the existing monitor stations is placed within the borders of the municipality of Maisach. For this reason, the respective authorities of both the municipality of Maisach and the county of Fürstenfeldbruck (FFB), where Maisach belongs to, were asked for data about the air quality in the region. However, none of the asked authorities had any available data and for that reason it was decided to examine air pollution levels in the three closest monitoring stations of Maisach and extrapolate results for the municipality of Maisach.

The chosen monitoring stations were München/Allach, Augsburg/LfU and Andechs/Rothenfeld. The station of München/Allach measures ozone and nitrogen oxide levels and no meteorological data and its type is “background suburban station”. The station of Augsburg/LfU measures particulate matters, ozone, carbon monoxide, nitrogen oxides and sulphur dioxide and the measured meteorological data are air pressure, wind speed and direction, air temperature, relative humidity and global radiation. The type of Augsburg/LfU is “background suburban station”. Finally, the station of Andechs/Rothenfeld measures particulate matters, ozone and nitrogen oxides and the measured meteorological data are the same as the ones of the station of Augsburg/LfU. Its type is “background rural regional station”.

Table 3.3 summarize the above information, whereas Figure 3.15 presents the exact positions of the four monitoring stations in correlation to the two study areas.

Information about Monitoring Stations	**Maxvorstadt**	**Maisasch**		
	München - Lothstrasse	**München - Allach**	**Augsburg - LfU**	**Andechs - Rothenfeld**
Measured Pollutants				
Particulate Matters (PM)	✓		✓	✓
Ozone (O_3)	✓	✓	✓	✓
Carbon Monoxide (CO)	✓		✓	
Nitrogen Oxide (NO_x)	✓	✓	✓	✓
Sulphur Dioxide (SO_2)			✓	
Meteorological Data				
Air pressure	✓		✓	✓
Wind speed and direction	✓		✓	✓
Air temperature	✓		✓	✓
Relative humidity	✓		✓	✓
Global Radiation			✓	✓
Type of Station				
Background station	✓	✓	✓	✓
Traffic station				

Table 3.3: Information about air pollution monitoring stations

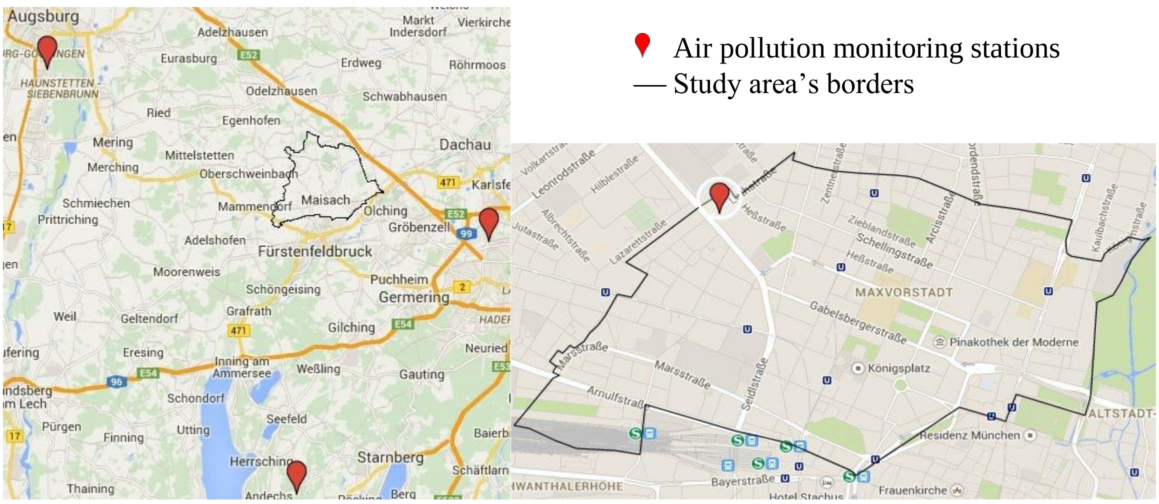


Figure 3.15: Air pollution monitoring stations

The available data that was gathered from the above stations were values of daily average (µg/m³) for PM_{10}, hourly and maximum hourly values (µg/m³) for NO_2, O_3 and SO_2 and 8-hours moving average and maximum 8-hours moving average (mg/m³) for CO. The following figures present an illustration of the concentrations of the air pollutants at the four monitoring stations for the selected time interval. For the pollutants were both mean and maximum values were available, it was chosen to present only the mean values in the figures, where also the respective thresholds are displayed. However, the remaining diagrams, are given in ANNEX 4.

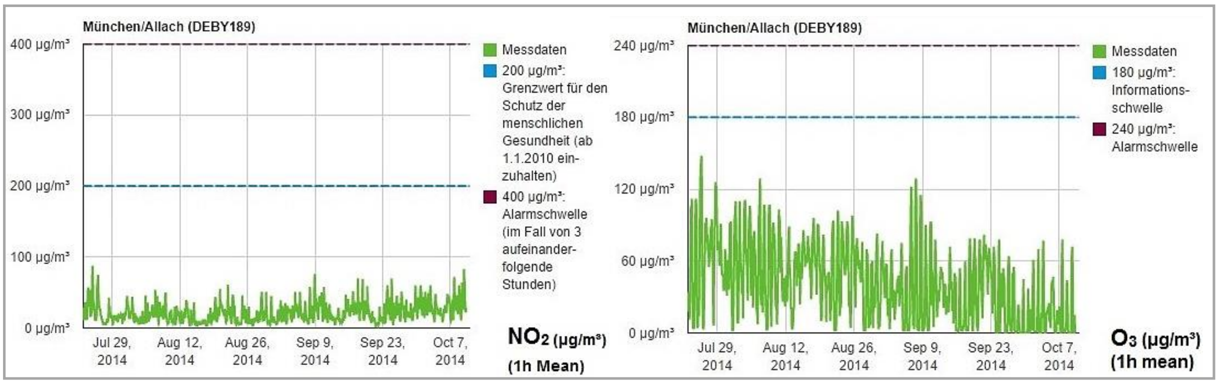


Figure 3.16: Air pollutants' concentrations for the station München – Allach (UBA, 2014b)

Figure 3.17 presents concentrations of PM_{10}, O_3, NO_2 and CO at the monitoring station of München/Lothstraße.

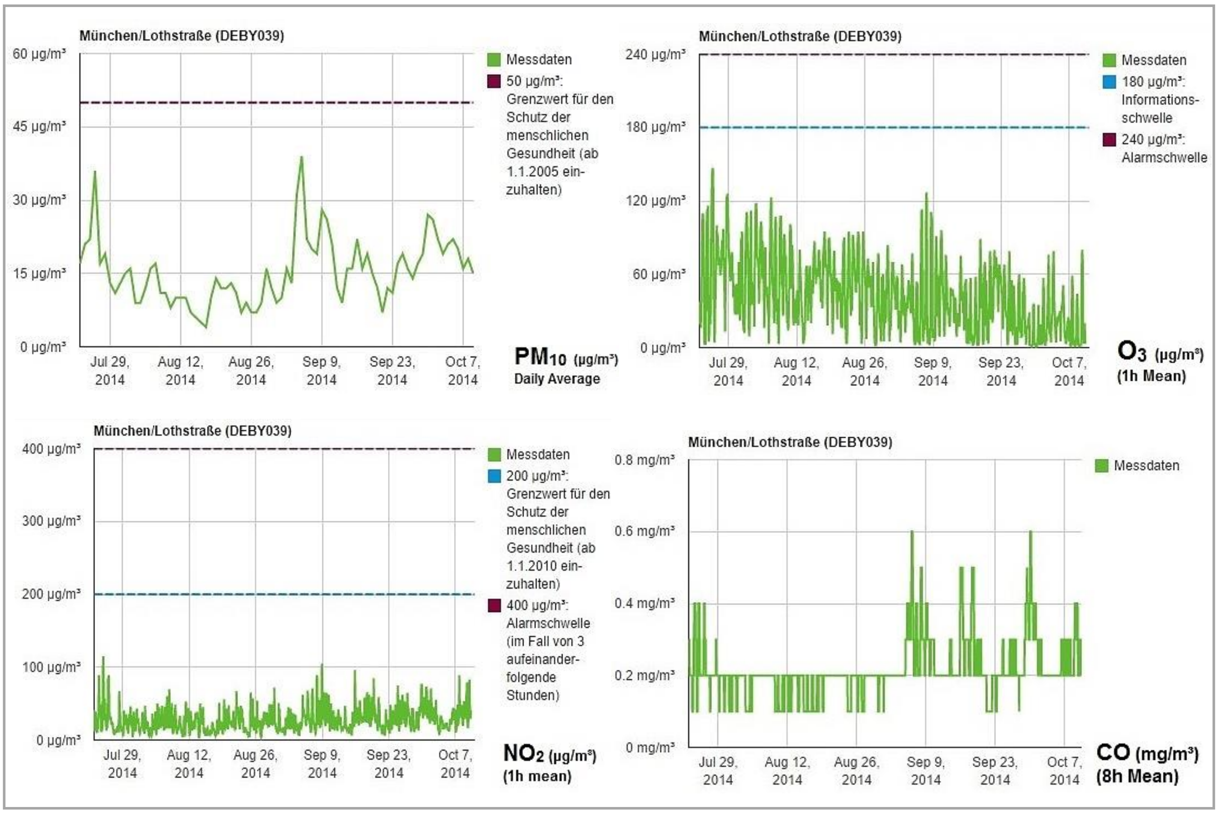


Figure 3.17: Air pollutant's concentrations for the station München – Lothstraße (UBA, 2014b)

Figure 3.18 shows the concentrations of PM_{10}, O_3, NO_2 at the monitoring station of Andechs/Rothenfeld during the time interval of the three last months before the survey.

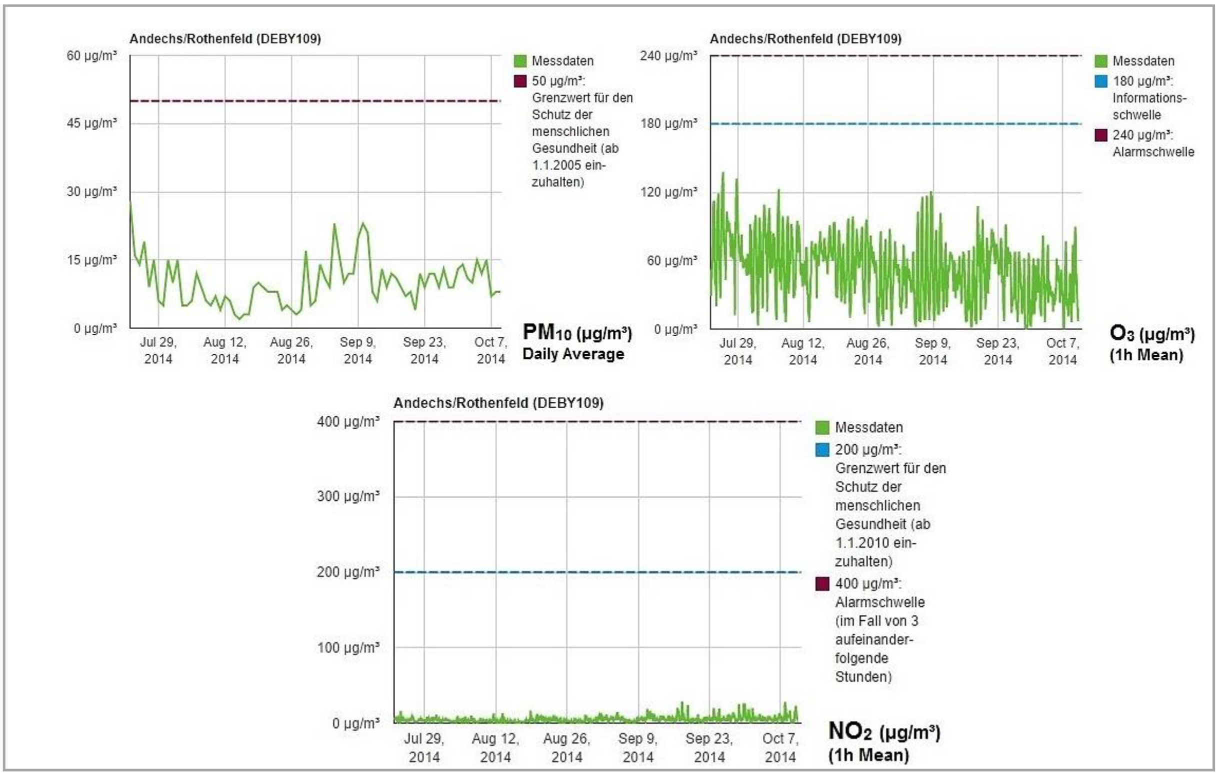


Figure 3.18: Air pollutants' concentrations for the station Andechs – Rothenfeld (UBA, 2014b)

Figure 3.19 shows the concentrations of PM_{10}, O_3, NO_2 and SO_2 and Figure 3.20 the concentration of CO at the monitoring statin of Augsburg/LfU.

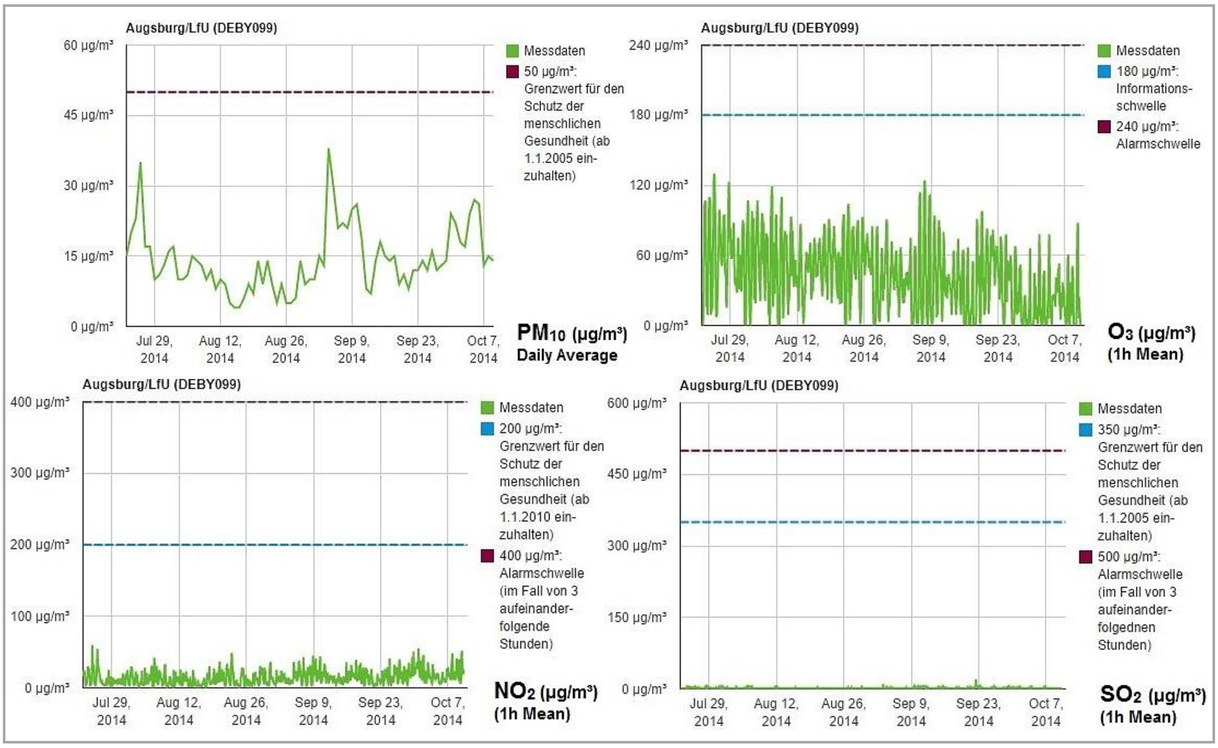


Figure 3.19: Concentrations of PM_{10}, O_3, NO_2 and SO_2 at the station of Augsburg/LfU.

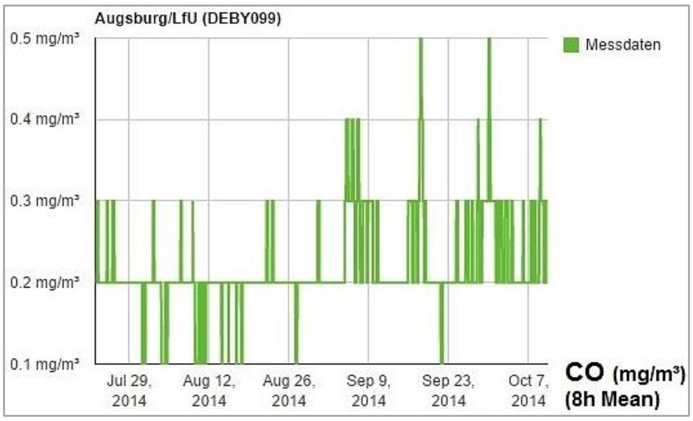


Figure 3.20: Air pollutants' concentrations for the station Augsburg – LfU (UBA, 2014b)

After gathering all the required data, the mean values for all the air pollutants and all the stations were calculated for the time period of the three months. The results are shown in the following tables.

Maxvorstadt			Maisach		
München - Lothstrasse			München - Allach		
Pollutant	Value	Units	Pollutant	Value	Units
PM10 (Daily Average)	15.3544	µg/m³	PM10 (Daily Average)	-	µg/m³
CO (8 St. - Mean)	0.2151	mg/m³	CO (8 St. - Mean)	-	mg/m³
CO (8 St. - Max)	0.2743	mg/m³	CO (8 St. - Max)	-	mg/m³
O3 (1 St. - Mean)	43.1561	µg/m³	O3 (1 St. - Mean)	42.0011	µg/m³
O3 (1 St. - Max)	77.9351	µg/m³	O3 (1 St. - Max)	78.7922	µg/m³
NO2 (1 St. - Mean)	27.3346	µg/m³	NO2 (1 St. - Mean)	21.1543	µg/m³
NO2 (1 St. - Max)	54.3636	µg/m³	NO2 (1 St. - Max)	44.2468	µg/m³
SO2 (1 St. - Mean)	-	µg/m³	SO2 (1 St. - Mean)	-	µg/m³
SO2 (1 St. - Max)	-	µg/m³	SO2 (1 St. - Max)	-	µg/m³

Table 3.4: Mean air pollutants' concentrations for the monitoring stations München/Lothstrasse and München/Allach

Maisach			Maisach		
Augsburg - LfU			Andechs - Rothenfeld		
Pollutant	Value	Units	Pollutant	Value	Units
PM10 (Daily Average)	14.2278	µg/m³	PM10 (Daily Average)	10.0217	µg/m³
CO (8 St. - Mean)	0.218	mg/m³	CO (8 St. - Mean)	-	mg/m³
CO (8 St. - Max)	0.2614	mg/m³	CO (8 St. - Max)	-	mg/m³
O3 (1 St. - Mean)	42.9645	µg/m³	O3 (1 St. - Mean)	52.9193	µg/m³
O3 (1 St. - Max)	79.3117	µg/m³	O3 (1 St. - Max)	84.026	µg/m³
NO2 (1 St. - Mean)	14.0847	µg/m³	NO2 (1 St. - Mean)	4.8519	µg/m³
NO2 (1 St. - Max)	30.9091	µg/m³	NO2 (1 St. - Max)	10.7662	µg/m³
SO2 (1 St. - Mean)	2.2579	µg/m³	SO2 (1 St. - Mean)	-	µg/m³
SO2 (1 St. - Max)	3.1429	µg/m³	SO2 (1 St. - Max)	-	µg/m³

Table 3.5: Mean air pollutants' concentrations for all monitoring stations Augsburg/LfU and Andechs/Rothenfeld

In order to use and compare the above values with the perceived environmental quality of the responders, the Common Air Quality Index (CAQI) was used. The CAQI is an index defined by the CITEAIR project of the European Commission, covering the most relevant air pollutants. CAQI was developed in order to transform all detailed measurements into a single relative figure, in order to present the air quality situation in European cities in a comparable and understandable way. The CAQI is calculated according to the grid, presented in the following table and by linear interpolation between the class borders. (CITEAIR, 2004; CITEAIR II, 2007; GAF AG, 2012)

Common air quality index calculation grid

Index Class	Grid	ROADSIDE INDEX						BACKGROUND INDEX							
		Mandatory pollutant			Auxiliary pollutant			Mandatory pollutant				Auxiliary pollutant			
		NO2	PM10		PM2.5		CO	NO2	PM10		O3	PM2.5		CO	SO2
			1 hour	24 hours	1 hour	24 hours			1 hour	24 hours		1 hour	24 hours		
Very High		>100	>400	>180	>100	>110	>60	>20000	>400	>180	>100	>240	>110	>60	>20000	>500
High	100	400	180	100	110	60	20000	400	180	100	240	110	60	20000	500
	75	200	90	50	55	30	10000	200	90	50	180	55	30	10000	350
Medium	75	200	90	50	55	30	10000	200	90	50	180	55	30	10000	350
	50	100	50	30	30	20	7500	100	50	30	120	30	20	7500	100
Low	50	100	50	30	30	20	7500	100	50	30	120	30	20	7500	100
	25	50	25	15	15	10	5000	50	25	15	60	15	10	5000	50
Very Low	25	50	25	15	15	10	5000	50	25	15	60	15	10	5000	50
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

- NO2, O3, SO2: hourly value / maximum hourly value in µg/m3
- PM10, PM2.5: hourly value / maximum hourly value or adjusted daily average in µg/m3
- CO: 8 hours moving average / maximum 8 hours moving average in µg/m3

Table 3.6: Common air quality index calculation grid (GAF AG, 2012)

According to CAQI's definition, "*The final index is the highest value of the sub-indices for each component. As can be seen there are two CAQI-s: one for traffic monitoring sites and one for city background sites. The traffic index comprises NO_2 and PM_{10}, with CO as an auxiliary component. The background index obligatory comprises NO_2, PM_{10} and O_3, with CO and SO_2 as auxiliary components. In most cities the auxiliary components will rarely determine the index (that is why they are auxiliary) but in a city with industrial pollution or a seaport SO_2 might occasionally play a greater role. Benzene is considered a long-term exposure issue. The number of cities with online monitoring of benzene is limited and it is therefore not included in the short-term indices*". (CITEAIR II, 2007, p. 9)

Following this definition, all the values of the air pollutants for all the monitoring stations were converted to the index classes of pollution. All the selected stations are type "background", so the transformations were made using the respective 'background index' grid of the table. Furthermore, the FINAL CAQI for each station was determined by the pollutant with the highest concentration. The results are presented in Table 3.7.

Maxvorstadt				Maisach			
Lothstrasse				München - Allach			
Pollutant	**Value**	**Units**	**CAQI**	**Pollutant**	**Value**	**Units**	**CAQI**
PM10 (Daily Average)	15.3544	$\mu g/m^3$	Low	PM10 (Daily Average)	-	$\mu g/m^3$	
CO (8 St. - Mean)	0.2151	mg/m^3	Very Low	CO (8 St. - Mean)	-	mg/m^3	
CO (8 St. - Max)	0.2743	mg/m^3	Very Low	CO (8 St. - Max)	-	mg/m^3	
O3 (1 St. - Mean)	43.1561	$\mu g/m^3$	Very Low	O3 (1 St. - Mean)	42.0011	$\mu g/m^3$	Very Low
O3 (1 St. - Max)	77.9351	$\mu g/m^3$	Low	O3 (1 St. - Max)	78.7922	$\mu g/m^3$	Low
NO2 (1 St. - Mean)	27.3346	$\mu g/m^3$	Very Low	NO2 (1 St. - Mean)	21.1543	$\mu g/m^3$	Very Low
NO2 (1 St. - Max)	54.3636	$\mu g/m^3$	Low	NO2 (1 St. - Max)	44.2468	$\mu g/m^3$	Very Low
SO2 (1 St. - Mean)	-	$\mu g/m^3$		SO2 (1 St. - Mean)	-	$\mu g/m^3$	
SO2 (1 St. - Max)	-	$\mu g/m^3$		SO2 (1 St. - Max)	-	$\mu g/m^3$	
FINAL CAQI	**Low**			**FINAL CAQI**	**Low**		

Maisach							
Augsburg - LfU				Andechs - Rothenfeld			
Pollutant	**Value**	**Units**	**CAQI**	**Pollutant**	**Value**	**Units**	**CAQI**
PM10 (Daily Average)	14.2278	$\mu g/m^3$	Very Low	PM10 (Daily Average)	10.0217	$\mu g/m^3$	Very Low
CO (8 St. - Mean)	0.218	mg/m^3	Very Low	CO (8 St. - Mean)	-	mg/m^3	
CO (8 St. - Max)	0.2614	mg/m^3	Very Low	CO (8 St. - Max)	-	mg/m^3	
O3 (1 St. - Mean)	42.9645	$\mu g/m^3$	Very Low	O3 (1 St. - Mean)	52.9193	$\mu g/m^3$	Very Low
O3 (1 St. - Max)	79.3117	$\mu g/m^3$	Low	O3 (1 St. - Max)	84.026	$\mu g/m^3$	Low
NO2 (1 St. - Mean)	14.0847	$\mu g/m^3$	Very Low	NO2 (1 St. - Mean)	4.8519	$\mu g/m^3$	Very Low
NO2 (1 St. - Max)	30.9091	$\mu g/m^3$	Very Low	NO2 (1 St. - Max)	10.7662	$\mu g/m^3$	Very Low
SO2 (1 St. - Mean)	2.2579	$\mu g/m^3$	Very Low	SO2 (1 St. - Mean)	-	$\mu g/m^3$	
SO2 (1 St. - Max)	3.1429	$\mu g/m^3$	Very Low	SO2 (1 St. - Max)	-	$\mu g/m^3$	
FINAL CAQI	**Low**			**FINAL CAQI**	**Low**		

Table 3.7: Transformation of air pollutants' values to Common air quality indices

The analysis shown in the tables above showed that the air pollution in all monitoring stations was low, which means that in the scale 1-5, with 1: 'very good' and 5: 'very bad', which was used during the survey, this can be translated as 'good' air quality for both study areas. The comparison with the perceived air quality along the paths of the responders of the survey is done in Chapter 4, where all the results are presented together.

3.3.2. Assessment of noise levels

In order to examine how the responders perceive noise levels along their paths, it was necessary to find data about the noise levels for the two study areas and then convert these values to the 1 to 5 scale that was used from the responders, while evaluating noise pollution. The required data was acquired by the Bavarian State Office for the Environment (LfU), the City of Munich and the Federal Railway Authority (Eisenbahn-Bundesamt). LfU has created a noise exposure cadastre for the whole area of Bavaria, in which the noise levels of the main streets, as well as noise exposure for different agglomerations are presented. In addition, the City of Munich offers a detailed noise map for the whole area of the city, including noise from street traffic, rail traffic (Tram and U-Bahn) and commercial-source noise. Finally, the Federal Railway Authority has created maps for noise levels along the rail tracks of Germany. This map was used for evaluating the noise from the rail tracks that pass through Maisach (stations: Gernlinden – Maisach - Malching).

All of the above data sources, present noise levels with the two same indicators, L_{DEN} and L_{night}. These are long-term averaged sound levels, determined over all the respective periods of a year and are defined in terms of A-weighted decibels (dB (A)). L_{DEN} (day-evening-night noise indicator) consists the noise indicator for overall annoyance, while L_{night} (night-time noise indicator) is the noise indicator for sleep disturbance and is the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the night periods of a year. (European Commission, 2002)

For the assessment done for this thesis, the indicator that was used was the L_{DEN}, which includes the average sound levels of a year, determined over all the day, evenings and night periods. Figure 3.21 and Figure 3.22 are presenting the street and rail noise levels at the study area of Maxvorstadt, as published by the City of Munich.

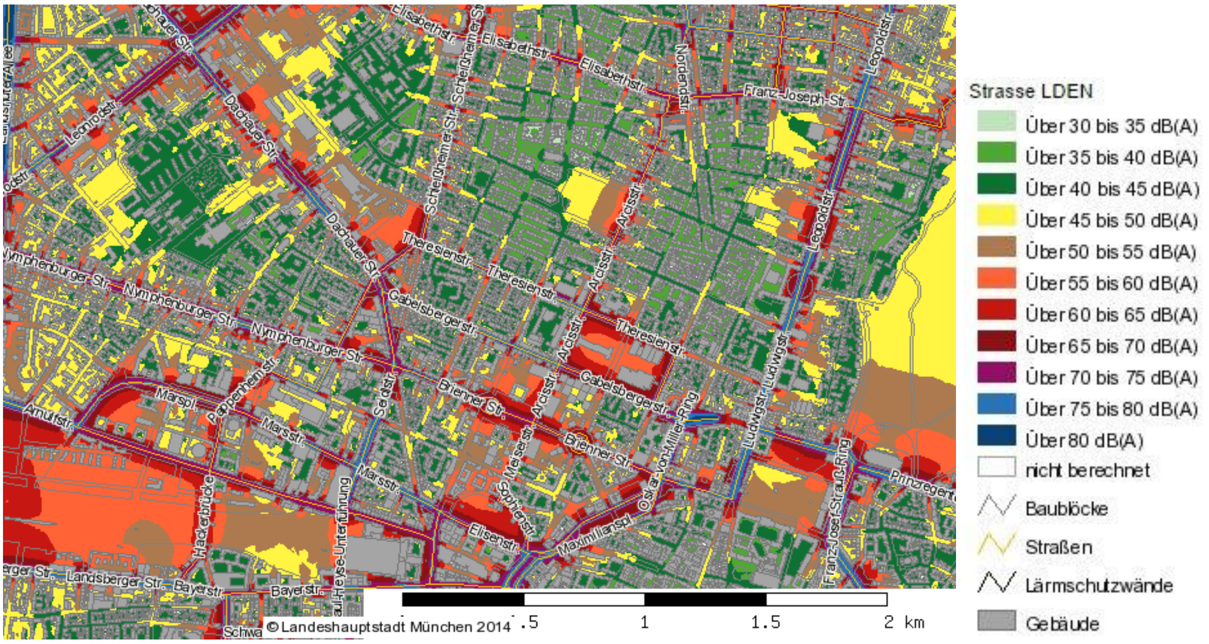


Figure 3.21: Street noise map in Maxvorstadt – year 2007 (Landeshauptstadt München, 2014)

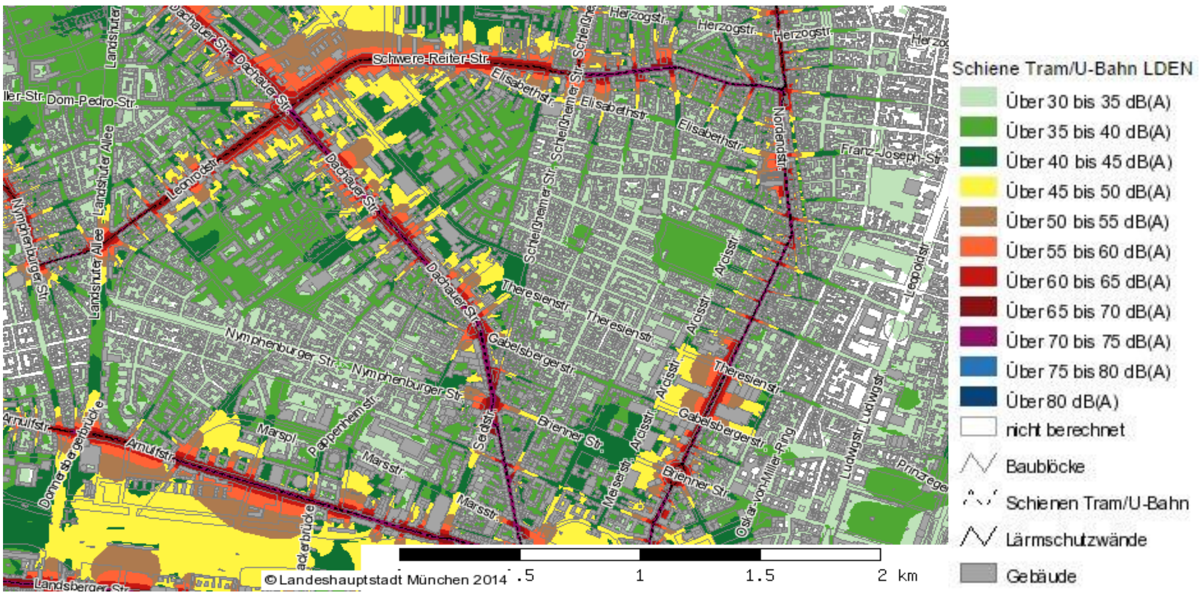


Figure 3.22: Rail noise map in Maxvorstadt – year 2007 (Landeshauptstadt München, 2014)

In order to evaluate the noise levels for each street of Maxvorstadt, the above two maps were combined. The final values were acquired based on the higher noise level of each street. For instance, for the case of Barrerstraße where both street and rail noise levels were available, the final value was assigned based on the map of rail noise, since the noise level was higher due to rail. Figure 3.23 and Figure 3.24 present the respective available data that was found for the municipality of Maisach.

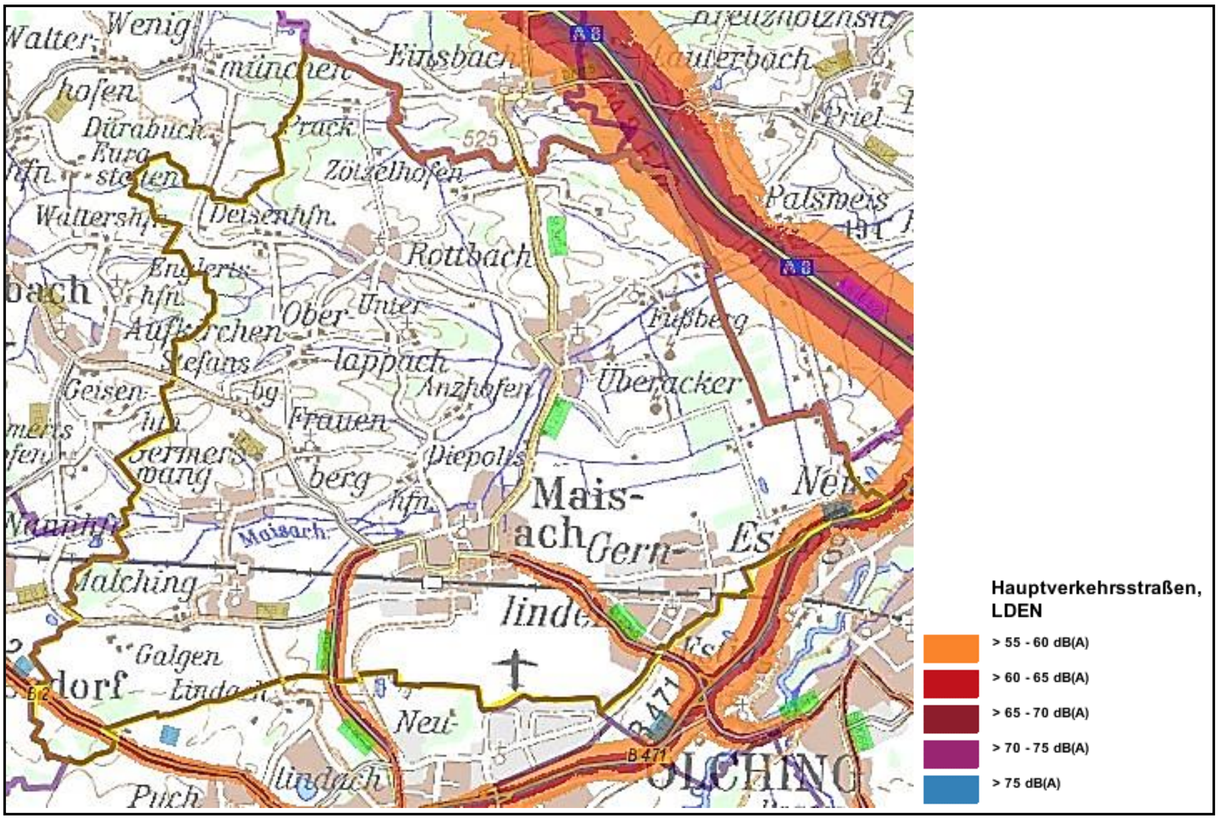


Figure 3.23: Noise levels at the main streets of Gemeinde Maisach (LfU, 2014b)

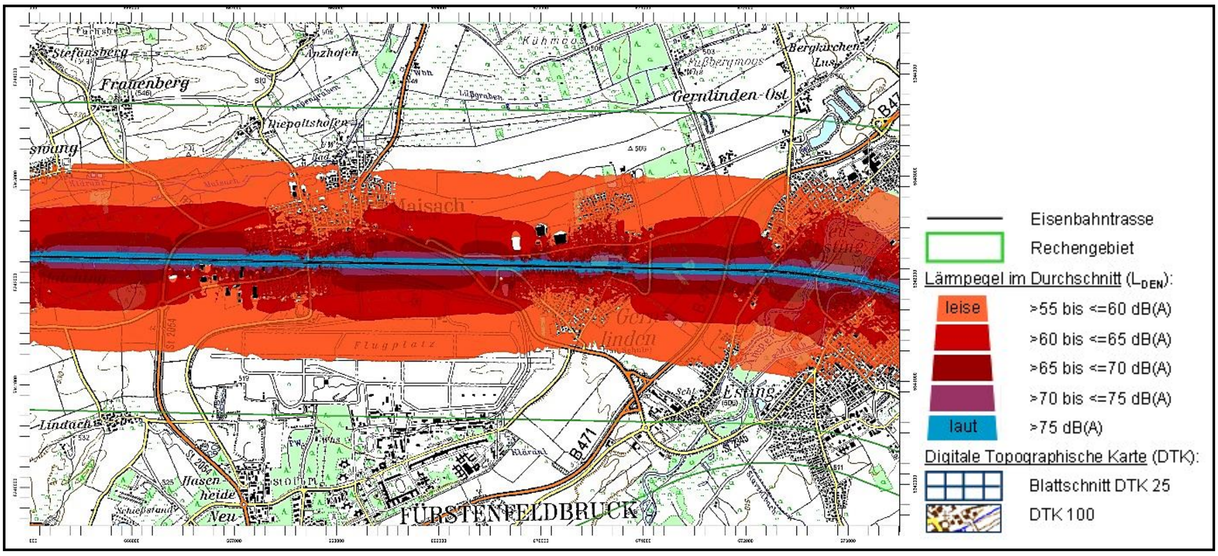


Figure 3.24: Noise levels along the rail tracks in Gemeinde Maisach (Eisenbahn-Bundesamt, 2008)

As seen in Figure 3.23, the only available official data for street noise levels of the municipality of Maisach, were for some parts of the St2054 and St2345, located at the south part of the municipality. For that reason, noise levels on the rest of the main streets were calculated using traffic volume data, acquired by the Bavarian Street Information System (BAYSIS) of the Bavarian Ministry of the Interior, Building and Transport.

Within the borders of Maisach there are five measuring points, which are presented together with the traffic volumes in the following figures.

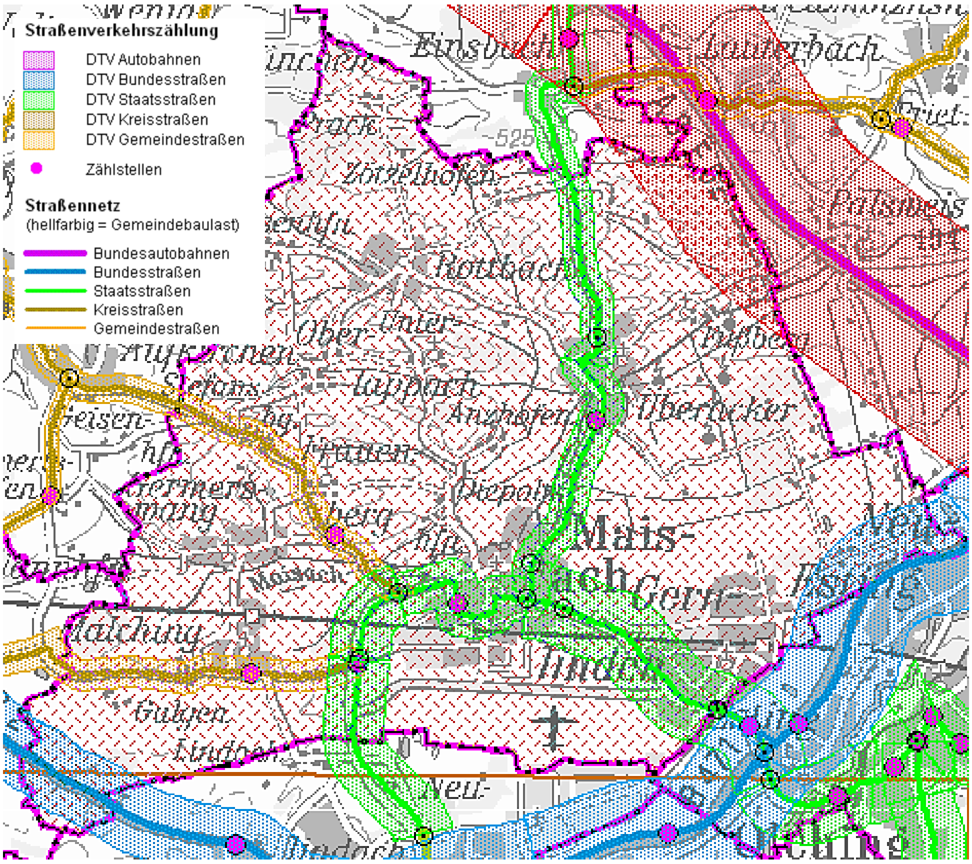


Figure 3.25: Traffic volume measuring stations in Maisach (BAYSIS, 2014)

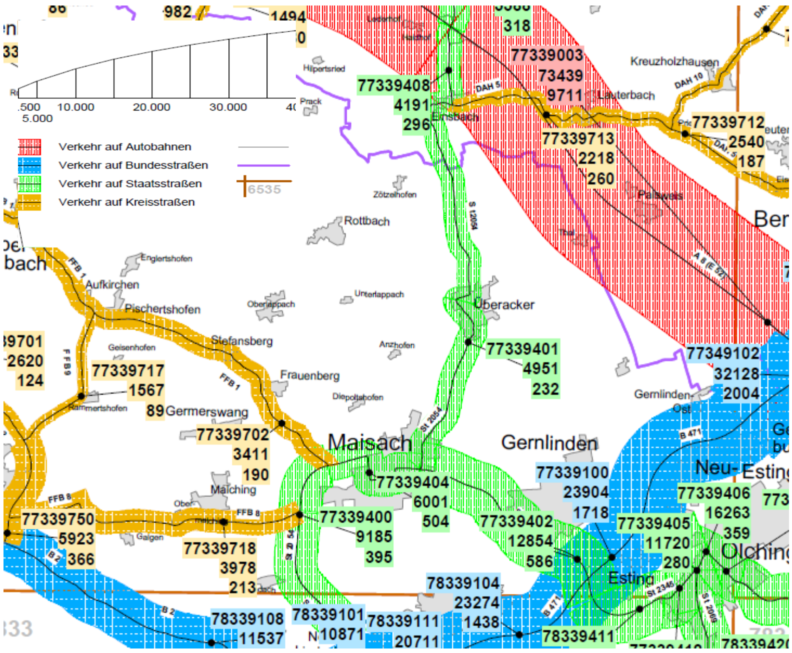


Figure 3.26: Traffic volumes in Gemeinde Maisach (BAYSIS, 2014)

As far as noise calculation is concerned, the RLS-90 (official guideline for street noise protection) was used. According to this guideline, noise is calculated based on the equivalent continuous sound pressure level, which is calculated from traffic volumes in correlation to the percentage of heavy goods vehicles. Then, this sound level is adjusted by applying some correction factors, according to the characteristics of the road. The formula used for calculating the noise level is presented in Equation 3.1 and is applicable for both day and night noise levels (Bundesministerium der Justiz und für Verbraucherschutz, 1990):

$$L_r = L_m + D_v + D_{StrO} + D_{Stg} + D_{S\perp} + D_{BM} + D_B + K, \text{ where:}$$

Equation 3.1: Sound pressure level calculation from traffic data

- L_m is the equivalent continuous sound pressure level in dB(A) and is calculated based on traffic volume data from the following diagram:

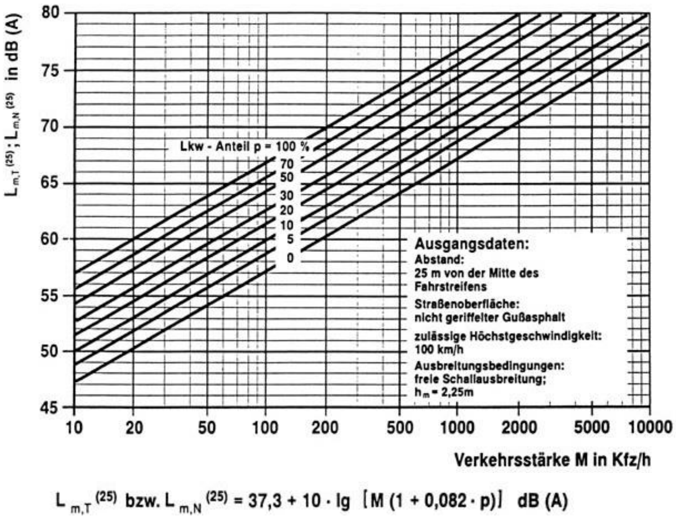


Figure 3.27: Dependency of the average sound level on traffic volume and truck percentage (Bundesministerium der Justiz und für Verbraucherschutz, 1990)

- D_v is the level corrections required for different speed limits depending on the percentage of trucks

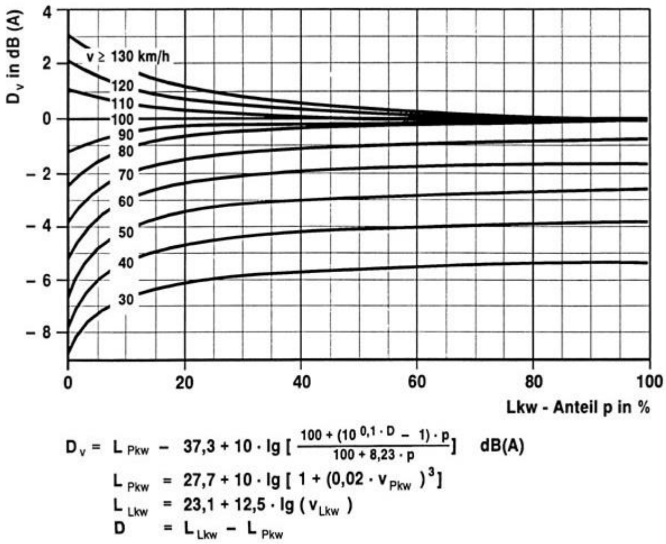


Figure 3.28: Sound pressure level correction for different speeds (Bundesministerium der Justiz und für Verbraucherschutz, 1990)

- D_{StrO} is correction of noise level according to different road pavements

Tabelle B: Korrektur D_{StrO} in dB(A) für unterschiedliche Straßenoberflächen bei zulässigen Höchstgeschwindigkeiten ≥ 50 km/h

	Straßenoberfläche	D_{StrO}*) in dB(A)
	1	2
1	nicht geriffelte Gußasphalte, Asphaltbetone oder Splittmastixasphalte	0
2	Beton oder geriffelte Gußasphalte	2
3	Pflaster mit ebener Oberfläche	3
4	Pflaster	6

*) Für lärmmindernde Straßenoberflächen, bei denen aufgrund neuer bautechnischer Entwicklungen eine dauerhafte Lärmminderung nachgewiesen ist, können auch andere Korrekturwerte D_{StrO} berücksichtigt werden, z. B. für offenporige Asphalte bei zulässigen Höchstgeschwindigkeiten > 60 km/h minus 3 dB(A).

Table 3.8: Correction of sound pressure level, according to different road pavements (Bundesministerium der Justiz und für Verbraucherschutz, 1990)

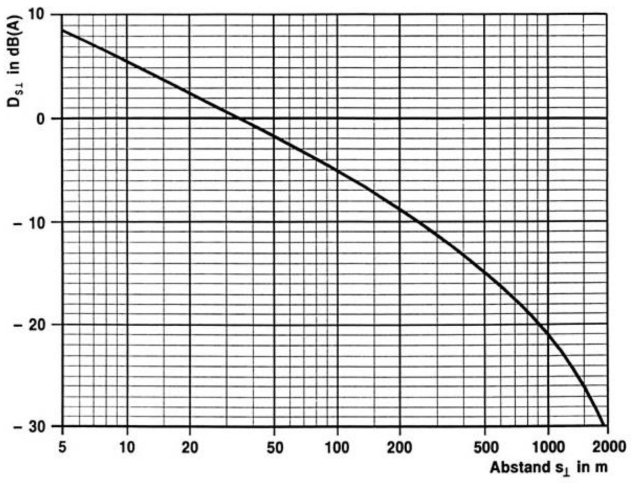
- D_{Stg} is the correction factor for the slope of the road

Tabelle C: Korrektur D^{Stg} in dB(A) für Steigungen und Gefälle

	Steigung/Gefälle in %	D_{Stg} in dB(A)
	1	2
1	≤ 5	0
2	6	0,6
3	7	1,2
4	8	1,8
5	9	2,4
6	10	3,0
7	für jedes zusätzliche Prozent	0,6
Zwischenwerte sind linear zu interpolieren		

Table 3.9: Correction of sound pressure level, according to different road slopes (Bundesministerium der Justiz und für Verbraucherschutz, 1990)

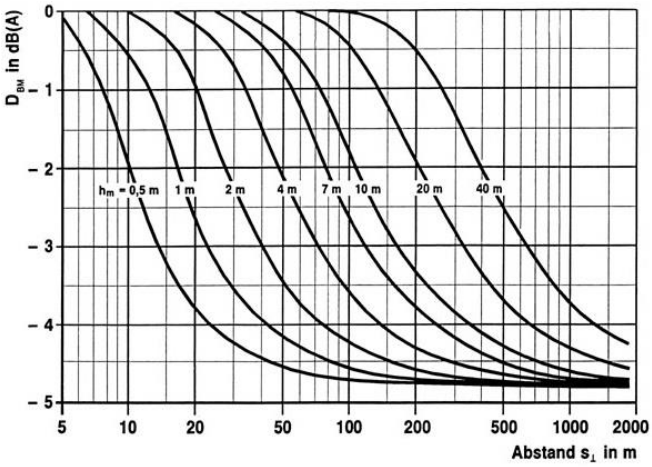
- $D_{S\perp}$ is the noise level correction based on the different distances between the sound source (0.5m above the centre of the observed lane) and the place of relevant immission, without soil and meteorology attenuation. The decisive immission depends on the circumstances of each case; for buildings the relevant immission point is taken as the ceiling height of the first floor (0.2 m above the upper window edge) of the protected space; in outdoor living areas the point of immission is 2 m above the centre of the outdoor living area.



$$D_{S\perp} = 15{,}8 - 10 \cdot \lg(s_\perp) - 0{,}0142 \cdot (s_\perp)^{0{,}9} \quad dB(A)$$

Figure 3.29: Dependency of the noise level (sound level variations) on the distance between place of immission and sound source (Bundesministerium der Justiz und für Verbraucherschutz, 1990)

- D_{BM} is the noise level correction, caused by soil and meteorology attenuation in correlation to the average mean height h_m. The average height h_m is the average distance between the ground and the connecting line between the emission and immission points. In flat terrains h_m is the arithmetic average of the heights of the emission location and immission above the ground.



$$D_{BM} = - \ 4{,}8 \cdot \exp \left[- \left(\frac{h_m}{s_\perp} \cdot \left(8{,}5 + \frac{100}{s_\perp} \right) \right)^{1{,}3} \right] \ \text{dB(A)}$$

Figure 3.30: Sound level pressure correction, caused by soil and meteorological attenuation (Bundesministerium der Justiz und für Verbraucherschutz, 1990)

- D_B is the sound pressure level correction due to topographic conditions and structural objects and reflections. For this correction factor, the existence of noise barriers and walls plays the biggest role.

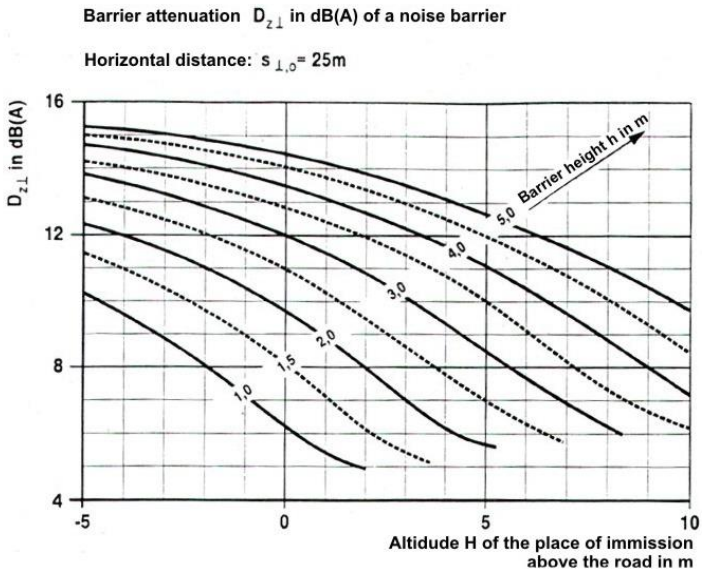


Figure 3.31: Shielding effect of walls and barriers on sound pressure levels (Ministerium für Verkehr und Infrastruktur Baden-Württemberg, 2014)

- K is the correction factor for junctions with traffic lights. Up to 3 dB(A) are added at junctions and crossings with traffic lights due to the additional noises from starting and braking - other than suggested by the above-mentioned estimation according to DIN 18005 (Ministerium für Verkehr und Infrastruktur Baden-Württemberg, 2014).

Tabelle D: Zuschlag K in db(A) für erhöhte Störwirkung von lichtzeichengeregelten Kreuzungen und Einmündungen

	Abstand des Immissionsortes vom nächsten Schnittpunkt der Achsen von sich kreuzenden oder zusammentreffenden Fahrstreifen	K in dB(A)
	1	2
1	bis 40 m	3
2	über 40 bis 70 m	2
3	über 70 bis 100 m	1

Figure 3.32: Addition of sound pressure level in dB(A), caused by junctions with traffic lights (Bundesministerium der Justiz und für Verbraucherschutz, 1990)

Following the above guideline, the noise levels on the main streets of the municipality of Maisach were calculated using the following values:

- The equivalent continuous sound pressure level (L_m) was calculated from the traffic volumes that were acquired from BAYSIS.
- The D_v correction factor was calculated based on the maximum speed limits. For the state roads (Staatstraßen) the speed limit was taken equal to 80 km/h and for the county roads (Kreisstrassen) equal to 60 km/h. Moreover, for the parts of the state roads that pass through residential areas, the speed limit was taken as 50 km/h.
- The road pavement was considered as no fluted mastic asphalt
- The slope of the streets was taken as smaller than 5%.
- The point of immission was taken 2 m above the ground, as the guideline suggests for outdoor areas and the distance between the points of sound source and the immission point was taken equal to 6,5 m.
- The parts of the streets that were examined in this noise estimation analysis, have no noise barriers or traffic-light-guided junctions along them. As a result, the respective sound pressure level correction factors were taken equal to 0 dB(A).
- Finally, the correction factor due to soil and meteorology attenuation was considered equal to zero, since no respective data was available.

The noise level estimation was made for three time periods; day (06-18 h), evening (18-22h) and nights (22-06 h) and is presented in the following tables.

Days												
TKZSTNR	Strasse	Maßgebende Verkehrsstärke M in Kfz	Maßgebender SV-Anteil p	L_m	D_v	D_{StrO}	D_{Stg}	$D_{S\perp}$	D_{BM}	D_B	K	L_{day} dB(A)
77339401	St 2054	315	5.1	63.8	-4.8	0	0	7.5	0	0	0	66.5
77339404	St 2054	382	8.9	65.5	-4.2	0	0	7.5	0	0	0	68.8
77339702	K FFB 1	217	6.1	62.4	-3.5	0	0	7.5	0	0	0	66.4
77339718	K FFB 8	253	5.8	63	-3.4	0	0	7.5	0	0	0	67.1
77339400	St 2054	584	4.7	66.4	-1.7	0	0	7.5	0	0	0	72.2
77339402	St 2345	818	5	67.9	-1.6	0	0	7.5	0	0	0	73.8

Evenings												
TKZSTNR	Strasse	Maßgebende Verkehrsstärke M in Kfz	Maßgebender SV-Anteil p	L_m	D_v	D_{StrO}	D_{Stg}	$D_{S\perp}$	D_{BM}	D_B	K	$L_{evening}$ dB(A)
77339401	St 2054	204	2.3	61.2	-5.5	0	0	7.5	0	0	0	63.2
77339404	St 2054	247	4.5	62.6	-4.8	0	0	7.5	0	0	0	65.3
77339702	K FFB 1	141	2.8	59.7	-4	0	0	7.5	0	0	0	63.2
77339718	K FFB 8	164	2.7	60.3	-4	0	0	7.5	0	0	0	63.8
77339400	St 2054	378	2.2	63.8	-2	0	0	7.5	0	0	0	69.3
77339402	St 2345	530	2.3	65.3	-2	0	0	7.5	0	0	0	70.8

Table 3.10: Estimated noise levels for day and evening periods in the main streets of Maisach

Nights												
TKZSTNR	Strasse	Maßgebende Verkehrsstärke M in Kfz	Maßgebender SV-Anteil p	L_m	D_v	D_{StrO}	D_{Stg}	$D_{S\perp}$	D_{BM}	D_B	K	L_{night} dB(A)
77339401	St 2054	45	5.8	55.5	-4.4	0	0	7.5	0	0	0	58.6
77339404	St 2054	54	12.3	57.7	-4	0	0	7.5	0	0	0	61.2
77339702	K FFB 1	31	6.9	54.1	-3.2	0	0	7.5	0	0	0	58.4
77339718	K FFB 8	36	6.6	54.7	-3.3	0	0	7.5	0	0	0	58.9
77339400	St 2054	83	5.3	58	-1.6	0	0	7.5	0	0	0	63.9
77339402	St 2345	116	5.6	59.6	-1.5	0	0	7.5	0	0	0	65.6

Table 3.11: Estimated noise levels for night periods in the main streets of Maisach

The indicators used by the official noise maps included noise levels for the whole period of a day ($L_{day\text{-}evening\text{-}night}$). In order to have the same base, when combining the data from the official maps, with the noise estimation done by this thesis, it was necessary to convert the above calculations to a one indicator for the whole period of a day (L_{den}). According to the "END" Directive of the European Commission (2002), the day-evening-night level is defined by the following equation:

$$L_{den} = 10\lg\frac{1}{24}\left(12*10^{\frac{L_{day}}{10}} + 4*10^{\frac{L_{evening}+5}{10}} + 8*10^{\frac{L_{night}+10}{10}}\right)$$

Equation 3.2: Definition of day-evening-night sound pressure level (European Commission, 2002)

The final noise levels, determined over the whole period of a day, are given in Table 3.12. The two last segments are the segments that are also presented in the official noise cadastre of the Bavarian State Office for the Environment. However, they were included in the calculations, in order to proof-check, whether the results of the calculations were correct. More specifically, for the St2054 and measuring station 77339400 the noise level was calculated 73,22 dB(A) and the official noise cadastre shows a noise level between 70 - 75dB(A), while for the St2345 and measuring station 77339402, the noise level was calculated 74,83 dB(A) and the noise cadastre shows a noise level between 70 - 75 dB(A). As a result, it is safe to say that the calculations are correct.

Measuring Station	Street	L_{den} db(A)
77339401	St 2054	67.60
77339404	St 2054	69.99
77339702	K FFB 1	67.47
77339718	K FFB 8	68.07
77339400	St 2054	73.22
77339402	St 2345	74.83

Table 3.12: Day-evening-night noise levels for the different segments of the roads in Maisach

In order to be able to compare the noise levels with the perception of noise given by the responders of the survey, it was necessary to transform the values in dB (A) into the 1 - 5 scale that was used as an indicator in the questionnaire. The threshold for noise levels in a residential area during the day is 59 dB (A) (Bundesministerium der Justiz und für Verbraucherschutz, 1990). Using the above information, as well as Figure 3.33 and the classification that has already been made by the official noise cadastre maps, the conversion from dB (A) values to the 1 – 5 scale was made and is presented in Table 3.13.

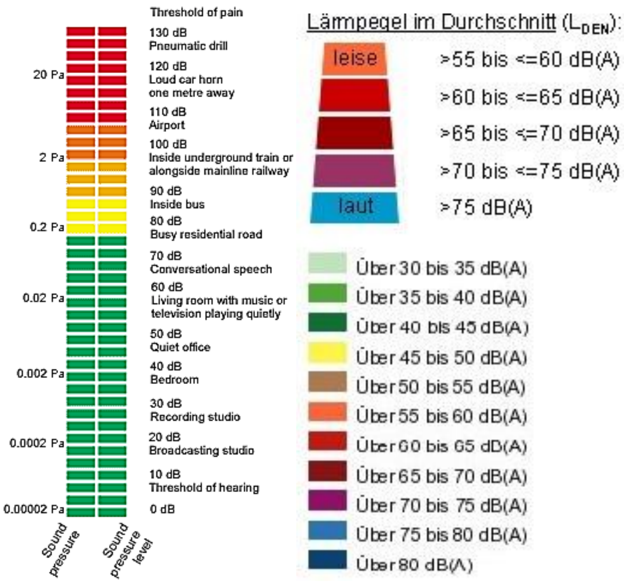


Figure 3.33: Classification of noise levels
(LfU, 2014b; Landeshauptstadt München, 2014; U.S. Department of Labor, 2014)

Noise Levels	Questionnaire Indicators
<60 dB(A)	very quiet
60 - 65 dB(A)	quiet
65 - 70 dB (A)	ok
70 - 75 dB(A)	loud
>75 dB(A)	very loud

Table 3.13: Correlation between noise levels in dB(A) and indicator's scale used in the survey

The information acquired from the data that is presented above, was used to create noise maps of the two study areas, with the help of a Geographic-Information-System (ArcGIS). The maps are shown in the Chapter 4, where the comparison between the actual and the perceived environmental quality is presented.

3.3.3. Assessment of available green spaces

Regarding the availability of green spaces in the two study areas, there was again the need to acquire data from the official authorities. However, there was no available data that could be useful for this analysis. The only data that was found was a quantitative representation of green spaces that are generally accessible by the public (see Figure 3.34) and a black & white representation of green spaces (see Figure 3.35), both for the city of Munich. However, these two maps were not enough for the comparison needed to be done to the perception of the responders, because they only represent the public open green spaces. However, when people were asked to evaluate green space availability, they considered their whole perception of green spaces, even if this includes just some trees along their route or private gardens that are visible from the street. This aspect is not included in the following maps and therefore another approach was needed.

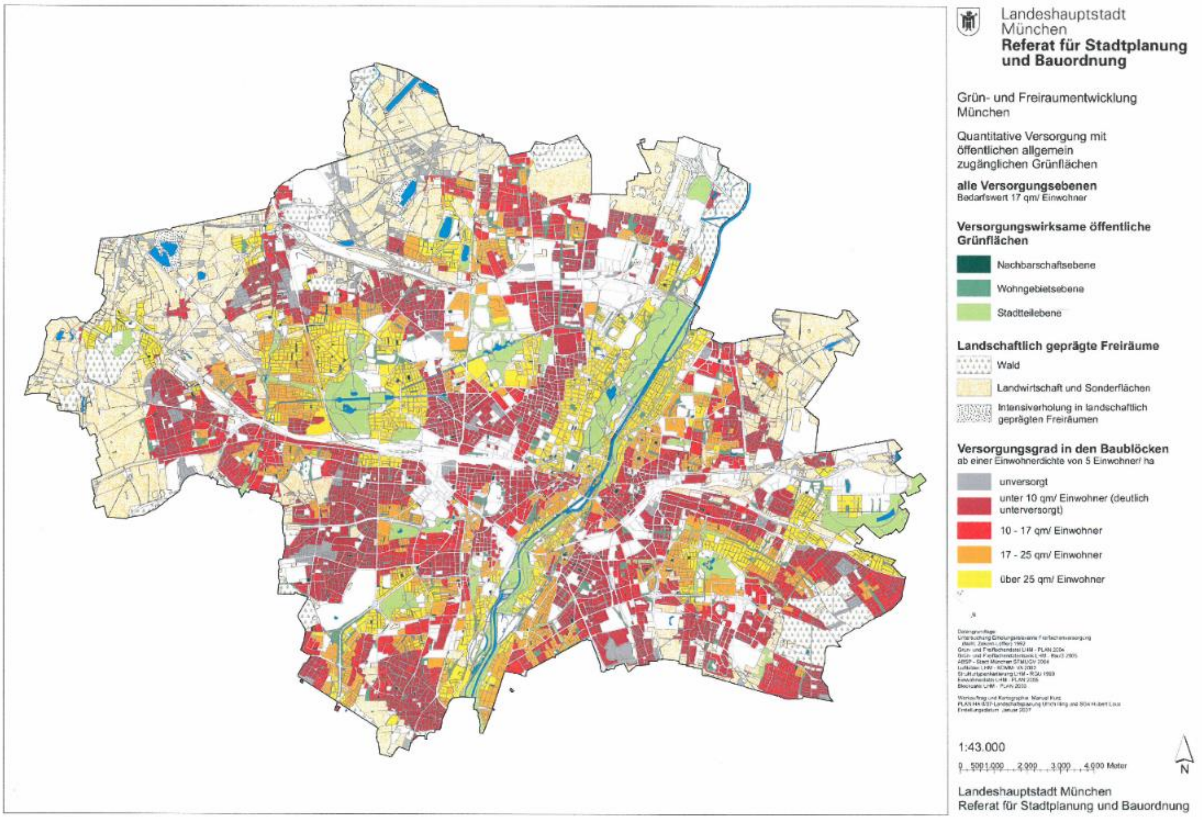


Figure 3.34: Quantitative representation of publicly accessible green spaces in Munich (Landeshauptstadt München, 2007)

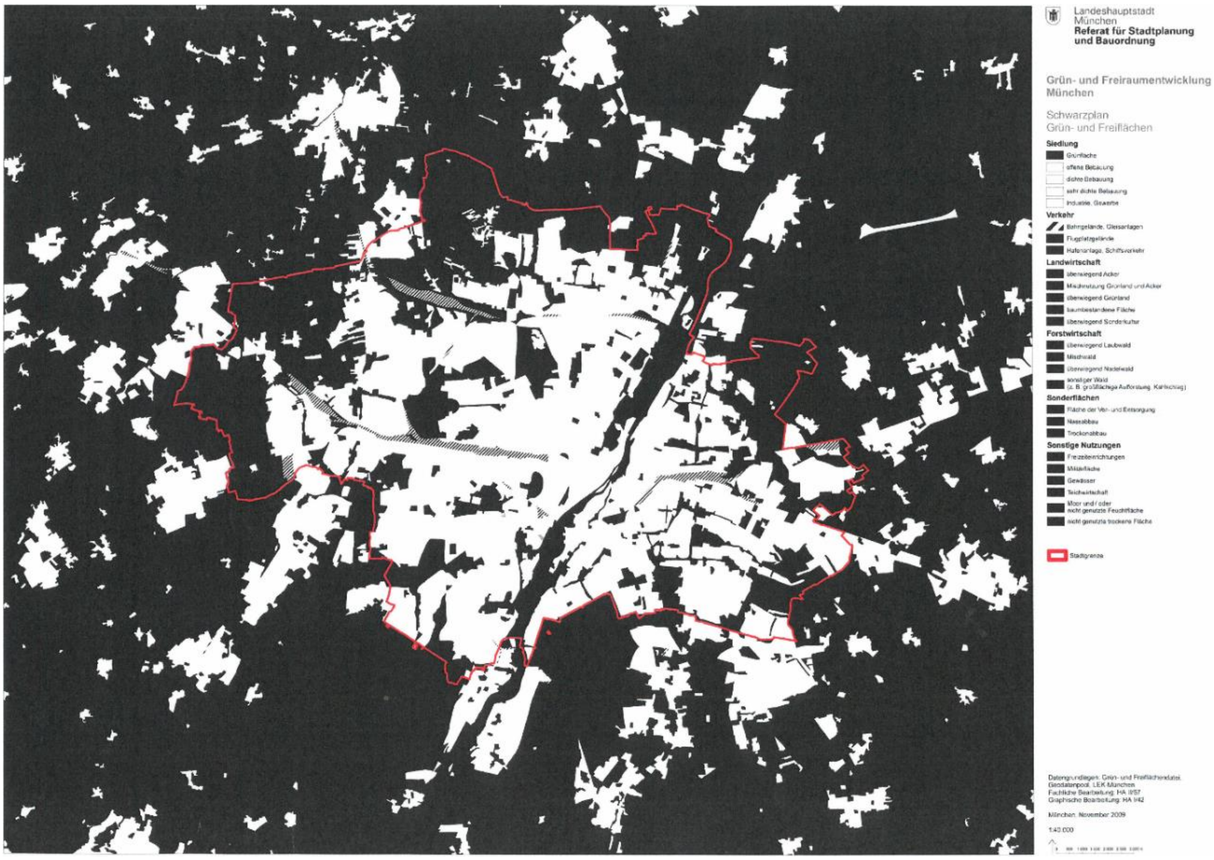


Figure 3.35: Black & white representation of green spaces in Munich (Landeshauptstadt München, 2009)

In order to overcome this problem, satellite images were used to identify the amount of green spaces visible and available along the paths of the two study areas. In addition to the satellite images and in order to have a more accurate evaluation, street view images were also used for the green space assessment. For the study area of Maxvorstadt, these photos were acquired from the Street View service of Google Maps©. Since such images were not available for the municipality of Maisach, a visit to the site was necessary in order to take own pictures.

Using the above data, a classification of the street network of the two areas was made, based on the indicators that were used during the survey. More specifically, an evaluation in a scale of 1 - 5, with 1 responding to “very green” and 5 “no green at all”, was made for each available photo and was mapped with the help of GIS. It is important to mention that an evaluation of green spaces within this analysis could not be made based on quantitative indicators. However, the assessment done by the author can be considered rather objective, since the focus was given only on the aspect of green elements along the paths. On the contrary, a participant’s perception of green spaces is affected additionally by other factors, such as traffic volumes, weather, season or other aspects of environmental quality. Moreover, in order to have a more objective assessment, the evaluation was done with the help of one of the two supervisors, as a landscape architecture.

The following images present some examples of the photos that were used, together with the value that was assigned to them. The final evaluation of the two study areas is presented in the next chapter, together with the perceived evaluation from the responders.

Figure 3.36: Example of classification of a street section in Maxvorstadt as 'very green' (Google Maps, 2014)

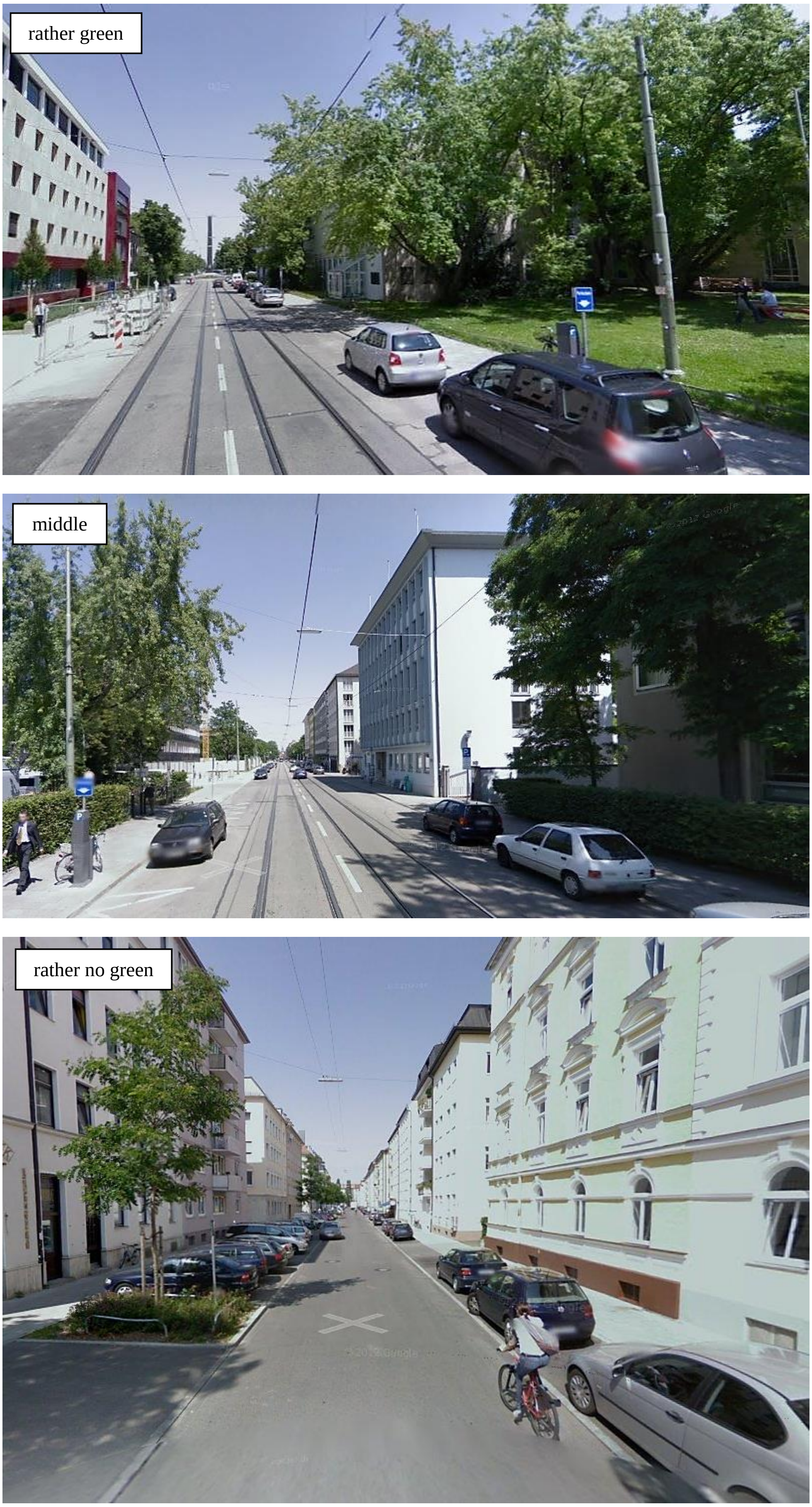


Figure 3.37: Photos used for evaluating availability of green spaces in Maxvorstadt (Google Maps, 2014)

Figure 3.38: Example of classification of a street section in Maxvorstadt as 'no green at all' (Google Maps, 2014)

The above figures presented examples of all the available green spaces' categories in the study area of Maxvorstadt. For the municipality of Maisach, the only available categories were 'very green', 'rather green' and 'middle' and therefore only examples of these levels are presented in the following images.

Regarding the availability of green spaces along the rail tracks of the suburban railway (S-Bahn), the value that was assigned was 'middle'. The reason for this assignment, was that, although there are parts where the path's landscape is very green, there are also parts that a passenger of the S-Bahn can only see the noise barriers, which are placed along the tracks and therefore there is no green space visible. As a consequence, the value 'middle' was assigned in order to cover this specialty.

Figure 3.39: Example of classification of a street section in Maxvorstadt as 'very green'

Figure 3.40: Photos used for evaluating availability of green spaces in Maisach

3.3.4. Summary of Quantitative Analysis

In order to examine how the responders perceive environmental quality along their routes, it was necessary to carry out an environmental assessment of the two study areas. Data about air quality, noise levels and availability of green spaces in Maxvorstadt and Maisach where gathered, analysed and then converted to the same indicators that were used during the survey. Having the data above, the actual environmental quality was visualized and mapped with the use of GIS. The results are presented in Chapter 4 and are compared to the evaluation of environmental quality that the responders made.

3.4. Method for comparing results between the quantitative and qualitative analysis

After conducting both the qualitative and the quantitative analysis, which were described in this chapter, a method was needed in order to efficiently compare the result between the two analyses. The comparison was done between each street section (Buff_id) of the street network for both study areas and it allowed the author to identify the frequency of coincidence between the evaluations of perceived and actual environmental quality.

More specifically, for each street section the difference between the quantitative values of perceived and actual quality was calculated (see Table 3.14). Then, this difference was used to classify the evaluation of the section, according to Table 3.15. Because the amount of comparisons done was too large to present them all here, the following table presents only an example of the comparison between noise evaluations for some street sections of the study area of Maxvorstadt. The rest of the tables with the analytic comparisons of each street segment can be found in ANNEX 6. Furthermore, a map with the ids of the segments for each study area can be found in ANNEX 5.

Maxvorstadt				
Buff_id	COUNT	NOISE (perc)	NOISE (actual)	Diff
220	1	4	4	0
221	2	4	4	0
222	4	2.5	4	1.5
223	2	3	2	-1
224	1	4	3	-1
226	1	4	3	-1
227	2	4	4	0
233	4	2.5	3	0.5
239	1	5	4	-1
240	1	5	5	0
242	1	3	3	0
244	5	3.6	2	-1.6
245	1	3	1	-2
246	5	3.333333	3	-0.333333
248	1	3	1	-2
250	4	4.666667	5	0.333333
252	2	4	5	1
255	1	5	4	-1
257	3	3.5	5	1.5

Table 3.14: Comparison between perceived and actual values of environmental quality

-4 Levels	-4 ≤ Diff < 3.5
-3 Levels	-3.5 ≤ Diff < 2.5
-2 Levels	-2.5 ≤ Diff < 1.5
1 Level worse	-1.5 ≤ Diff < 0.5
Same Evaluation	-0.5 ≤ Diff ≤ 0.5
1 Level better	0.5 < Diff ≤ 1.5
+2 Levels	1.5 < Diff ≤ 2.5
+3 Levels	2.5 < Diff ≤ 3.5
+4 Levels	3.5 < Diff ≤ 4

Table 3.15: Comparison between perceived and actual values of environmental quality

3.5. Summary of the methodology

This chapter presented the methodology that was followed in order to answer the objective of this thesis. At first, the chapter defines the extent to which the investigation within this thesis is done. After presenting the parameters of mobility behaviour and environmental quality to which the focus was given, information about the two chosen study areas are presented. Then, the reasons for choosing to conduct a qualitative and a quantitative analysis are outlined.

As far as the qualitative analysis is concerned, the chapter gave an extensive description of all the processes that were followed. The fundamental part of designing the survey was presented and all the aspects that were taken into account were explained. What is more, this chapter gave a detailed description of the procedure used in order to process the answers from the responders, in order to firstly present the work that was done, but also to offer an informative guideline for researchers that want to follow the same methodology in the future.

Regarding the quantitative analysis, it was not able to find available data from the official authorities, as it was initially intended. As a result, it was necessary to gather or estimate data about the environmental quality of the two study areas. After processing these data, the different environmental factors were visualized with the help of GIS and the maps are presented in the following chapter.

Finally, in order to examine the amount of coincident evaluations between the responder's perception and the assessment done by the author, a method to compare the evaluations was developed. Figure 3.41 gives a summary of the methodology, in order to offer a clearer view of the procedures that were followed.

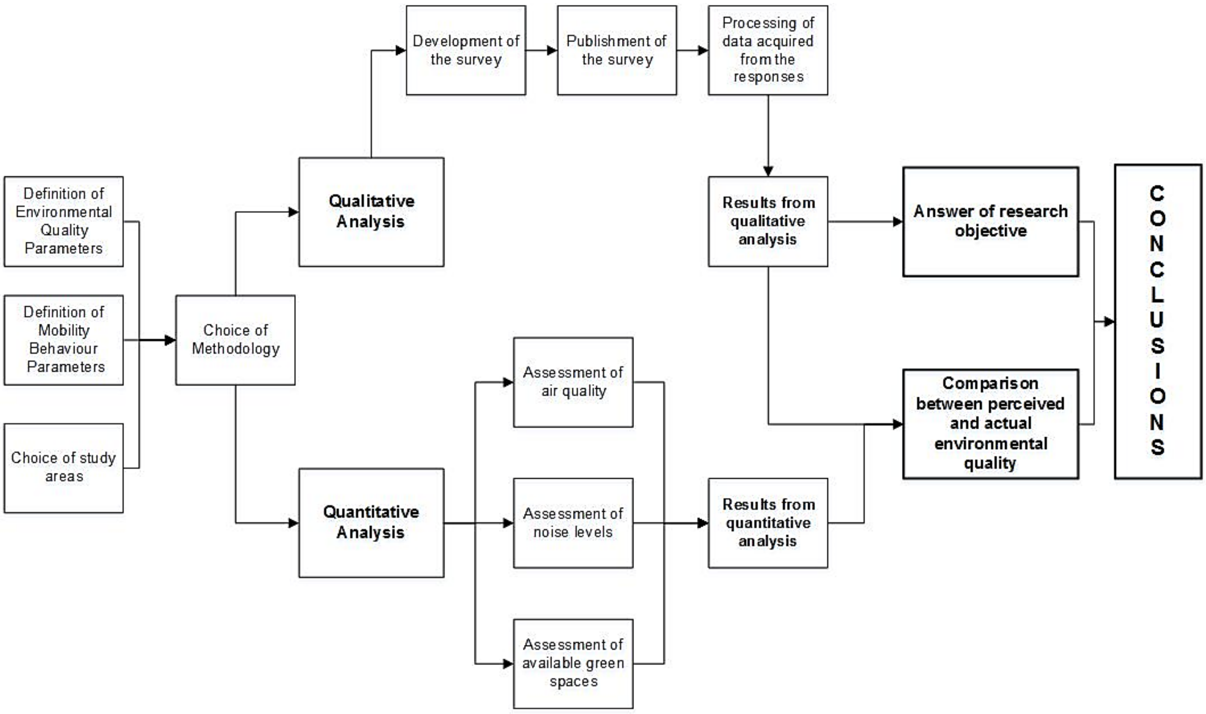


Figure 3.41: Overview of the methodology

4. Results and Discussion

This chapter presents the results from the answers of the survey and compares the perception of the environmental quality given by the responders to the actual levels of quality, as calculated from the assessment done in Chapter 3.3.

The total number of people who visited the website and answered, fully or partially, the survey accounted to 205. However, there were 38 cases that answered only the first part of the survey, which contained questions related to the information about their transport mode, and then quitted the survey. The majority of these cases abandoned the questionnaire when they visited its second page and namely the part concerning their most frequent trip.

This can be explained by two possibilities. Either they were overwhelmed by the fact that they had to input a relative big amount of data, combining the Google Maps© platform and filling up the table with their evaluation along the trip, a fact that played a restraining factor for continuing the rest of the survey, or they considered that the required information that was asked was too private to give. Although it was mentioned both in the beginning of the survey, as well as during the question, that the answers were considered private and would only be used in aggregated datasets, it is highly possible that these responders considered inappropriate to give personal information, including the addresses of their residence or working place and decided to abandon the survey. In any case, it is a fact that should be taken into account, when designing comparable surveys in the future.

The above mentioned 38 cases were not included in the analysis of the results that is presented in this chapter, leaving a remaining sample of 167 responses, 73 of which belong to the study area of the municipality of Maisach and 94 to the study area of Maxvorstadt. Six responders did not belong to any of the two study areas. However, their working place did. For instance, there were two cases of residents of the municipality of Mammendorf, whose working place is in Maisach and therefore the trip they gave had as destination the municipality of Maisach. Thus, these answers were integrated to the sample of the municipality of Maisach. The rest four similar cases were treated respectively.

In general, the response rate in both study areas was rather low, considering that around 1000 postcards were distributed in each area. The 73 answers from the study area of Maisach lead to a response rate of 7.3%, while the response rate of the study area of Maxvorstadt accounts to 9.4%. Considering both study areas, the response rate was 8.35%.

The chapter begins by giving an overview of the sociodemographic data of the responders, gathered during the survey. Then the general information, regarding the availability of transport mode of the responders is presented. Furthermore, an overview of the trips of the participants is given, together with some statistical information about the chosen transport mode, the travel distances and the travel times of their trips. What is more, the evaluation of the environmental quality along these trips is compared to the actual environmental quality, in order to examine how the participants perceive the latter. Finally the extent to which different factors of environmental quality influence mobility behaviour is presented. All the above results are presented separately for three cases; the sample of the municipality of Maisach, the sample of Maxvorstadt and the whole sample who answered the survey, including both of the two sub-samples.

4.1. Sociodemographic data of the sample

The survey included questions related to different sociodemographic aspects, such as age, sex, occupation and monthly income of the participants. These questions were asked in order to better understand the background of the responders and to identify differences between the two samples.

4.1.1. Sex

Figure 4.1 shows that in both study areas the responses were equally given by men and women.

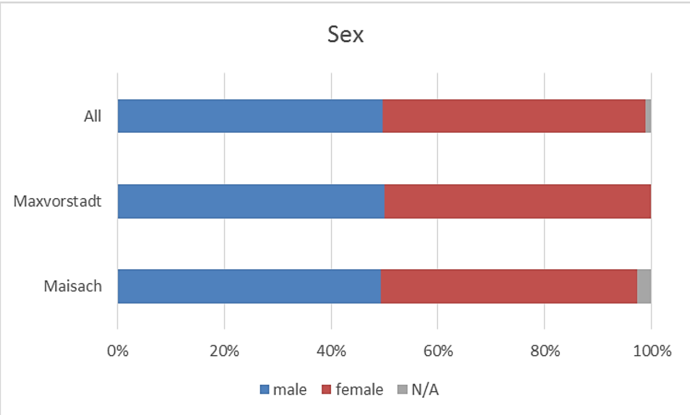


Figure 4.1: Sex of the samples

4.1.2. Age

As far as the age of the responders is concerned, there is a high dominance of people between the age of 18 and 29 years old for the study area of Maxvorstadt, while in the municipality of Maisach the vast majority of the participants belonged to ages between 30 and 64 years.

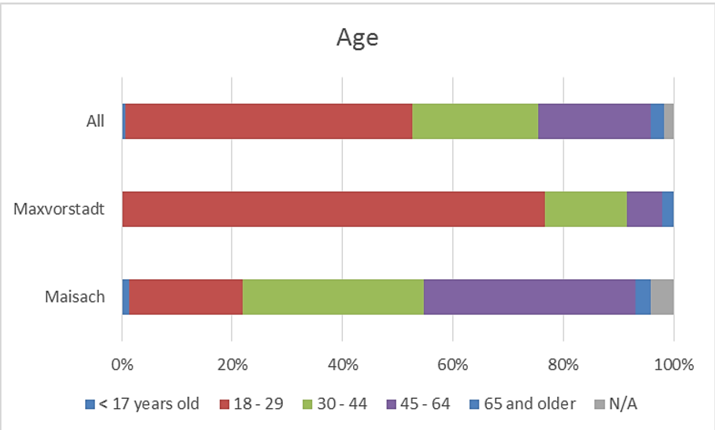


Figure 4.2: Age of the samples

In general for both study areas, slightly more than half of the responders were between the age of 18 and 29 years old and the rest of them were almost equally distributed in the classes of 30 - 44 and 45 - 64 years old. Responders that were younger than 18 or older than 65 years old consisted only a 5% of the whole sample.

4.1.3. Occupation

Regarding the occupation of the responders, Figure 4.3 shows that students are dominating the sample of Maxvorstadt and employees the sample of the municipality of Maisach. The higher percentage of responses for both study areas is represented by people who are working (54%), followed by a 37% of answers which were given by students.

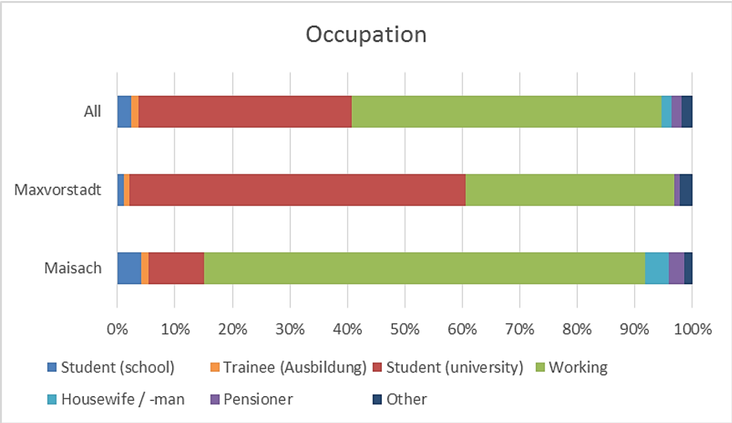


Figure 4.3: Occupation of the two samples

4.1.4. Monthly income

The answers related to the monthly income are presented in Figure 4.4. The main difference between the two samples is that 46% of the responders coming from the sample of Maxvorstadt have a low income (0 - 1000 €) whereas 37% of the participants coming from Maisach belong to the exact opposite class, the one of high income (more than 3500 €). This can be also explained by the fact that the majority of the answers in Maxvorstadt came from students, while in Maisach came from employees.

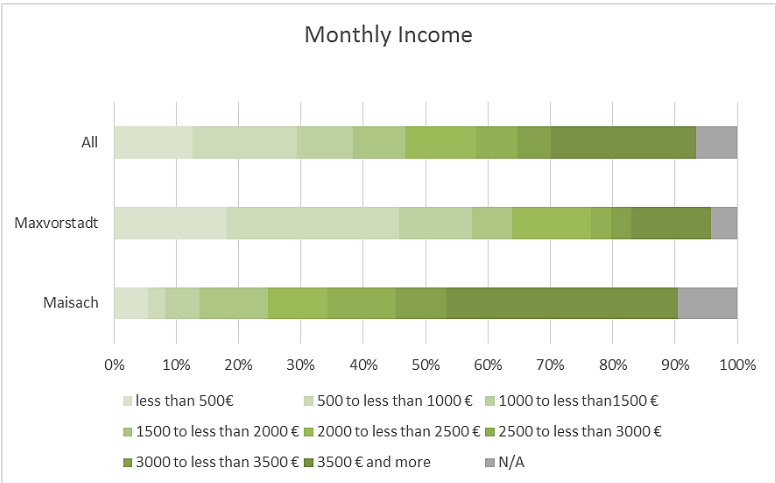


Figure 4.4: Monthly income of the two samples

4.2. General information about the transport mode availability of the sample

In this part of the survey, questions related to the availability of different transport modes were asked to the participants. The following figures present the amount of the responders that own a bicycle, a car or a monthly public transport ticket. In addition, it was asked whether they are a member of a car sharing programme or not. Finally, the participants evaluates in a scale 1 to 5, how much is their transport mode choice influenced by different factors.

4.2.1. Availability of bicycle

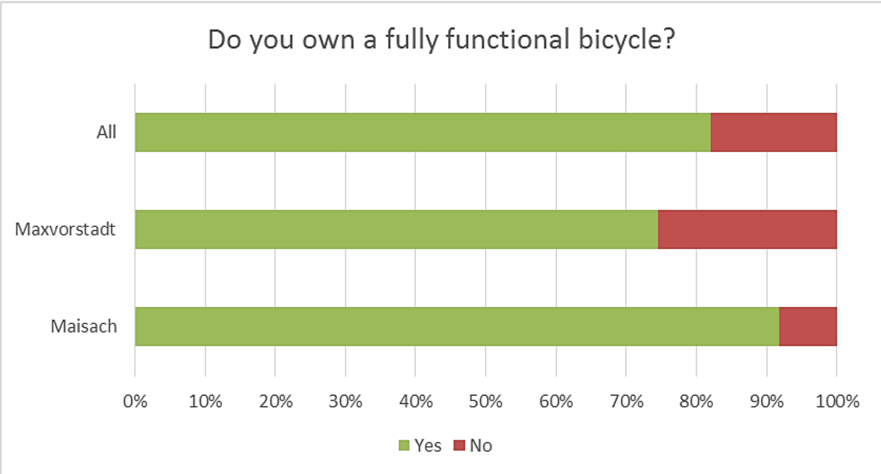


Figure 4.5: Availability of a fully functional bicycle

Figure 4.5 shows that almost all of the responders from Maisach own a fully functional bicycle, whereas the respective percentage for the city of Munich accounts to 75%. In general, an 83% of the responders from both samples, have access to a bicycle.

4.2.2. Availability of a personal car

As can be seen in Figure 4.6, in the municipality of Maisach an 85% have access to a personal car, while in the sample of Maxvorstadt the percentage is 29%.

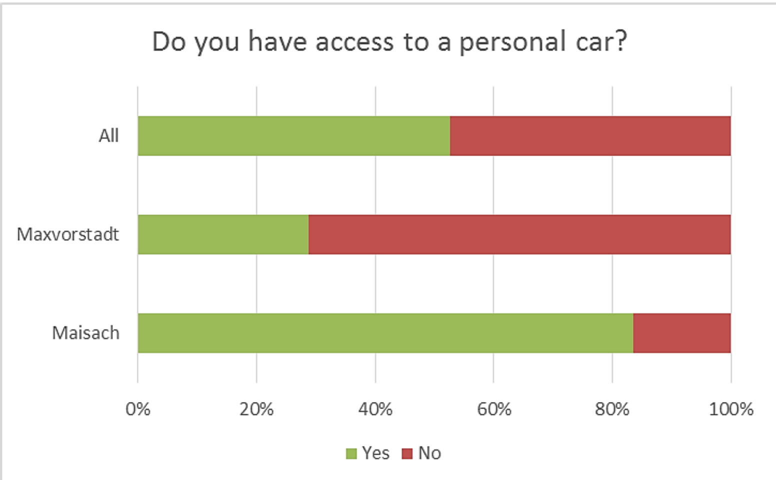


Figure 4.6: Availability of a personal car

4.2.3. Availability of a monthly public transport ticket

As shown in Figure 4.7, the vast majority of the sample of Maxvorstadt owns a monthly public transport ticket, whereas in Maisach only a 45% seem to be regular users of public transport.

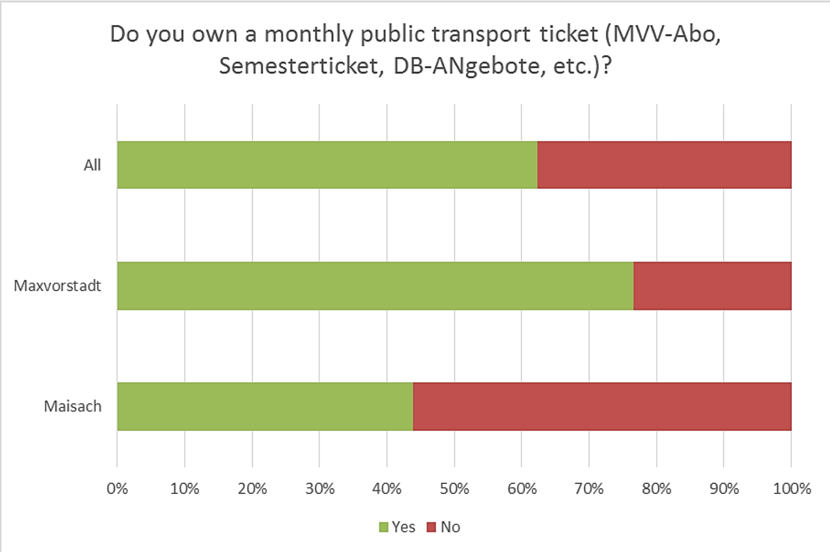


Figure 4.7: Availability of a monthly public transport ticket

4.2.4. Availability of car-sharing programme membership

In addition to the availability of a personal car, the participants of the survey were also asked if they are a member of a car-sharing programme. In the municipality of Maisach almost none is a member of such a programme. This is understandable, since there is no available programme in the municipality, apart from only one car-sharing offer, available at four S-Bahn stations of the county of Fürstenfeldbruck, where Maisach belongs to. On the contrary, an 18% of the responders from the sample of Maxvorstadt are members of car-sharing programmes.

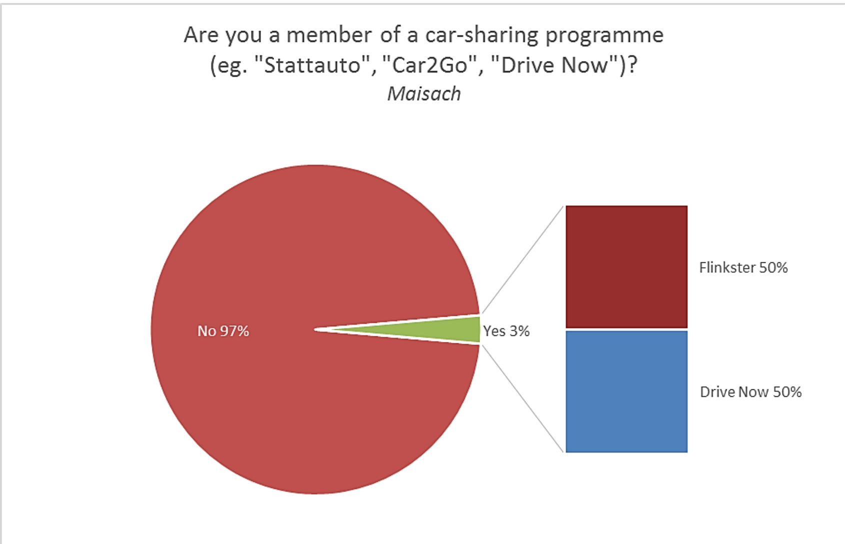


Figure 4.8: Availability of car-sharing programme membership in Maisach

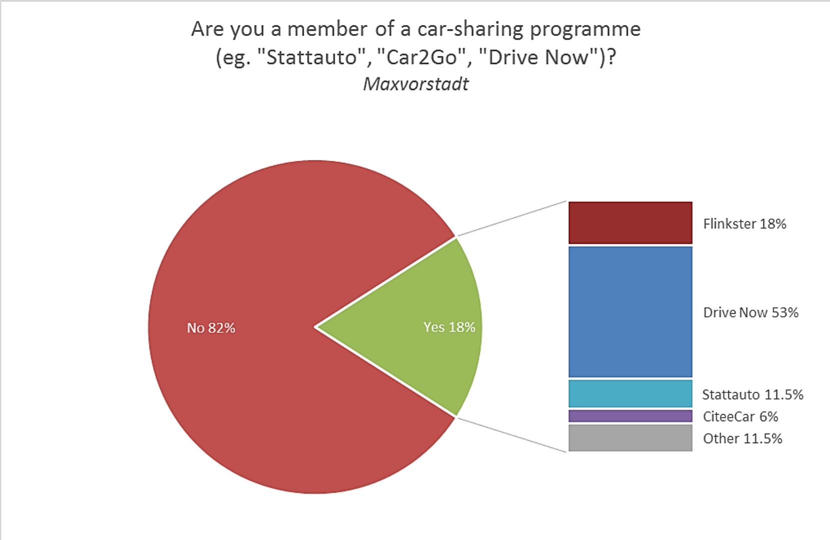


Figure 4.9: Availability of car-sharing programme membership in Maxvorstadt

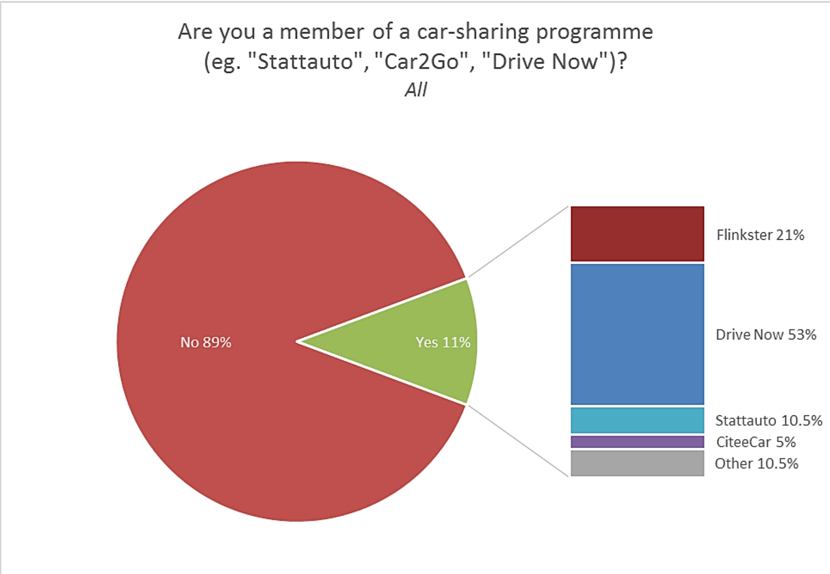


Figure 4.10: Availability of car-sharing programme membership in both samples

4.2.5. Influencing factors on transport mode choice

This thesis also examined which factors seem to play an important role in transport mode choice. The results are sorted for each sample at a descending order, from the most influential factor to the least one, in order to examine where the environmental friendliness of the mode stands.

Figure 4.11 present the results regarding the municipality of Maisach and show that trip purpose, travel time and comfort seem to be the more influential factors, with weather, habit and travel costs standing in a neutral position. On the other hand health, safety and environmental friendliness of the mode seem to have no strong influence on choosing a transport mode.

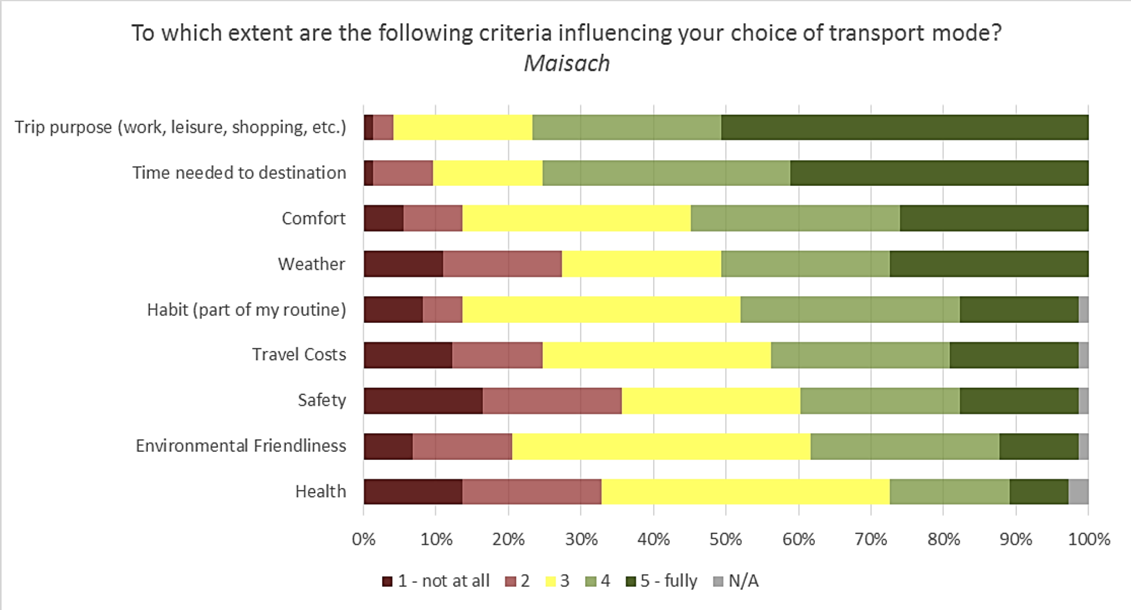


Figure 4.11: Extent to which different factors influence transport mode choice in Maisach

Regarding the sample of Maxvorstadt, Figure 4.12 shows that travel time, travel costs and weather influence fully or almost fully the transport mode choice, whereas health, safety and environmental friendliness are again the least influential factors. Habitual parameters, trip purpose and comfort seem to have only a moderate influence on transport mode choice for the responders of the study area of Maxvorstadt.

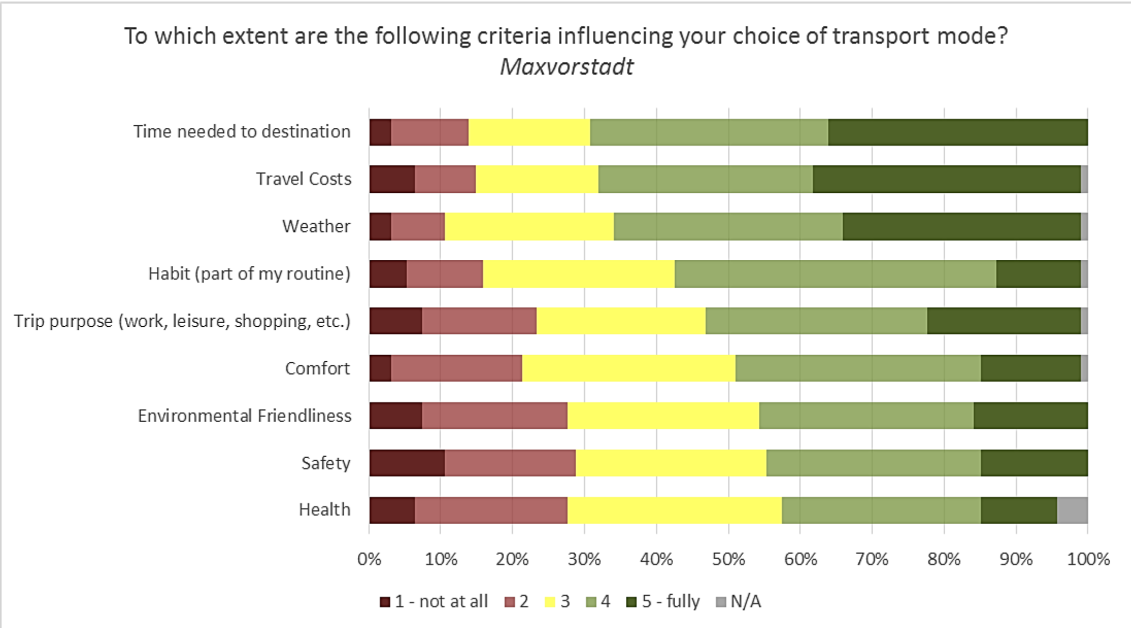


Figure 4.12 : Extent to which different factors influence transport mode choice in Maxvorstadt

In general for both samples, travel time, trip purpose, weather and travel costs are the factors with the highest importance to the participants and health, safety and environmental friendliness are the ones with the least (Figure 4.13).

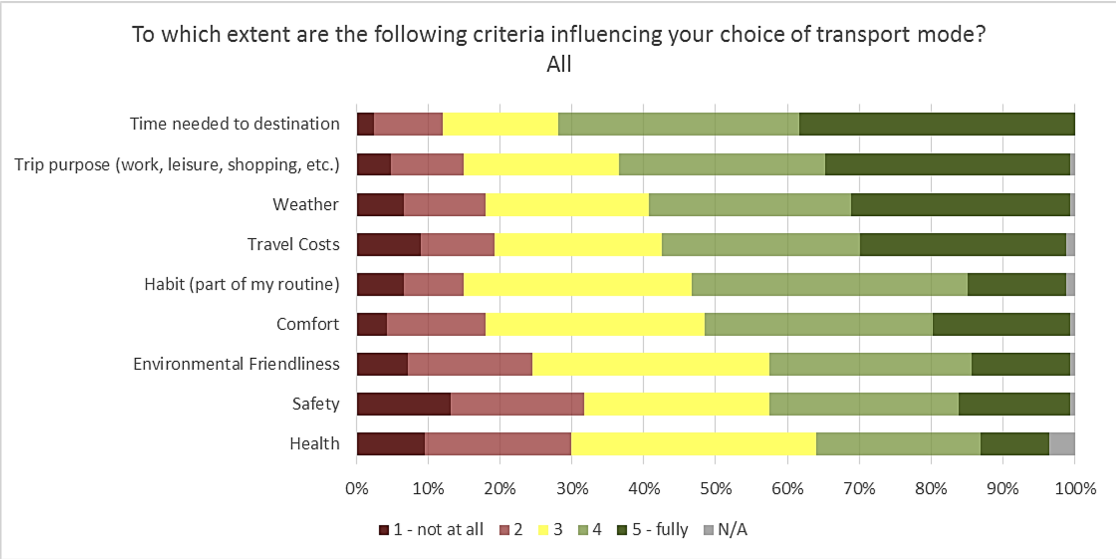


Figure 4.13: Extent to which different factors influence transport mode choice in both samples

The analysis done in this part showed that most of the people who belonged to the sample of Maisach, have a variety of options regarding their transport mode, since almost all of them own a bicycle, the majority has access to a personal car and half of them own a monthly public transport pass. On the other hand, the people who belong to the sample of Maxvorstadt seem to be more captive users of public transport or to favour more non-motorized private transport, since most of them do not have access to a private car or a car sharing programme. As a result, in the next part where the participants had to input their most frequent trip, it was expected that most of the trips of the responders from the city of Munich were done by public transport or non-motorised transport modes (bicycle, on foot). For the municipality of Maisach, since all transport modes were available, it was interesting to see which mode people really chose.

4.3. Information about the most frequent trip of the responders

In this part of the survey, people had to input their most frequent trip under the week and evaluate the environmental quality along it. From the 167 full answers, there were three responses that did not contain any information about their trip, leaving out a sample of 164 trips. An overview of these trips is shown in the following figures. What is more, statistics of the travel time in minutes, travel distances, the transport mode that the responders chose for their trip, as well as the purpose of their trip are also presented.

4.3.1. Overview of the participants' trips

Figure 4.14 shows an overview of the trips as given by the responders and classified based on the transport mode. In general, the representation of the trips showed that both study areas have short-distance and long-distance commuters. Among the responders of the municipality of Maisach, there are quite a few who travel outside the municipality, for example to Munich, Augsburg or Kempten. On the other hand, although there were some cases of responders who travel to Maxvorstadt from distant areas, such as Tutzing or Starnberg, the majority of the trips of this study area are done within the city of Munich.

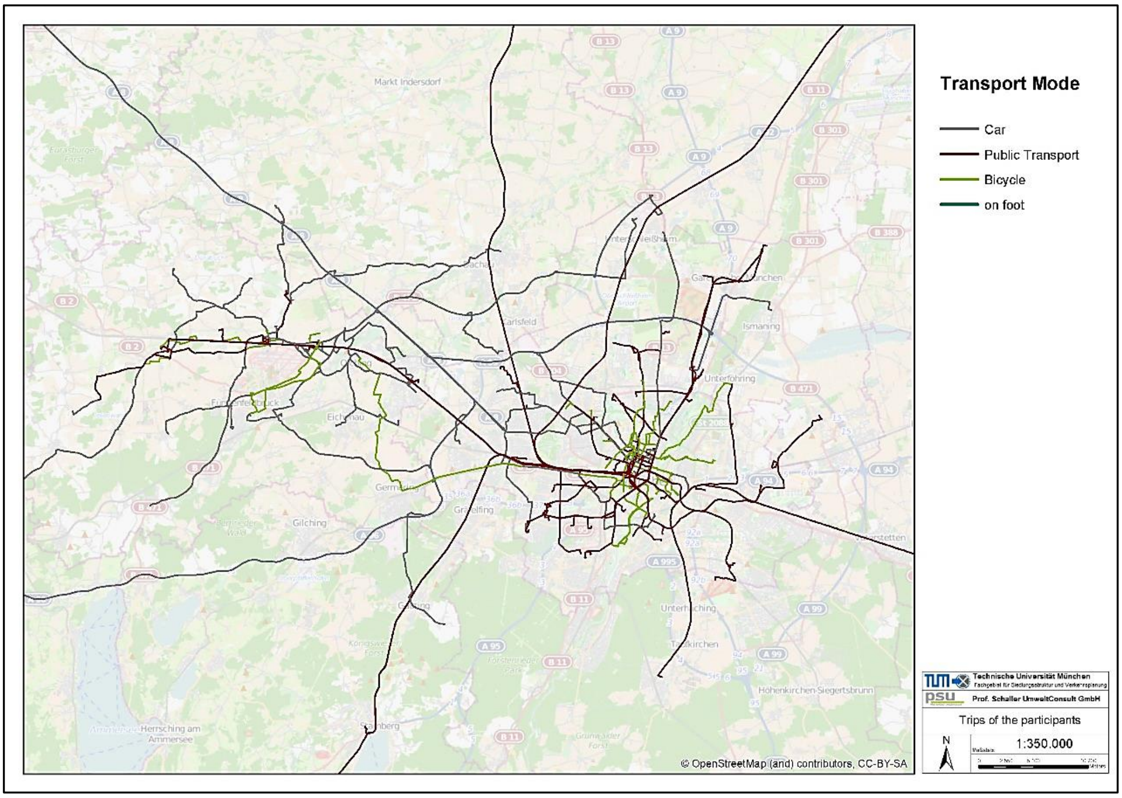


Figure 4.14: Overview of the participants' trips

Figure 4.15 and Figure 4.16 show a closer representation of the trips in the two study areas.

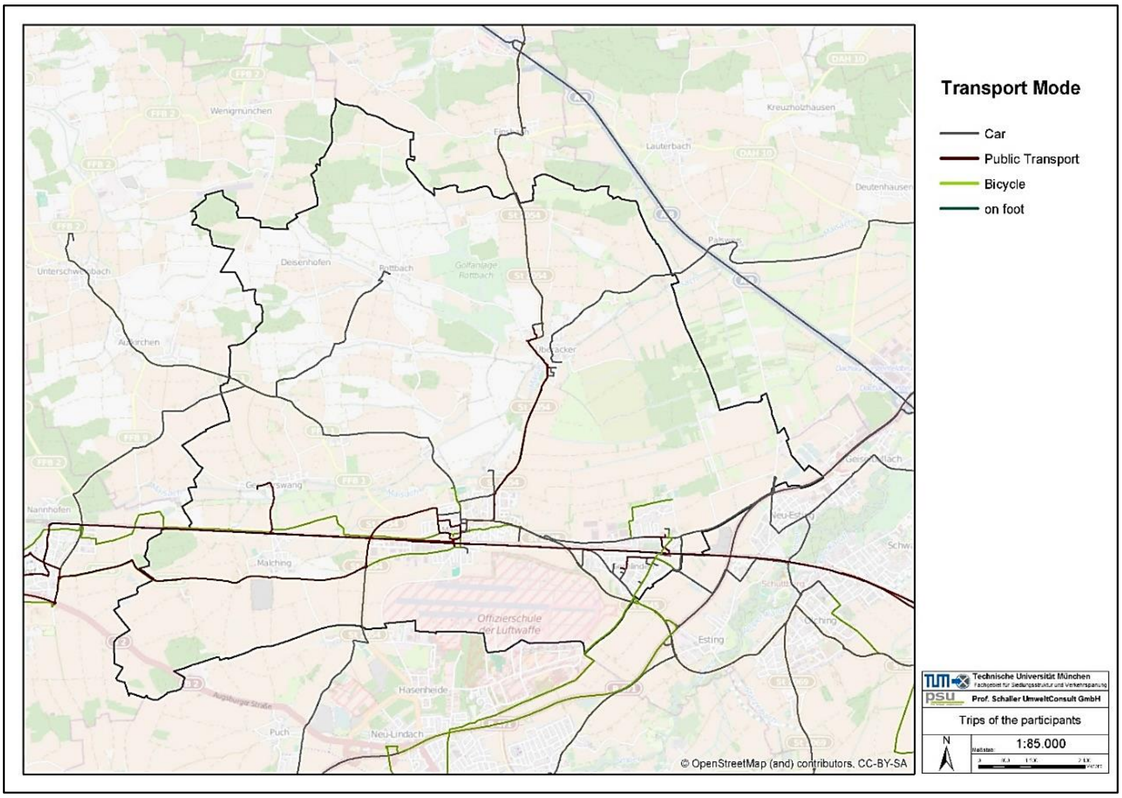


Figure 4.15: Overview of the participants' trips in Maisach

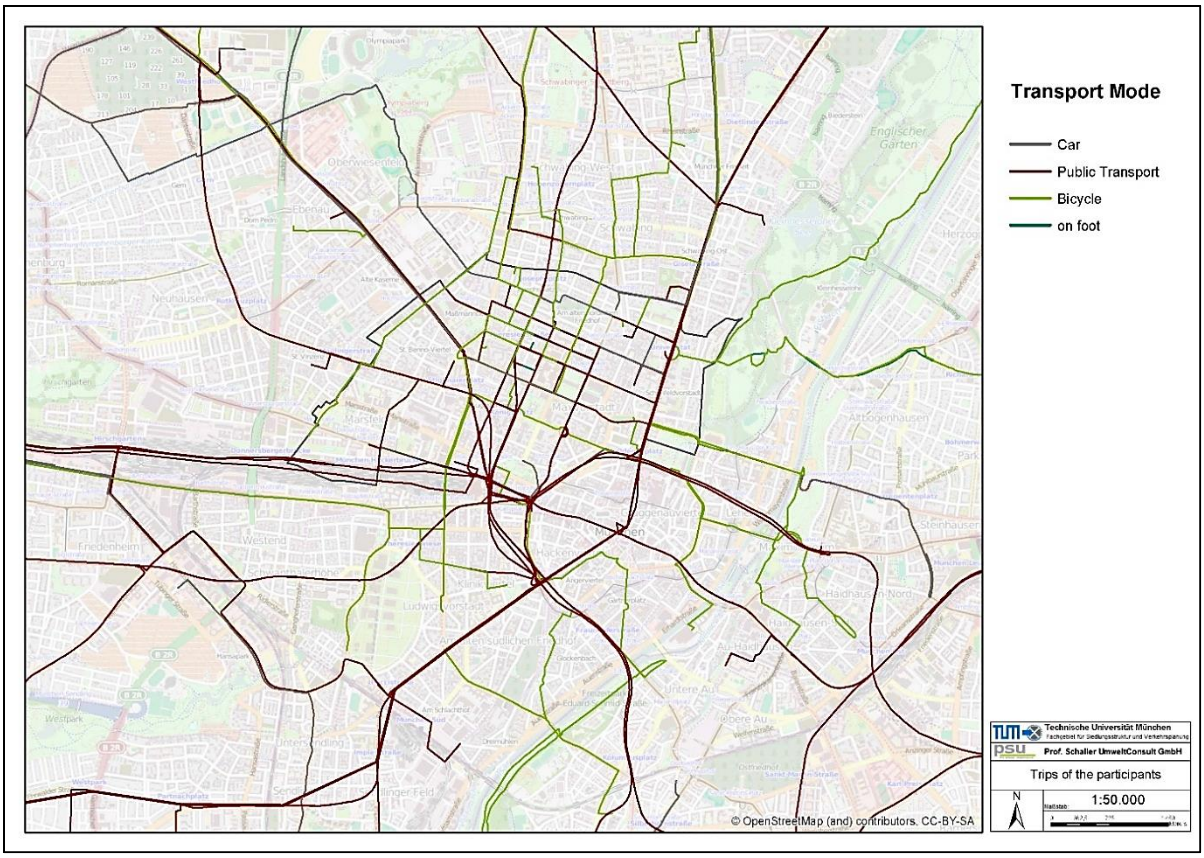


Figure 4.16: Overview of the participants' trips in Maxvorstadt

4.3.2. Travel distances

As observed in Figure 4.17, almost 40% of the trips made by the citizens of Maisach are 25 - 100 km long, whereas most of the responders of Munich travel from 2 - 25 km. This is also explained by the fact that many participants from the sample of Maisach travel outside the municipality, while the responders from Maxvorstadt have destinations within the city of Munich.

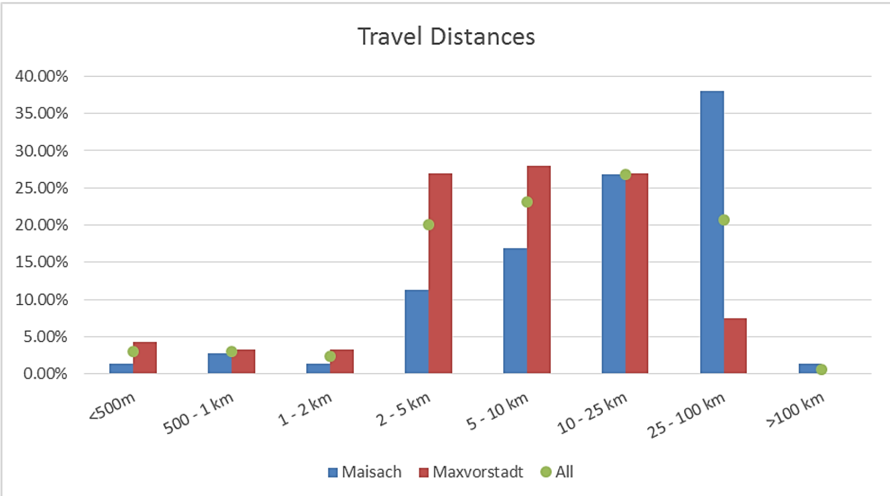


Figure 4.17: Distance travelled during the most frequent trips of both samples

4.3.3. Transport mode

As described before, the percentage of the participants from the study area of Maxvorstadt who have accessibility to a private car accounts to 25%. Taking into account also the shorter distances, it is no surprise that 60% of their trips is done by public transport and a 35% by non-motorised modes. As far as Maisach is concerned, Figure 4.18 shows that 60% of the trips were done by car, 27% by public transport and 13% by non-motorised modes.

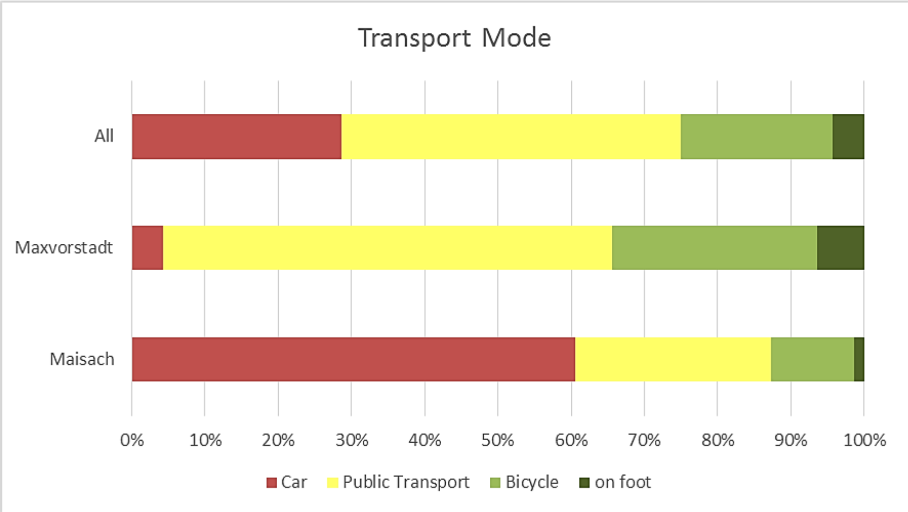


Figure 4.18: Modal split for the participants' trips of both samples

4.3.4. Travel time

Regarding the time needed for their trips, more than half of the responders from both samples need less than 30 minutes to reach their destination, with participants from Maisach travelling longer, a fact that is also justified by the longer distances.

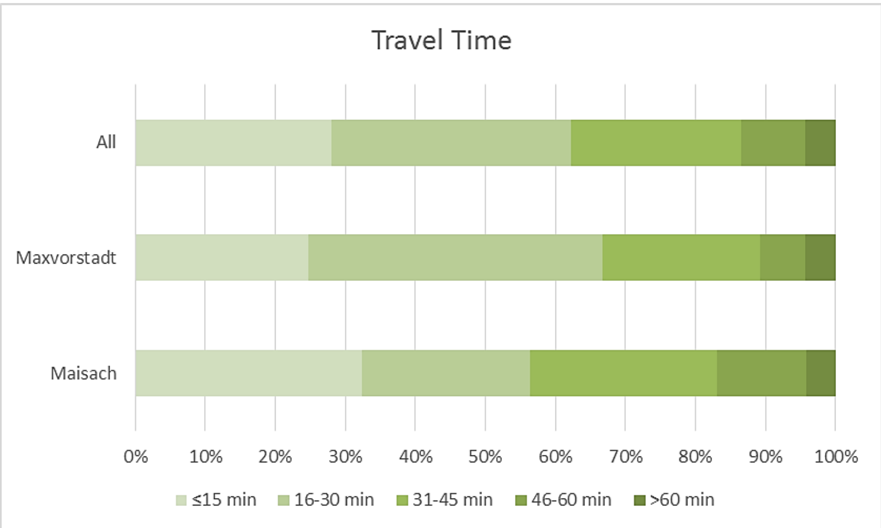


Figure 4.19: Travel times for the participants' trips of both samples

4.3.5. Trip purpose

The question related to the purpose of the trip showed that almost all of the trips were done due to working or educational reasons. More specifically, 80% of the trips of the sample of Maisach have a working place as a destination, whereas the respective percentage for the sample of Maxvorstadt accounts to 45%. Almost 50% of the rest of the trips of the sample of Maxvorstadt has educational purposes. The fact that 59% of the responders of Maxvorstadt are students, but only 50% of the trip purposes are marked as "school/university", shows that there is a 9% of students whose trip's destination was to a work/internship position. To conclude, there is an approximately 5% in both study areas, whose most frequent trip during the week had a different trip purpose, such as shopping, leisure or sports activities.

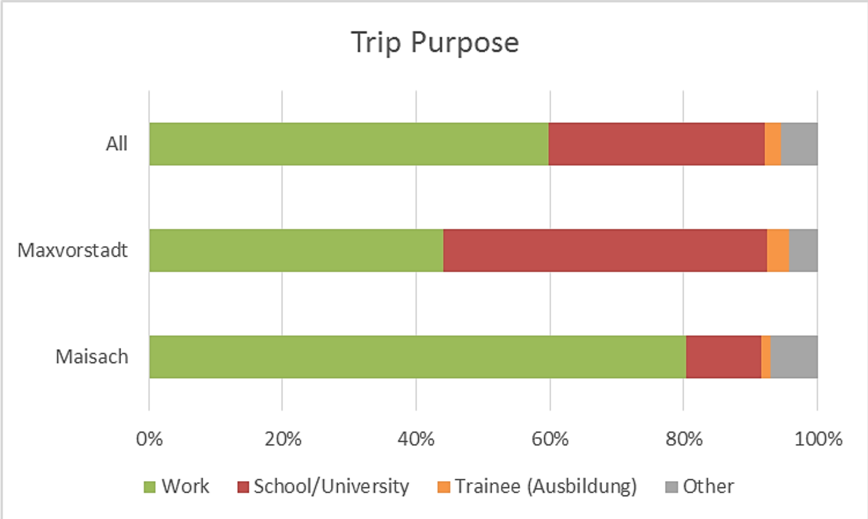


Figure 4.20: Purpose of the most frequent trips of both samples

4.4. Comparison between perceived and actual environmental quality of the two study areas

A central part of this thesis is to examine the responder's perception of environmental quality. Following the procedure described in Chapter 3.2.4 the evaluation of the three factors of environmental quality, as given by the responders of both studies areas, was visualized in ArcGIS. In addition, the evaluation of environmental quality based on actual data, as estimated and described in the chapter of the methodology, was also visualized in the same way, so that the comparison between them could be easier. The mapping of the environmental quality, perceived and actual, is presented in the following pages.

4.4.1. Air quality

The following two figures present how people evaluated air quality along the routes of the two study areas. The thickness of the lines represent the amount of evaluations that were available for each street section.

As observed in Figure 4.21, people in the municipality of Maisach generally considered air quality ‘very good’ or ‘good’ and only a few street sections, basically located at the main streets, were evaluated with the value of ‘middle’.

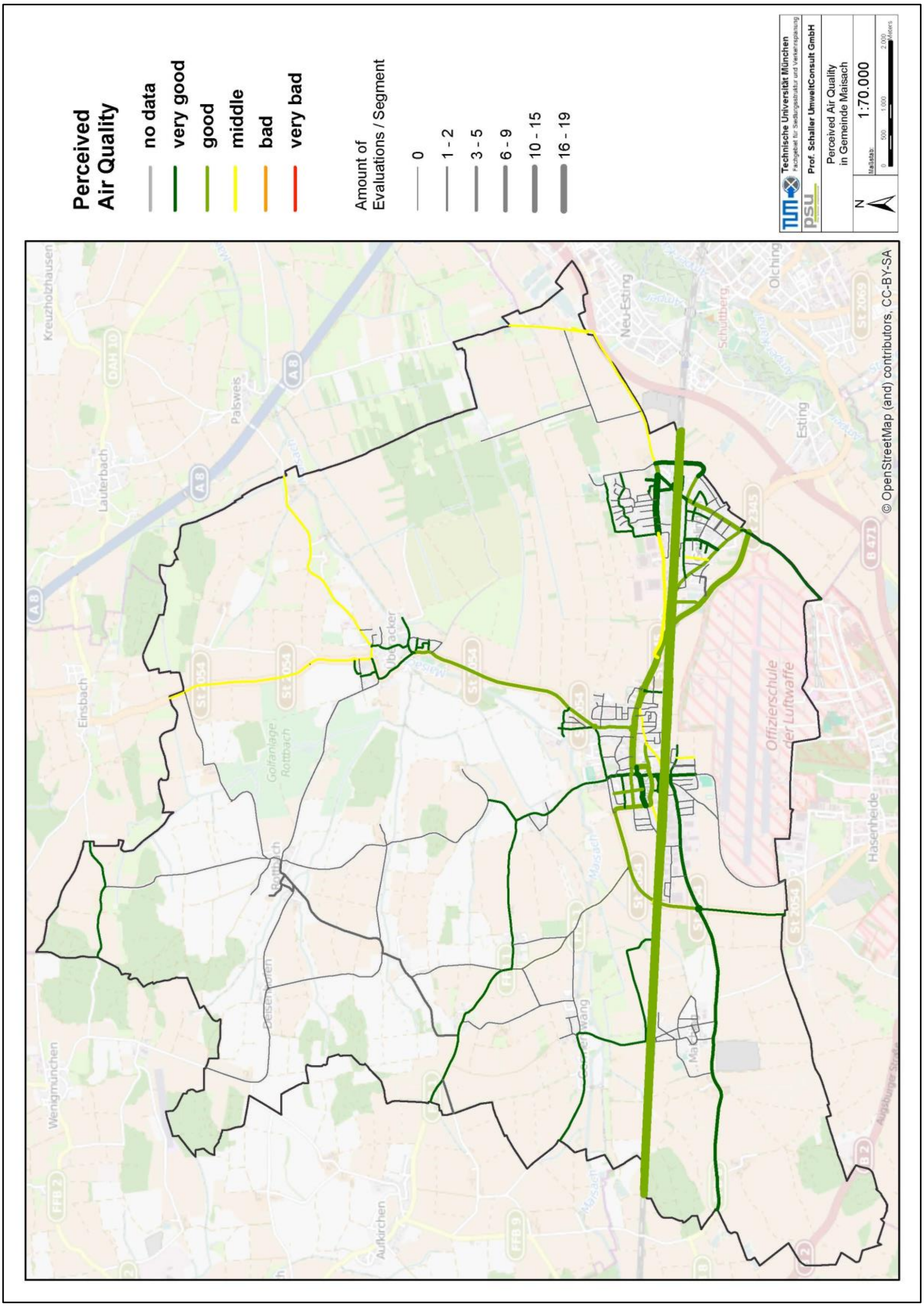


Figure 4.21: Perceived air quality in Maisach

The evaluation in the study area of Maxvorstadt presents a wider variety of values. As Figure 4.22 shows, bigger streets with usually larger traffic volumes, had a worse evaluation of air quality. On the other hand, a better value was assigned to smaller streets or streets with higher availability of green spaces.

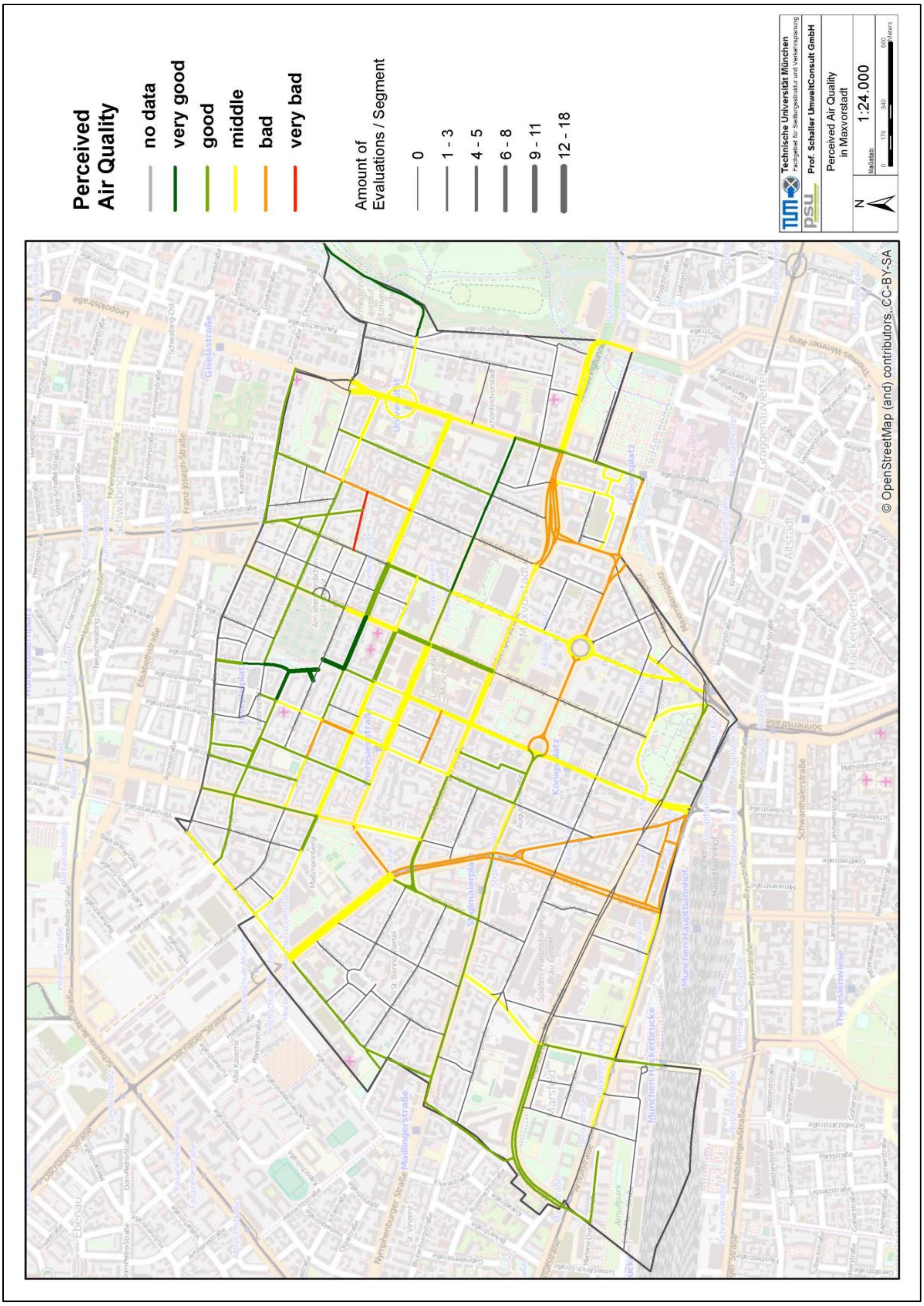


Figure 4.22: Perceived air quality in Maxvorstadt

The above figures show how the participants of the survey perceived air quality along the streets of the two study areas. The analysis done in Chapter 3, showed that the air quality was in both areas ‘good’ (a value of 2, in the scale of 1 - 5). The available data did not allow a more precise representation of the actual air quality for each street section. For that reason, it was considered that the air quality was homogeneous within the study areas and namely a value of 2 (‘good’) was assigned to each part of the street network.

In order to have a first overview of the comparison between the evaluations, a mean value was calculated for the perceived air quality of the two areas and is presented in Table 4.1.

Comparison of mean values of air quality	Mean Air (perceived)	Mean Air (actual)
Maisach	2.0	2
Maxvorstadt	2.6	2
All	2.3	2

Table 4.1: Comparison of mean values of air quality in both study areas

The result shows that the air quality’s evaluation, given by the responders of Maisach, agrees to the evaluation done by the quantitative analysis of this thesis, whereas the responders from the sample of Maxvorstadt evaluated air quality a bit worse than the analysis that was done, based on actual air quality data.

In both study areas the first overview showed that there is a close match between the perceived and the actual air quality. Additionally, a more analytic comparison was carried out, focusing on the level of each street section. The analysis showed that in 65% of the street sections of the municipality of Maisach, the evaluation that was given by the responders was the same with the evaluation that was assigned by the author. The rest of the evaluations were either one level more negative or one level more positive than the actual air quality, with more responders perceiving air quality one level better than it actually is.

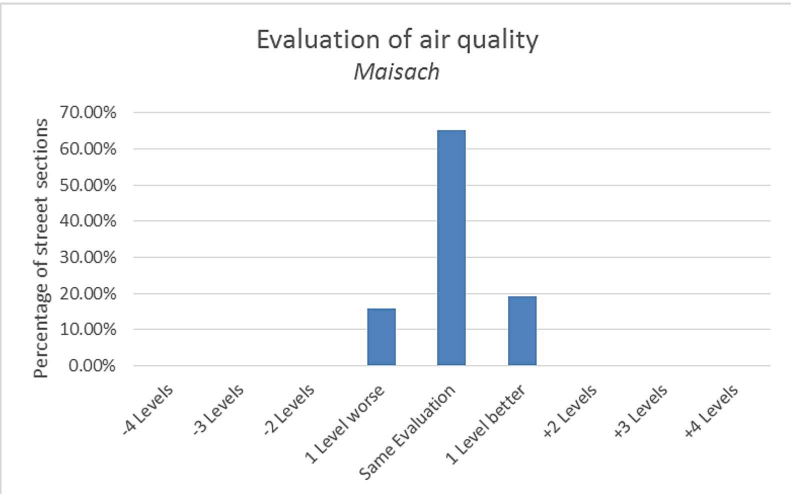


Figure 4.23: Comparison between perceived and actual evaluation of air quality in Maisach

In the study area of Maxvorstadt the same evaluation was found in less than half of the street segments, and namely in 47% of the street sections. In almost all of the remaining parts of the street network, people evaluated air quality one (41%) or two (8.5%) levels worse than the evaluation done based on actual data.

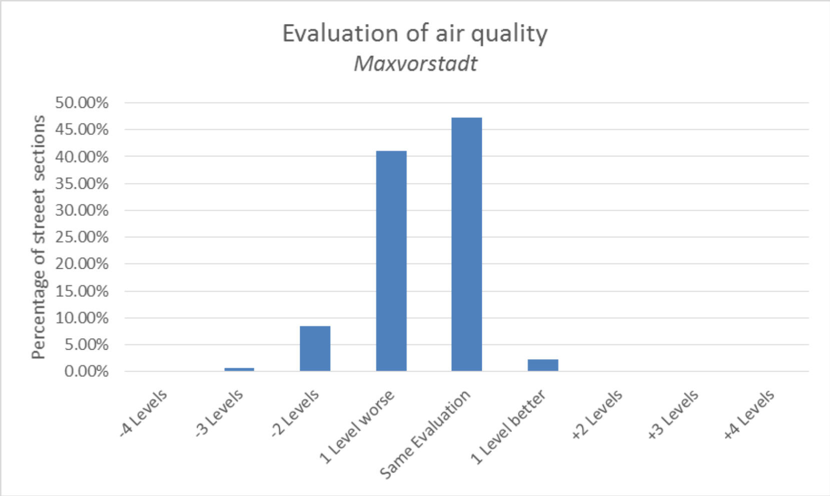


Figure 4.24: Comparison between perceived and actual evaluation of air quality in Maxvorstadt

Regarding both samples, the comparison between actual and perceived air quality, showed that in the majority of the streets, there is a concurrence between the responders' evaluation and the assessment done by the author. The main difference between the two samples is that responders from the study area of Maisach seemed to perceive air quality more accurately than those from the study area of Maxvorstadt. In Maxvorstadt, although we have a relative large amount of matching evaluations, a large number of people tended to perceive the air quality worse than it actually was.

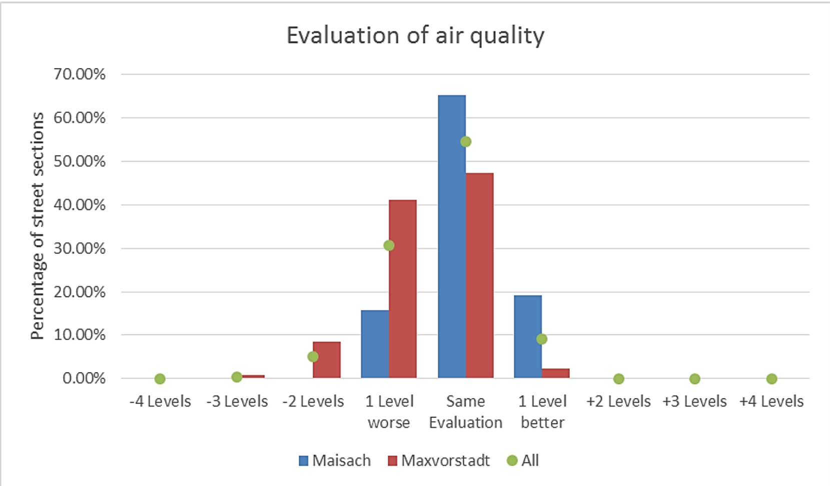


Figure 4.25: Comparison between perceived and actual evaluation of air quality

By examining the two study areas' structures, the above difference may be explained by the fact that in the area of Maxvorstadt there are larger streets and more traffic, as well as less green spaces than in the municipality of Maisach. What is more, it seems that there is a positive correlation between green spaces and a more positive perception of air quality, since street sections with high levels of green spaces were assigned in general a better value. A more extended discussion of the results and the correlation between green spaces and the other environmental quality factors can be found in Chapter 4.6.

4.4.2. Noise

The following figures present the mapping of perceived and actual noise levels for both study areas. A quick overview of Figure 4.26 shows that people in Maisach consider the noise levels at the main streets ‘middle’ or ‘loud’. On the other hand, streets located at the countryside and along more rural landscapes were evaluated as ‘quiet’.

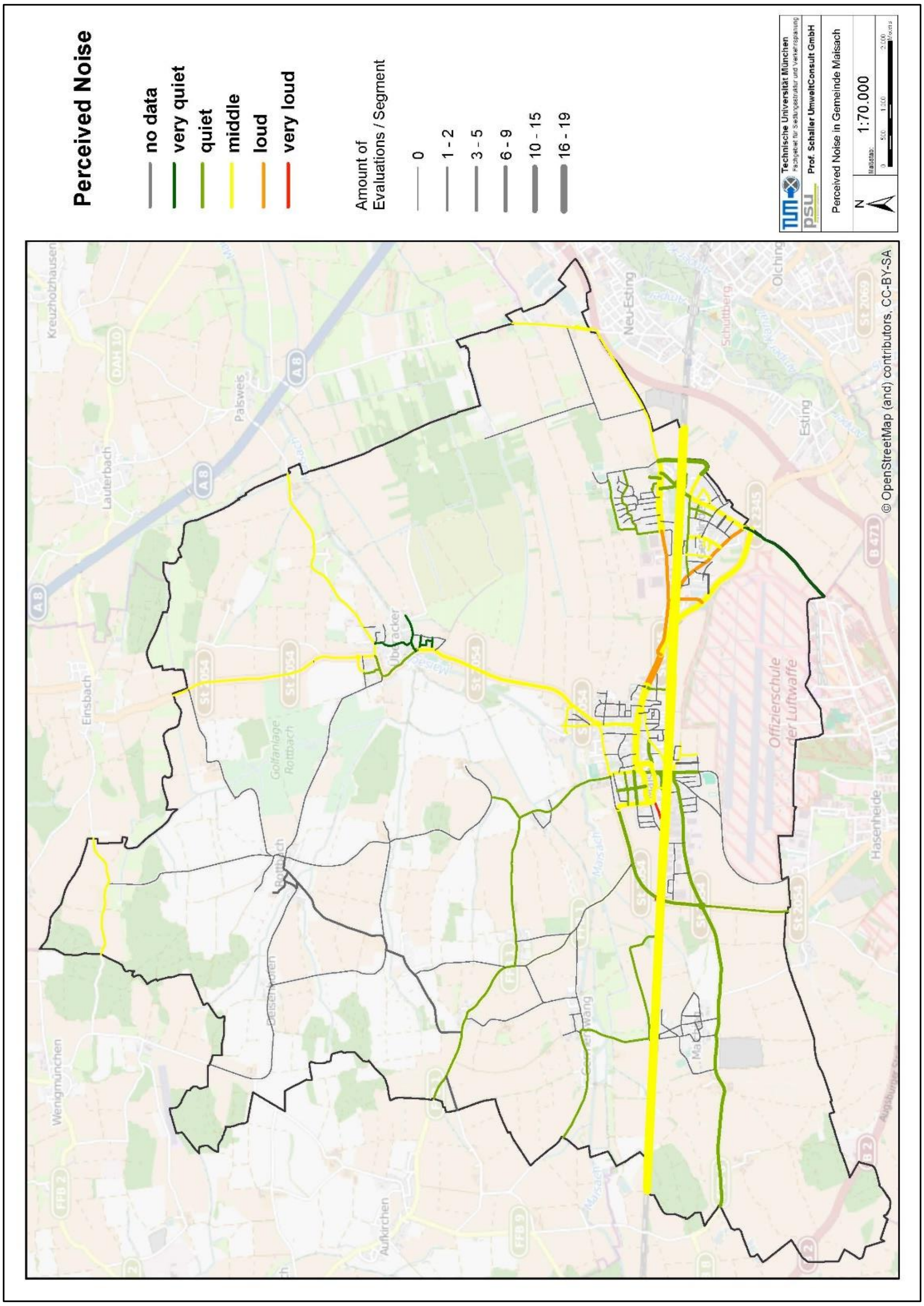


Figure 4.26: Perceived noise levels in Maisach

The comparison to the actual noise levels could be done unfortunately only for the main streets and the rail tracks, where respective data was available. The assessment done in the previous chapter showed that the noise levels at the main streets are indeed ‘middle’ or ‘loud’.

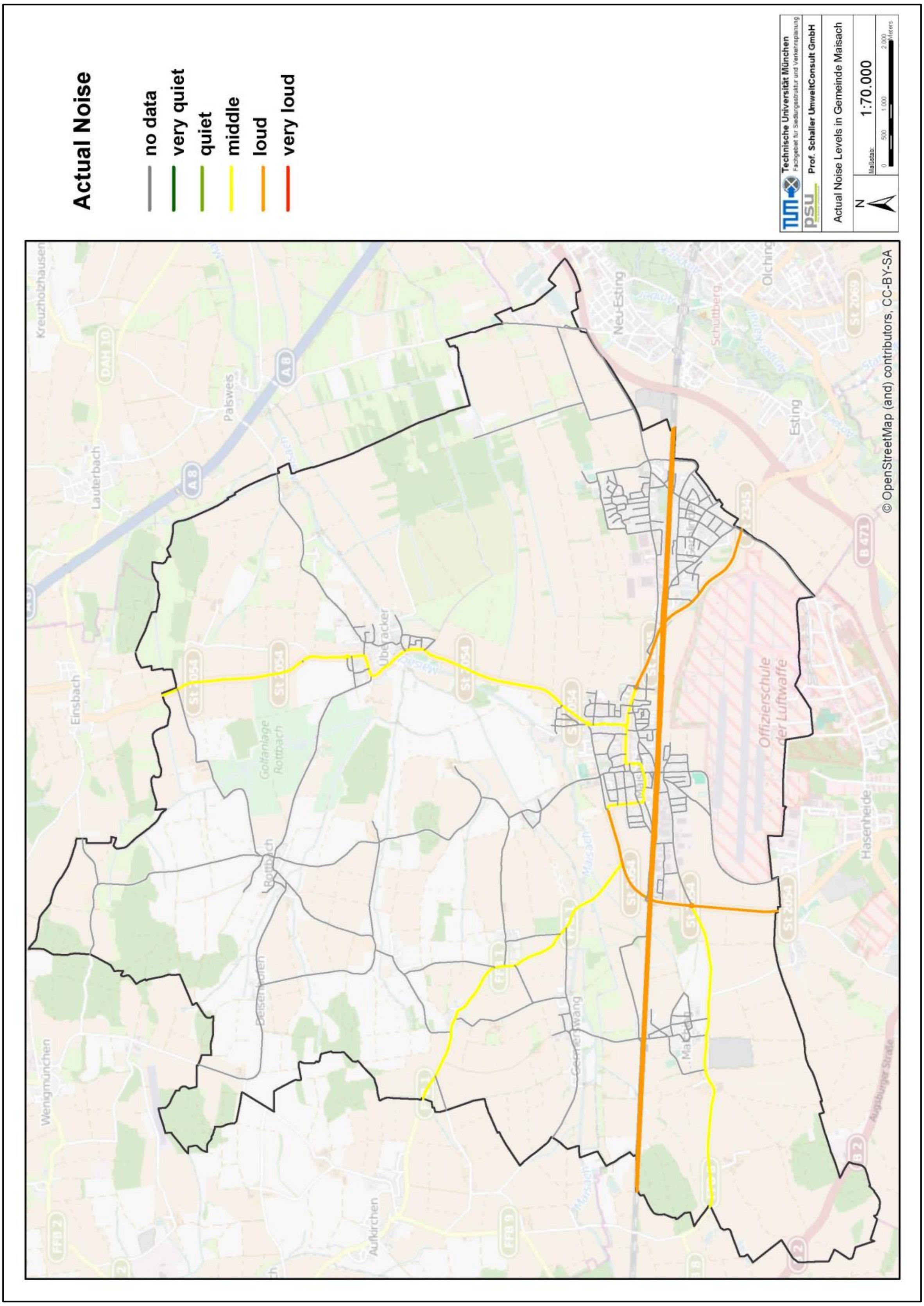


Figure 4.27: Actual noise levels in Maisach

Regarding the study area of Maxvorstadt, it seems that there is again a correlation between the city structure and the perception of noise. Larger streets with possibly larger traffic volumes were evaluated with a worse value than smaller streets. In general most of the street segments have values from ‘middle’ to ‘very loud’ and only a few of them were considered ‘quiet’ or ‘very quiet’.

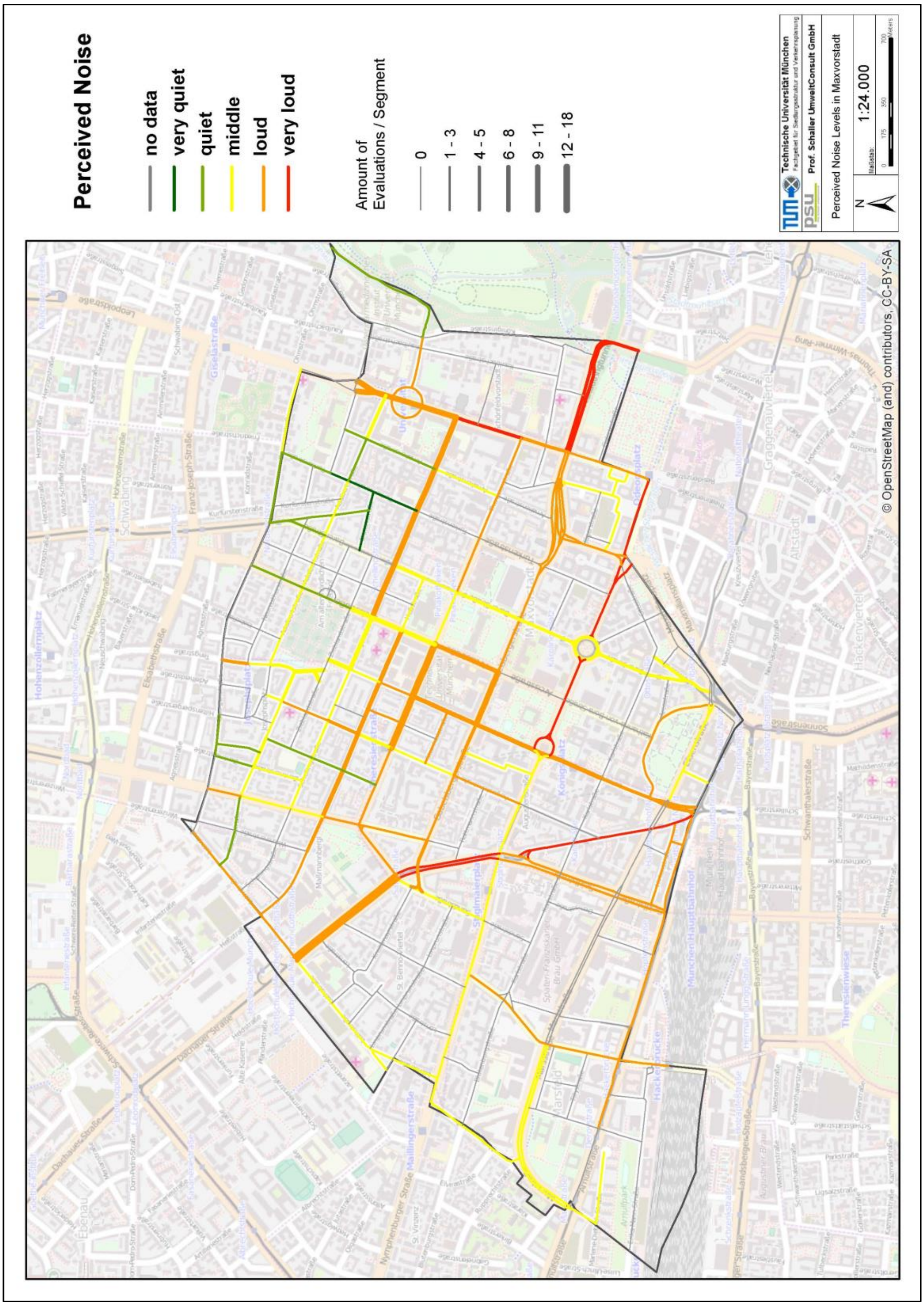


Figure 4.28: Perceived noise levels in Maxvorstadt

The noise assessment done in Chapter 3.3.2 showed that indeed almost all of the main streets are either ‘loud’ or ‘very loud’. However, there is a large number of street segments, located in the northern part of Maxvorstadt, which are rather ‘quiet’ or ‘very quiet’.

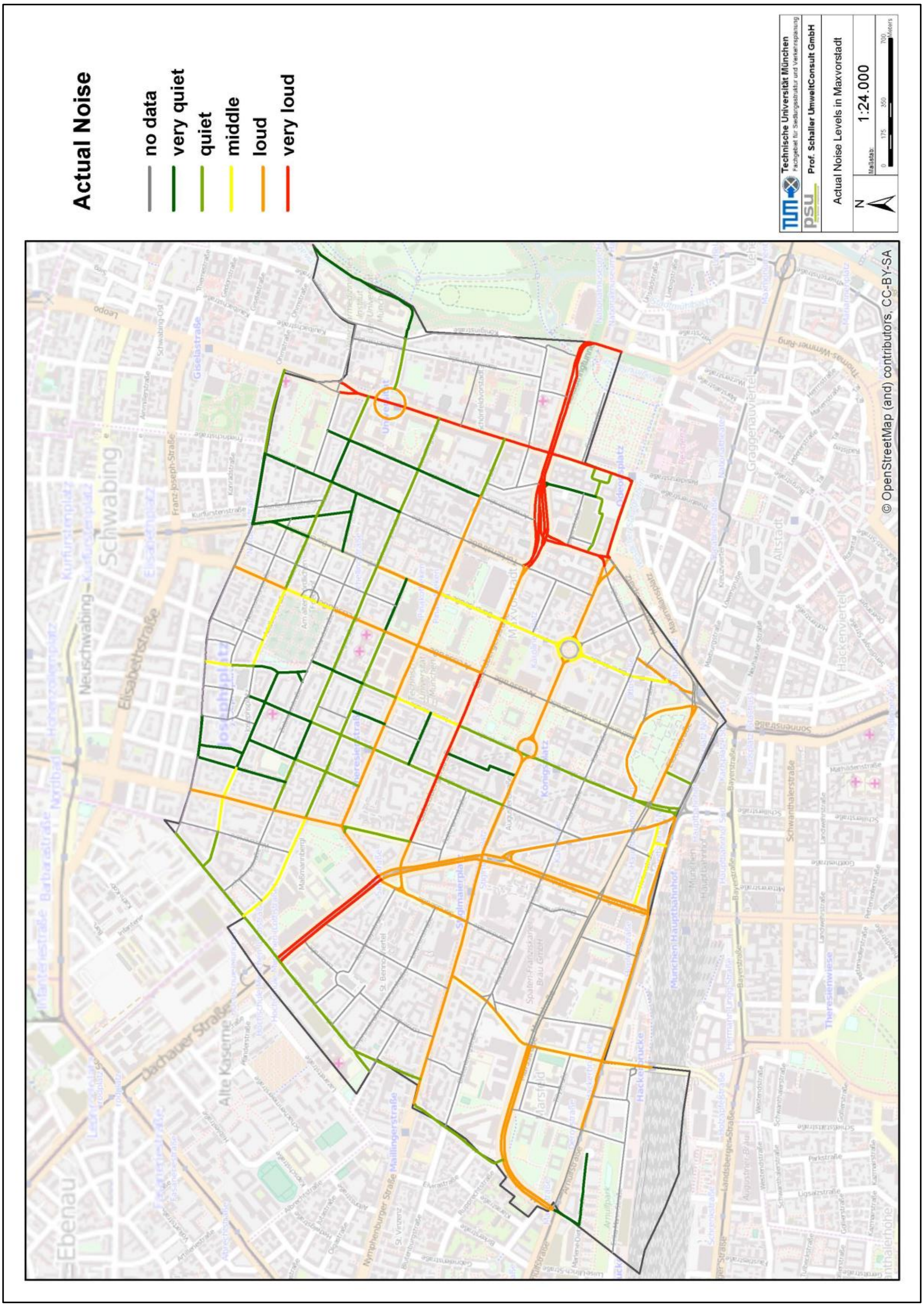


Figure 4.29: Actual noise levels in Maxvorstadt

The comparison of the evaluations at each street section showed that in the municipality of Maisach, an agreement between the actual and perceived noise levels was found in a 60% of the street sections, from those where data was available. As seen in Figure 4.30, the rest of the street segments showed a more positive perception of noise than the actual noise levels.

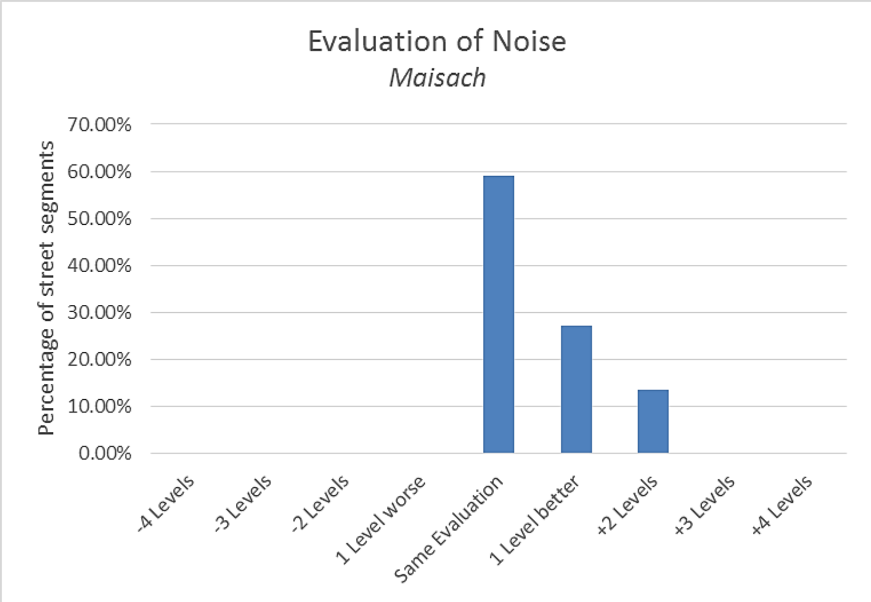


Figure 4.30: Comparison between noise level evaluations in Maisach

On the other hand, the sections of the study area of Maxvorstadt, where a consensus between the evaluations was found, accounted to 28%. A percentage of 29% and 20% of the street sections were evaluated with one or two levels more negative than the actual noise levels. In addition, Figure 4.31 shows that there is also an 18% of street sections, where the responders considered that noise is one level better than it actually is.

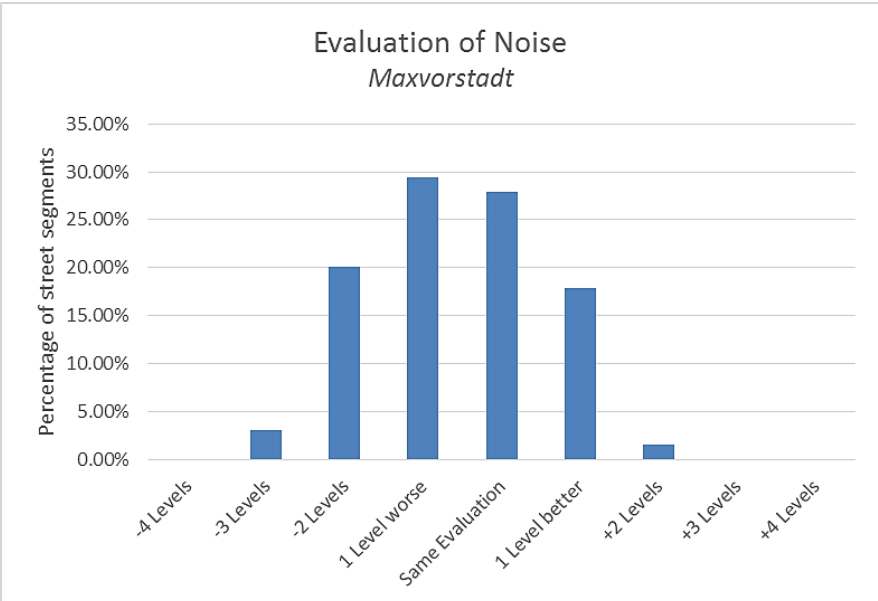


Figure 4.31: Comparison between noise level evaluations in Maxvorstadt

As far as both samples are concerned, the comparison between the noise levels, showed that the evaluations of actual and perceived noise levels agreed in a 32.5% of the street sections. In the rest of the sections both more positive and negative evaluations are met (Figure 4.32). This leads to the conclusion, that noise is a more subjective matter of perception and comparing to air quality, it is perceived in a less precise way.

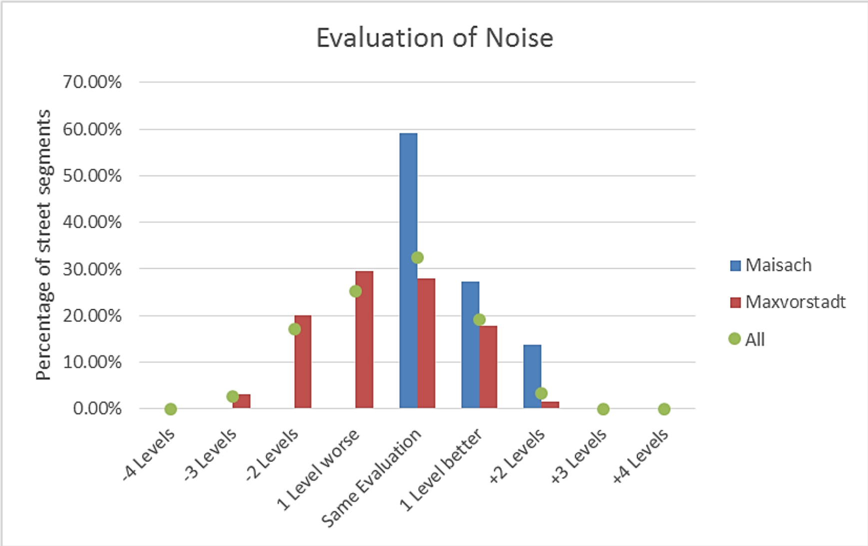


Figure 4.32: Comparison between noise level evaluations

4.4.3. Availability of green spaces

This section is examining how the responders perceive the availability of green spaces along their routes. As seen in Figure 4.33, almost all of the street segments located within the study area of Maisach, were evaluated as ‘green’ or ‘very green’. In addition, the availability of green spaces along the rail tacks was evaluated as ‘middle’.

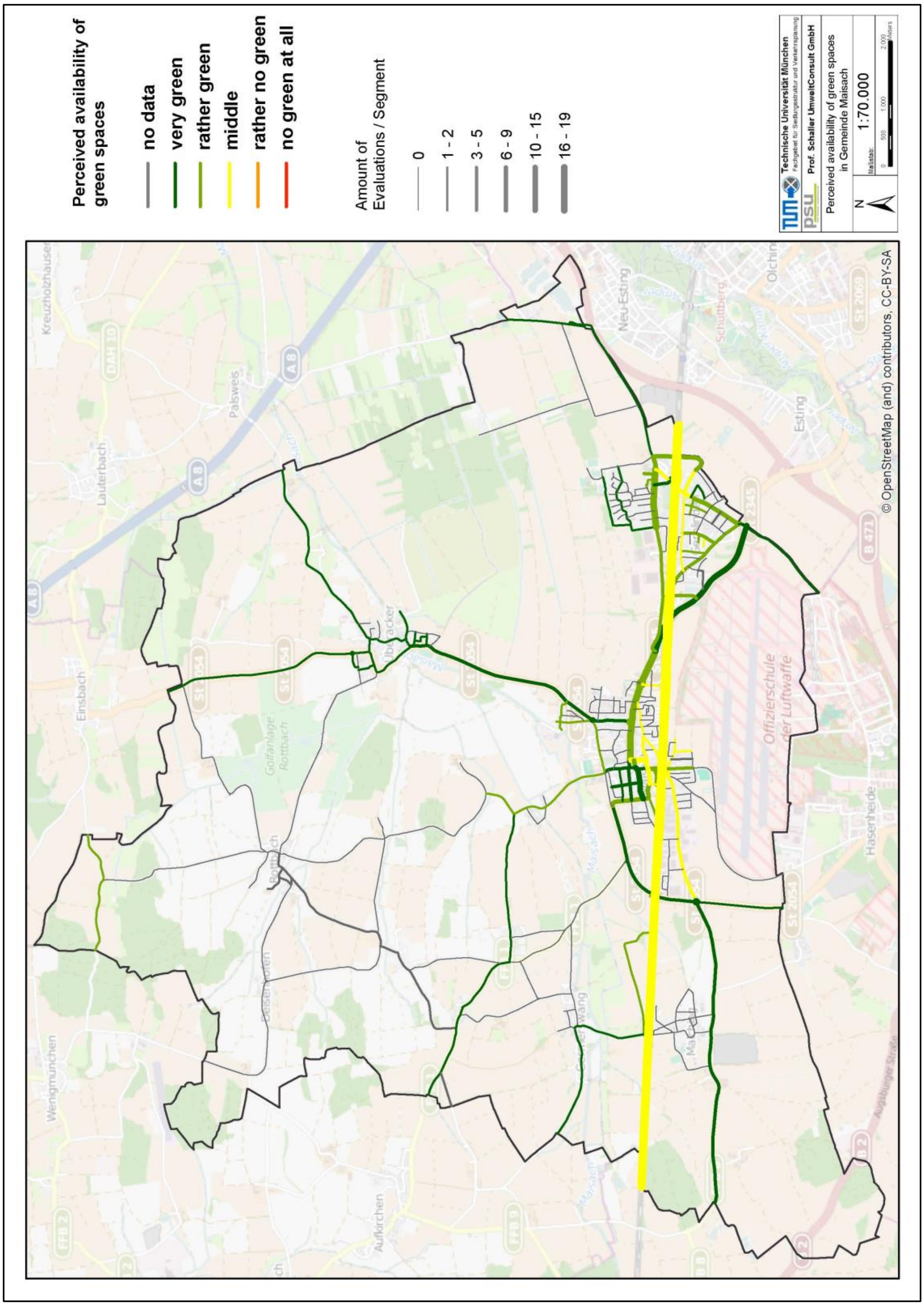


Figure 4.33: Perceived availability of green spaces in Maisach

The analysis with satellite images and photos of the street network, showed that indeed most of the streets of the municipality of Maisach are ‘very green’. As explained in the previous chapter, the route along the rail tracks was evaluated as ‘middle’, because of the existence of the noise barrier walls.

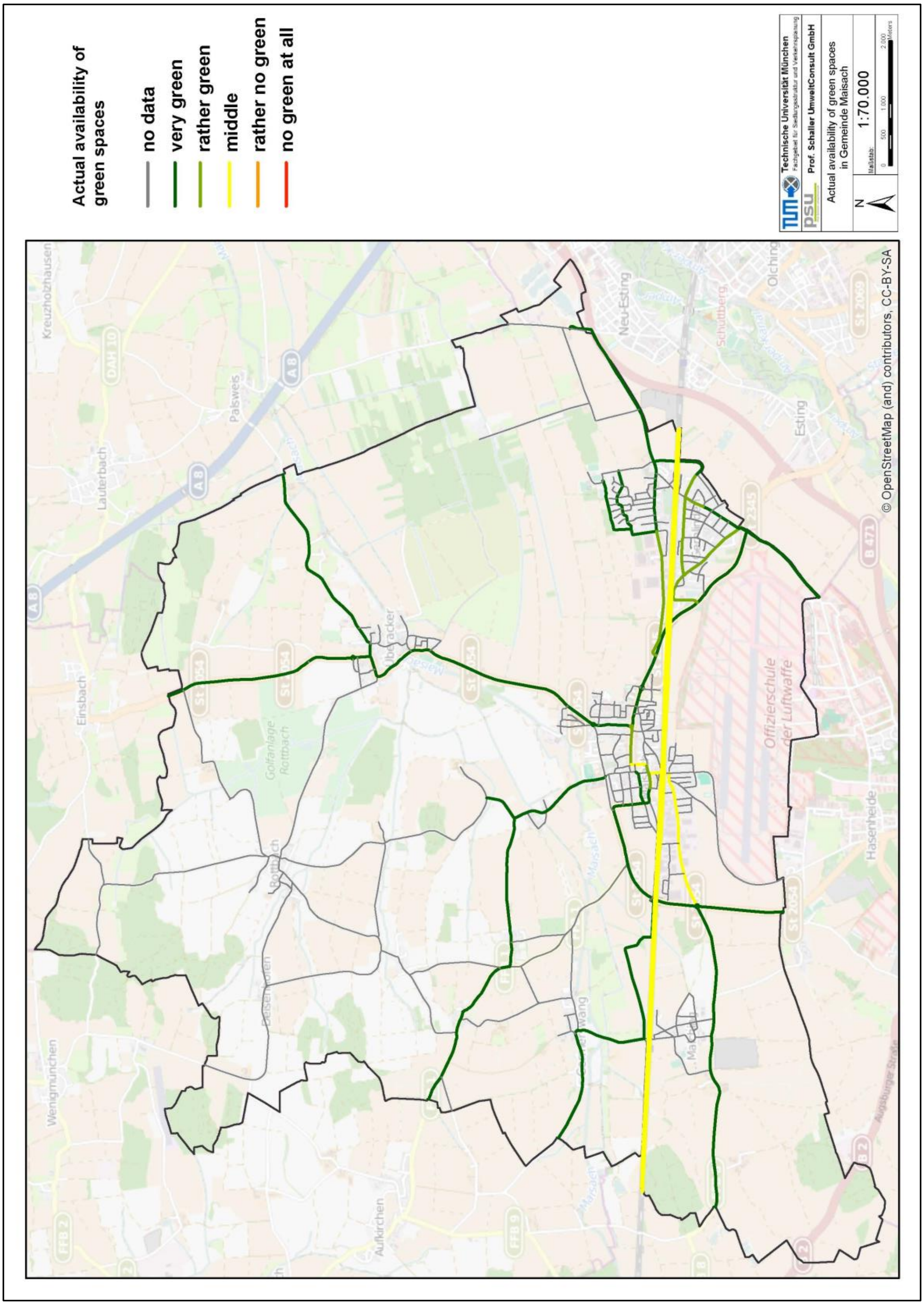


Figure 4.34: Actual availability of green spaces in Maisach

Figure 4.35 presents the perceived availability of green spaces in Maxvorstadt, as given by the participants of the survey.

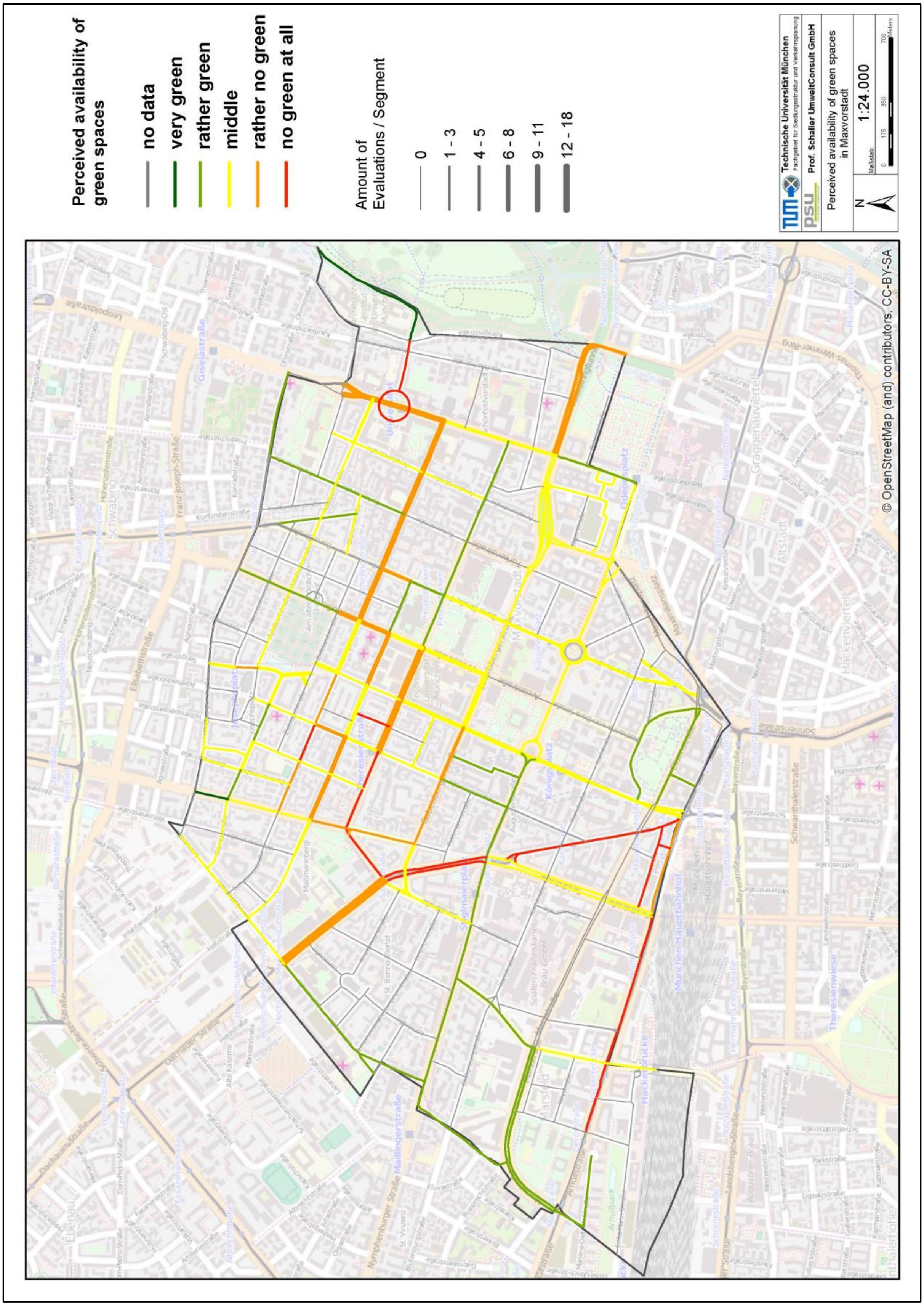


Figure 4.35: Perceived availability of green spaces in Maxvorstadt

Figure 4.36 gives an overview of the actual availability across the study area, as appraised by the author.

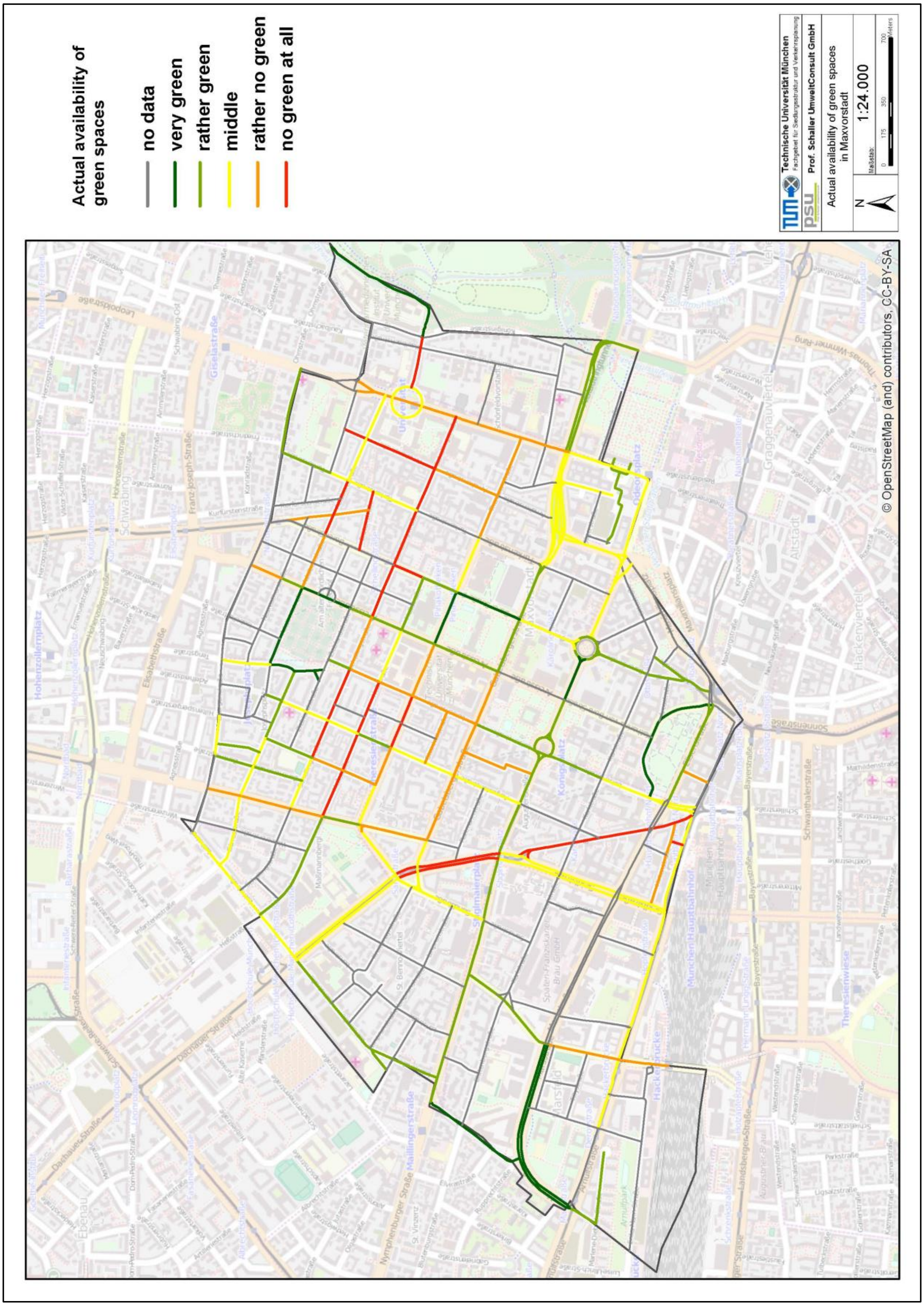


Figure 4.36: Actual availability of green spaces in Maxvorstadt

The comparison between the evaluations showed that in the municipality of Maisach 63% of the street sections had a same evaluation between the responders and the assessment done by the author. As observed in Figure 4.37, the remaining streets were evaluated with 1 level worse.

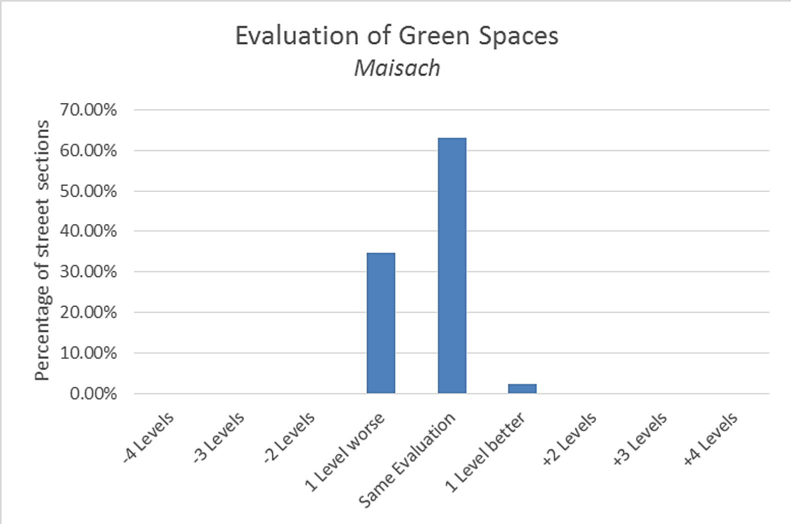


Figure 4.37: Comparison between green space's evaluations in Maisach

As far as the study area of Maxvorstadt is concerned, only a 40% of the segments showed a concurrence between the evaluations. Regarding the rest of the segments, both more negative and positive evaluations were met, with a higher percentage of street sections having a negative evaluation (Figure 4.38).

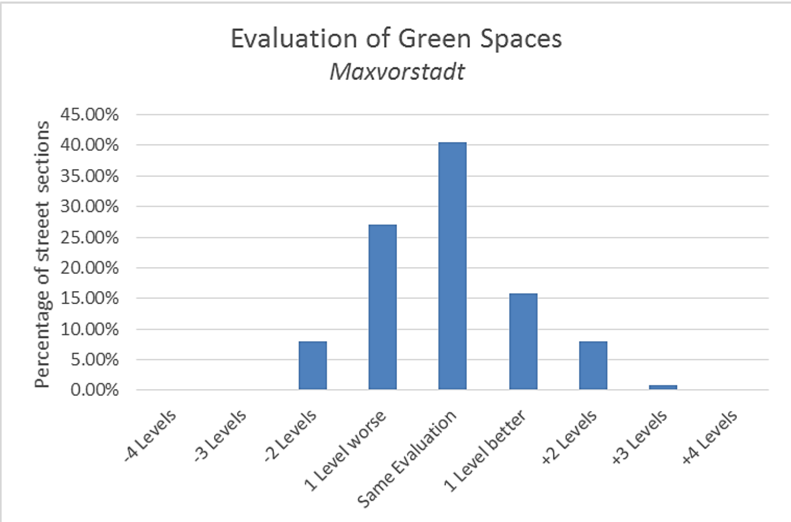


Figure 4.38: Comparison between green space's evaluations in Maxvorstadt

In general, in both samples the majority of the street sections were evaluated by the responders in a same way to the assessment of this thesis, but there was also a considerable amount of them, which was evaluated one level more negative (Figure 4.39).

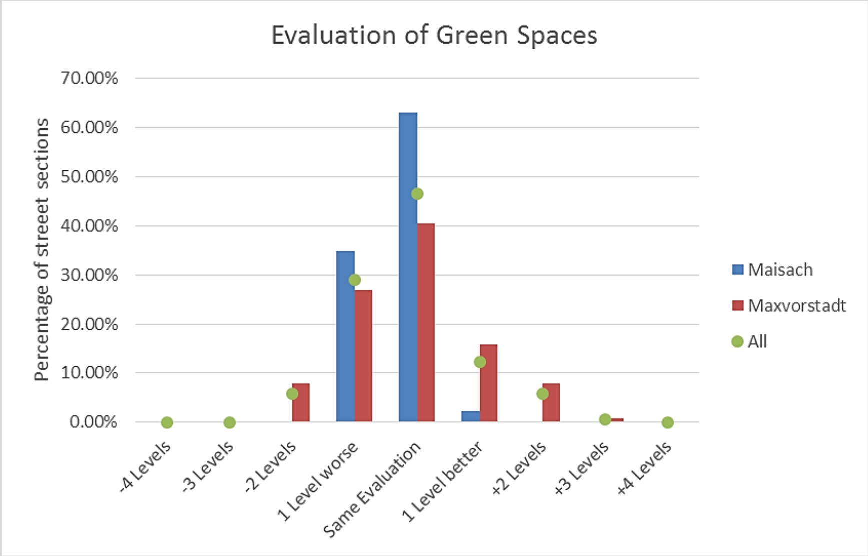


Figure 4.39: Comparison between green space's evaluations

4.5. Correlation between mobility behaviour and environmental quality

This part of the questionnaire aimed to answer the core objective of this thesis; if and to which extent different factors of environmental quality play a role in mobility behaviour. The questions that were asked involved aspects of air quality, noise levels, green spaces and provision of information about environmental quality and their interplay with specific mobility decisions.

4.5.1. Correlation between air quality and transport mode choice

This question of the survey aimed to answer whether air quality plays a role in the choice of transport mode. There was a hypothesis for instance, that someone would prefer to travel with motorised transport when he perceives bad air quality, in order to protect himself from pollution. The results of this question can be seen in the following figure.

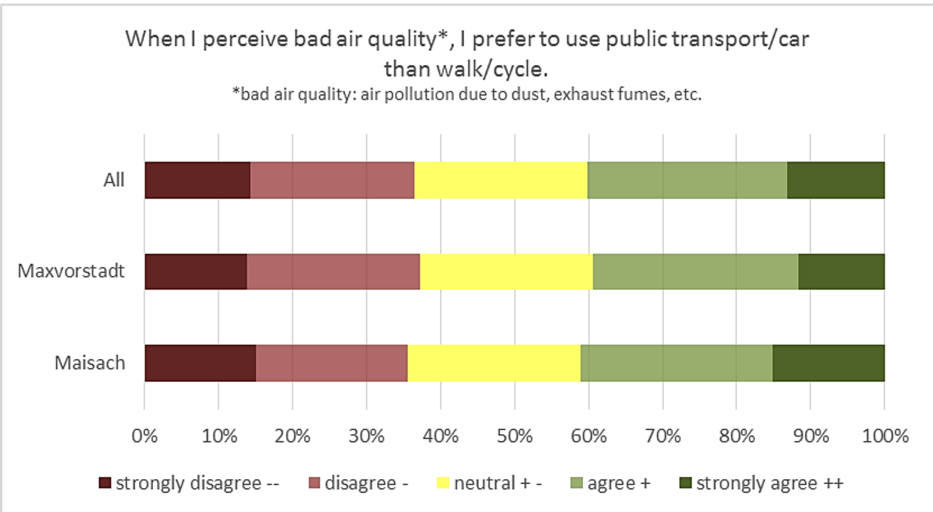


Figure 4.40: Influence of air quality on transport mode choice

A first look at the results, shows that there is an equal distribution of the possible answers to this question. In both study areas approximately a 40% of the responders considered that bad air quality can lead them to use preferably motorised transport modes. However, a slightly smaller percent of 37% in both samples believe that air quality has no influence on their choice for motorised transport modes. Finally, the rest of 23% hold a more neutral attitude towards this question.

The results from this question show that there is no direct impact of air quality to transport mode choice. Air quality seems to play a role for a 40% the responders, but almost a same amount of participants answered that air quality is not influencing their transport mode choice. An examination of the characteristics of the responders who had a positive attitude towards this question would be interesting for further research, in order to examine to which groups of people air quality plays a role in their mobility behaviour. However, within the limited time frame of this study, such an examination was not carried out.

4.5.2. Correlation between noise levels and transport mode choice

The second statement aimed to answer whether high noise levels along a route can be a constraining factor for walking and cycling. The results are presented in Figure 4.41.

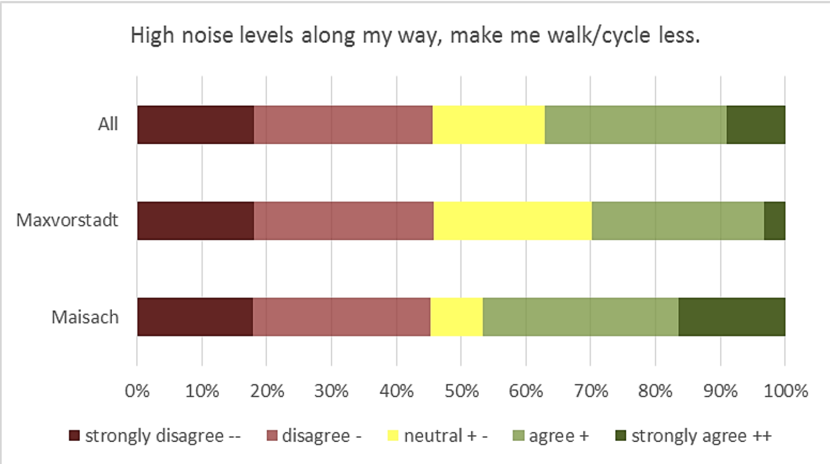


Figure 4.41: Influence of noise levels on transport mode choice

A 45% of the responders from both study areas considered that high noise levels do not make them walk or cycle less. In the study area of Maisach, there is also a 47% for whom strong noise pollution is a restraining factor for using non-motorised transport modes, whereas for the area of Maxvorstadt that percentage accounts to 30%. This difference may be explained by the fact that the responders from the municipality of Maisach are older than those from Maxvorstadt. As it is also suggested by the study of UBA regarding environmental awareness in Germany, older people present a higher annoyance due to noise than people younger than 29 years old. (UBA, 2013)

Again a straightforward correlation between noise levels and transport mode choice cannot be extracted from the above results, since almost a same amount of responders answered positively and negatively towards this statement. A more analytical examination of the background of the responders who replied positively towards this statement, might show to which groups of people, noise is considered important for choosing their transport mode. However, as explained before, due to time-constraining factors such an analysis was not done and therefore is recommended as a topic for further research.

4.5.3. Correlation between availability of green spaces and transport mode choice

This question examined the effect that green spaces have on walking and cycling, and furthermore whether more green spaces and cycle paths can achieve a modal shift from motorised transport to non-motorised.

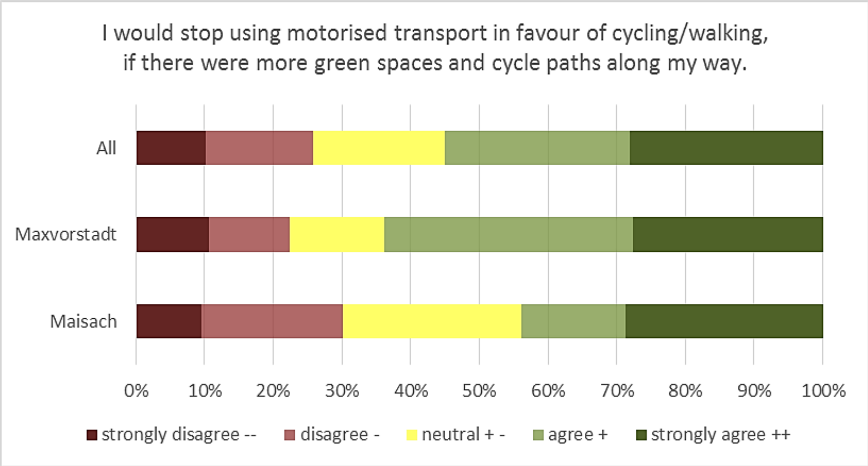


Figure 4.42: Influence of green spaces on transport mode choice

The results show a more clear correlation between transport mode choice and green spaces than air quality or noise levels. Regarding the study area of Maxvorstadt in particular, almost 65% of the responders replied that they would shift to non-motorised transport modes, if there were more green spaces and cycle paths available.

The respective percentage for the municipality of Maisach accounts to a bit less than 45%, a fact that could be expected, since the assessment done for this study area showed that already most of the paths in Maisach have a rather high availability of green spaces.

In general for both study areas, more than half of the responders replied positively to this statement. Therefore, it is safe to say that green spaces can be considered of a higher importance for choosing a non-motorised transport mode.

4.5.4. Correlation between provision of information about air quality and choice of transport mode

The following statement described to the responders the scenario that they read in the newspaper about the exceedance of the air pollution thresholds and asked them whether this would change their choice of transport mode. The statement aimed to examine the importance of provision of information regarding environmental quality to the public and moreover to understand to which extent people are willing to contribute on their own to achieving sustainable mobility.

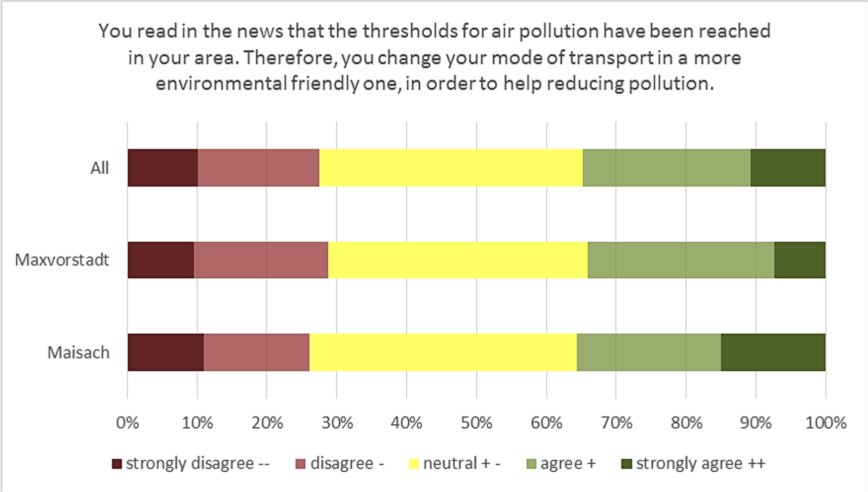


Figure 4.43: Influence of provision of information about environmental quality on mobility behaviour

As observed in Figure 4.43, a large number of responders in both study areas kept a rather neutral attitude towards this statement, whereas in general a 35% of the participants seemed willing to change their transport mode to an environmental friendlier one. As also found in the literature, air quality advisories for the public are not effective in changing individuals' behaviour, even in severe air quality episodes, and generally behaviour change is predominately motivated by the perception of environmental quality. (Semenza, et al., 2008)

As a consequence, provision of information about environmental quality in the news or by different means of communication, such as the internet or smartphone-applications, seems to not be a powerful measure to influence mobility behaviour changes. Furthermore, in case that publication of air quality episodes could trigger behaviour changes, the percentage of the responders, who seem to be willing to contribute personally to reducing air pollution at their area, is 35%.

4.5.5. Influence of green spaces on route choice

The last statement that was asked to the participants of the survey aimed to understand whether availability of open green spaces can have an impact in choosing a route.

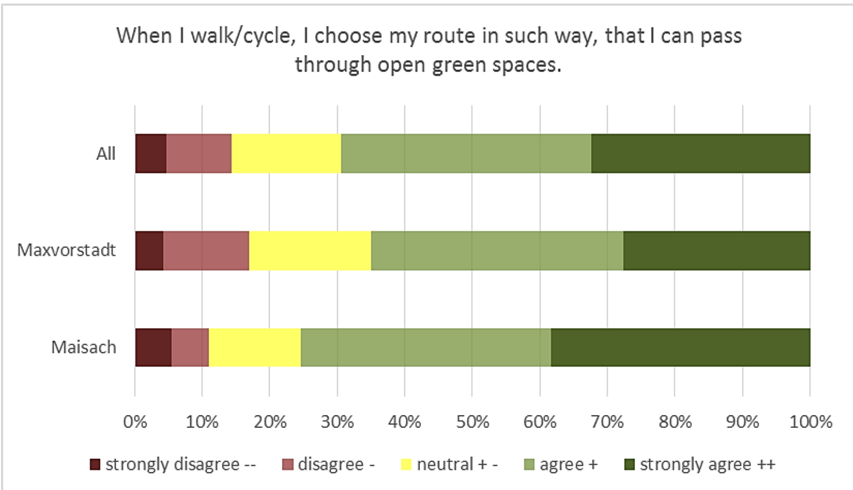


Figure 4.44: Correlation between availability of green spaces and choice of route

The results show a clear influence of green spaces on route choice for non-motorised transport. Roughly 70% of the responders agreed or strongly agreed that when they use non-motorised transport modes, they choose their path in such a way that they can pass through open green spaces. The result from this question agrees also with the outcome of other studies, found in the literature. A survey in London investigated the decisions that cyclists make when they decide which route to take. The result showed that almost half of the responders would change their route in order to travel through parks and/or green spaces, with around 15% saying that they would be prepared to use a significantly longer route. (Transport for London, 2012)

4.6. Discussion of the results

This chapter gave an extensive presentation of the answers that were given by both samples. In general, both genders answered equally the survey, with younger ages dominating the sample of Maxvorstadt and older ages the sample of Maisach. In correspondence to the ages, the sample of Maxvorstadt contained mostly students with lower income, whereas the majority from the municipality of Maisach were employees with high income.

Regarding the availability of transport modes, the participants from Maisach had a variety of modes available, while in the contrary, the majority of the responders from Maxvorstadt were more captive users of public transport, but also owned a fully functional bicycle. The analysis of the answers showed furthermore that in both study areas health, safety and environmental friendliness seem not to have a strong influence on transport mode choice. Instead, trip purpose, travel time, travel costs and weather proved to be the most important factors to choose a transport mode.

During the survey the participants were asked to input information about the most frequent trip they undertake during the week. The result showed that people from Maisach travel longer distances (25 - 100 km) than the responders of Maxvorstadt (2 - 25 km) and most of their trips are done by car, whereas the majority from the sample of Maxvorstadt choose public transport instead. Both samples need less than half an hour to reach their destination and their trip purpose is highly dependent on their occupation.

As far as the perception of environmental quality is concerned, the results showed that in general the sample of Maisach perceive more precisely the environmental quality than the sample of Munich. The factors that are better perceived are green spaces and air quality, while noise seems to be a more subjective matter. The mapping of the perceived environmental quality with the help of ArcGIS, showed that there is also a correlation between the perception of quality and the structures of the study areas. Maisach is a rural area with a sparse development and low density of buildings. In addition, the assessment done in Chapter 3 showed that most of its paths contain a high amount of green elements. On the other hand, the area of Maxvorstadt is located in the core part of the city of Munich. High density of high buildings, as well as bigger streets with high traffic volumes are met within the area.

By comparing the evaluations given by the responders and are not corresponding to the evaluation done by the author, it can be observed that most of them coming from the rural area of Maisach were usually more positive than the evaluation assigned for the actual environmental quality. Compared to Maisach, most of the respective evaluations within the urban area of Maxvorstadt were more negative.

This difference is possibly observed, due to the different structures of the two areas. For instance, streets in the municipality of Maisach with a high availability of green spaces showed more positive evaluations of air quality and noise than the actual values, whereas street sections of Maxvorstadt with a small amount of green elements, showed more negative evaluations than the actual values. To sum up, green areas and air quality are generally more precisely perceived, but it should be also taken into consideration that spatial structure can also play a role in the perception of the environmental quality, where more sparse settlements, with less traffic volumes and more green spaces, can lead to a more positive perception of environmental quality than it actually is.

The main objective of this thesis was to examine to which extent the different factors of environmental quality play a role in taking a mobility decision. The results showed that air quality and noise levels do not seem to have a strong influence on mobility behaviour and more specifically to transport mode choice for the majority of the responders. On the other hand, the correlation between green spaces and mobility behaviour is more blatant. Open green spaces can urge people to shift to non-motorised transport modes and consist also an important factor for pedestrians and cyclists to choose their route. Finally, provision of information regarding air quality seems not to be able to trigger behaviour changes and the percentage of the responders that appeared to be willing to contribute personally to sustainable mobility accounts to 35%.

5. Conclusions and Outlook

This final chapter gives a compact summary of this thesis, in order to help the reader receive a condensed overview of the work that was done. In addition, the basic conclusions drawn by this study are outlined in this chapter. Finally, it gives an overview of the study's contribution to the field of sustainability and gives some recommendations for researchers who would like to further investigate this topic.

5.1. Conclusions

The aim of this thesis was to examine whether and to which extent environmental quality can play a role into taking a mobility decision. Generally, it is widely accepted that the transport sector highly contributes to the intervention that humans have on the planet and its environment. Mobility behaviour is only a small part of a transportation system but with a strong influence on environmental quality and quality of life. However, it was not thoroughly examined so far, whether there is a counteraction of environmental quality on mobility behaviour.

Initially, an extensive literature review was carried out in order to cover all the aspects that were necessary for developing a suitable methodology, which would meet the answering of the study's research question. After examining the gaps that exist in the existing literature, the limits that this thesis was bound to were set up. The wider terms of mobility behaviour and environmental quality were adjusted to the framework of a Master's Thesis and the parameters of these terms that this study would examine were selected.

By the same token, it was necessary to define also some geographical boundaries of the investigation. The effect that environmental quality has on mobility behaviour was examined for two types of spatial structures, a rural and an urban settlement. The municipality of Maisach was selected as an example for the rural area and the district of Munich, Maxvorstadt, was selected as the case study of the urban area. Finally, both a qualitative and a quantitative analysis were conducted.

Regarding the qualitative analysis, an online survey was designed to answer the objective of the study. A new method was used, which allowed the responders to give their exact route of their most frequent trip, a feature that was not available so far in a frame of an online survey. Along this trip, the participants evaluated how they perceive the selected factors of environmental quality. Moreover, the survey gathered data regarding sociodemographic aspects of the two samples, availability of different transport modes in the two study areas and factors that influence the choice of them. Finally, it examined the aspects that were needed to answer the core objective of the thesis.

In order to examine the evaluations of environmental quality given by the participants, it was also necessary to conduct a quantitative analysis, which appraised the actual environmental quality within the two study areas. Data containing information about air quality, noise levels and availability of greens paces were gathered or estimated and its analysis led to a visual representation of environmental quality within the two study areas, done with the help of ArcGIS. After presenting the two analyses that were carried out, the results were communicated to the reader with the help of maps and descriptive graphs.

The results showed that air quality and noise levels along a path do not seem to have a straightforward relationship with transport mode choice, at least for the majority of the responders. On the other hand, availability of green spaces along a path can play a more vital role in sustainable mobility behaviours. The outcome showed that open green spaces have the potential to achieve a modal shift to non-motorised transport modes and furthermore can play a role in choosing a route.

Another aspect that this thesis examined was the perception of environmental quality. The results showed that air quality and green spaces' availability are more precisely perceived than noise levels, which seemed to be a more subjective matter. A strong correlation was also found between spatial structure and perception of environmental quality. Within the rural case study, where more green elements are visible and smaller traffic volumes are measured, the evaluations that did not agree with the assessment based on the actual data, tended to be more positive than the actual values of environmental quality. On the contrary, within the urban case study, where green spaces are strongly fewer than the rural area and the transport scheme leads to higher traffic volumes, there was a remarkable amount of evaluations that described the environmental quality of the area more negative than it really was.

These dissimilarities between the two different spatial settlements show that green spaces can play a major role in sustainable mobility and the level of 'quality of life' of an area. As a consequence, this thesis suggests to policy makers to invest in developing more green spaces. Furthermore, during the conduction of the survey the author received some emails with comments regarding the traffic situation at the municipality of Maisach. These comments included aspects regarding barriers that keep cycling from being a safe and attractive alternative of a transport mode, problems with infrastructure, as well as critical comments regarding the land-use development of the municipality.

Close to the residential areas of Maisach and Gernlinden, an industrial area was massively developed the last years, which led to a remarkable increase of traffic volumes and percentage of trucks in the streets. The residents of the municipality complained that the trucks are now passing through the residential areas, causing a proportional increase of noise levels.

As far as the latter is concerned, two comments were saying that although the noise levels from the rail tracks are higher, the annoyance is not so strong. "*The noise from the S-Bahn is somehow smoother and it does not disturb me so much*". On the other hand, all of the received comments described the noise, caused by street traffic, as much more disturbing; "*Traffic noise have now reached dramatic proportions*", "*The traffic volume and volume levels has greatly increased, whereas on the other hand the quality of life has (directly proportional) decreased*". The last comments show a strong will from the residents, for putting more effort regarding mitigation of street noise. All the above comments were forwarded to the Department of

Planning and Building Inspection (Bauamt) of Maisach, with the hope that will be taken into consideration to the future transport and land-use development plans of the municipality.

Finally, this thesis contributed to the wider field of conducting qualitative analysis in the transportation research field. The feature of integrating a map platform at an online survey, in order to receive exact routes of the participants, was widely asked from transport researchers. However, no one had published a solution to this until the day that this thesis was submitted. This fact played also its role for investing the time in developing such a feature.

The methodology that was followed by this thesis was however not unproblematic and some critical comments are required to be mentioned. The basic barrier that was met during the implementation of the methodology was the lack of available data regarding the environmental quality. Although all of the respective authorities were asked, no available data could be found. That led to the need to estimate own noise levels for the municipality of Maisach and to extrapolate conclusions about the air quality from neighbour areas. In addition, although there is a monitoring station within the study area of Maxvorstadt, the concentrations of air pollutants are representative for the point where the station is located and a radius around it. The local pollution in the rest of the street network may vary, due to the different traffic volumes at each street.

As far as the assessment of available green spaces is concerned, although the appraisal done by the author tried to be as objective as possible, it is possible that subjective aspects may have also been taken into consideration. As a consequence, it would be interesting to also have an analysis of green spaces with quantitative indicators, a method that was not used during this thesis, due to time-constraining factors and lack of available data.

In any case, it is strongly highlighted that there is a need for more detailed and up-to-date data and is suggested to the authorities to invest more in environmental quality mapping, since it can be proven a really useful tool for further research or similar studies.

Another aspect of the methodology that might have required a more detailed analysis was the comparison between perceived and actual environmental quality. During the survey, the responders were given the option to omit the evaluation of environmental quality along the trips that were done by motorised transport modes. However, most of the responders evaluated eventually also these trips, and thus it was decided to take into account these evaluations.

The problem of this decision, lies on the fact that it is not clear whether the evaluation was given for the outdoor environmental quality of the route or considering the environmental quality from inside the motorised transport mode. On the other hand, the environmental assessment done by the author examined only the outdoor environmental quality along the routes. Therefore, the comparison made between the perceived and actual appraisals, might lack of accuracy.

5.2. Outlook

The data that was gathered through this survey has a very big potential of further analysis. For instance, it would be interesting to examine the social characteristics of the responders who had a positive attitude towards the statements, which examined the correlation between environmental quality and mobility behaviour. A further examination would possibly allow researchers to identify a group of characteristics of individuals, for whom environmental quality factors can play indeed a role in their travel behaviour, which in turn can aid urban and transport policy, planning and design.

Moreover, the responders of the survey chose the most important factors for choosing a transport mode. Although a representation of this evaluation was given by this thesis, there is more potential in further analysis of this data. Using the different factors (travel time, trip purpose, etc.) as independent variables and in combination to the transport mode the responders actually choose for their most frequent trip, a binary logistic regression can show, which the probability of choosing a specific transport mode instead of another is, based on the different factors.

To conclude, no matter what the technological inventions of the future will be or what scientists and engineers suggest, the highest potential in achieving sustainability within our societies is located inside each human being. Personal behavioural changes are mandatory in order to refute the negative scenarios describing the future. This thesis tried to contribute to the better understanding and assessment of human behaviours, with the hope that it will help authorities to develop the appropriate methods that will enable everyone realise how vital their own contribution is and that will push them to more sustainable behaviours.

References

BAYSIS, 2014. *BAYSIS - Bayerisches Straßeninformationssystem.* [Online]
Available at: https://www.baysis.bayern.de/
[Accessed 25 October 2014].

Bundesministerium der Justiz und für Verbraucherschutz, 1990. *Sechzehnte Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes (Verkehrslärmschutzverordnung - 16. BImSchV).* s.l.:s.n.

Bush, J., Moffatt, S. & Dunn, C. E., 2001. Keeping the public informed? Public negotiation of air quality information. *Public Understanding of Science*, 10(2), pp. 213-229.

Butler, H. et al., 2008. *The GeoJSON Format Specification.* [Online]
Available at: http://geojson.org/
[Accessed 22 October 2014].

Cervero, R., 2002. Built environments and mode choice: toward a normative framework. *Transportation Research Part D: Transport and Environment*, 7(4), pp. 265-284.

CITEAIR II, 2007. *Comparing Urban Air Quality Across Borders - A review of existing air quality indices and the proposal of a common alternative*, Schiedam, The Netherlands: DCMR, Environmental Protection Agency Rijnmond.

CITEAIR, 2004. *CITEAIR.* [Online]
Available at: http://citeair.rec.org/home.html
[Accessed 16 Ocotber 2014].

Clifton, K. J. & Handy, S. L., 2001. *Qualitative Methods in Travel Behaviour Research,* Davis: Institute of Transportation Studies, University of California.

Coppola, P. & Papa, E., 2013. Accessibility planning tools for sustainable and integrated Land Use/Transport (LUT) development: an application to Rome. *Procedia - Social and Behavioral Sciences,* Volume 87, pp. 133 - 146.

Curtis, C. & Perkins, T., 2006. *Travel Behaviour: A review of recent literature. Impacts of Transot LED Development in a new rail corridor - Working Paper No. 3.* [Online]
Available at: http://urbanet.curtin.edu.au/local/pdf/ARC_TOD_Working_Paper_3.pdf
[Accessed 02 June 2014].

den Boer, L. C. & Schroten, A., 2007. *Traffic noise reduction in Europe,* Delft: CE Delft.

ECMA International, 2013. *The JSON Data Interchange Format,* Geneva: ECMA International.

EEA, 2009. *Ensuring quality of life in Europe's cities and towns,* Copenhagen: European Environment Agency.

EEA, 2010a. *Urban Atlas.* [Online]
Available at: http://www.eea.europa.eu/data-and-maps/data/urban-atlas
[Accessed 05 June 2014].

EEA, 2010b. *The European environment — state and outlook 2010: synthesis,* Copenhagen: European Environment Agency.

EEA, 2013a. *The contribution of transport to air quality,* Copenhagen: European Environment Agency.

EEA, 2013b. *Air Pollution Fact Sheet 2013 -Germany,* Copenhagen: European Environment Agency.

EEA, 2014. *Sectoral GHG emissions by IPCC sector,* Copenhagen: European Environment Agency.

Eisenbahn-Bundesamt, 2008. *Lärmkartierung.* [Online]
Available at: http://laermkartierung.eisenbahn-bundesamt.de/
[Accessed 17 October 2014].

EPA, 2013. *Our Built and Natural Environments: A Technical Review of the Interactions among Land Use, Transportation, and Environmental Quality,* Washington: US Environmental Protection Agency.

EPA, 2014a. *Climate Change Indicators in the United States: Greenhouse Gases.* [Online]
Available at: http://www.epa.gov/climate/climatechange/science/indicators/ghg/index.html
[Accessed 18 June 2014].

EPA, 2014b. *What is Open Space/Green Space?.* [Online]
Available at: http://www.epa.gov/region1/eco/uep/openspace.html
[Accessed 06 June 2014].

Eriksson, L., 2008. *Pro-environmental travel behavior: The importance of attitudinal factors, habits, and transport policy measures,* Sweden: Department of Psychology, Umeå University.

EU Project: Add Home, 2009. *Factors of influence on mobility behaviour and the choice of transport mean.* [Online]
Available at: http://add-home.eu/docs/Factors_Influence_Mobility_Behaviour.pdf
[Accessed 28 May 2014].

EU, 2008. *Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.* Brussels: European Parliament.

EU, 2013. *Speech by Janez Potočnik, European Commissioner for Environment, 'Air quality: Meeting the challenge of protecting our health and environment', SPEECH/13/4.* Brussels: European Commision.

European Comission, 2009. *Action Plan on Urban Mobiltiy.* [Online]
Available at:
http://ec.europa.eu/transport/themes/urban/urban_mobility/doc/com_2009_490_5_action_plan_on_urban_mobility.pdf
[Accessed 28 May 2014].

European Commision, 2014. *Noise - The EU Policy on environmental noise.* [Online]
Available at: http://ec.europa.eu/environment/noise/home.htm
[Accessed 10 June 2014].

European Commission, 1996. *FUTURE NOISE POLICY European Commission Green Paper.* Brussels: European Commission.

European Commission, 2001. *Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development.* [Online]
Available at: http://aei.pitt.edu/42719/1/COM_%282001%29_264_final.pdf
[Accessed 28 May 2014].

European Commission, 2002. *Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise - Declaration by the Commission in the Conciliation Committee on the Directive relating to the assessment.* and management of environmental noise Brussells: European Parliament.

European Commission, 2003. *Integration of environment into transport policy – from strategies to good practice.* [Online]
Available at: http://ec.europa.eu/environment/archives/gpc/pdf/transp_policy_en.pdf
[Accessed 28 May 2014].

European Commission, 2010. *Perception Survey on Quality of Life in European Cities: Analytical Report, Fieldwork: November 2009, Flash Eurobarometer No. 277,* Brussels: European Commission.

GAF AG, 2012. *obsAIRve - a GMES air quality service.* [Online]
Available at: http://www.obsairve.eu/
[Accessed 2014 October 2014].

Gemeinde Maisach, 2014. *Gemeinde Maisach.* [Online]
Available at: http://www.maisach.de
[Accessed 01 September 2014].

GEMET, 2004. *General Multilingual Environmental Thesaurus.* Copenhagen: European Topic Centre on Catalogue of Data Sources (ETC/CDS) and the European Environment Agency.

Geofabrik, 2014. *Download OpenStreetMap data for this region: Oberbayern.* [Online]
Available at: http://download.geofabrik.de/europe/germany/bayern/oberbayern.html
[Accessed 04.06.2014].

Gidlöf-Gunnarsson, A. & Öhrström, E., 2007. Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas. *Landscape and Urban Planning,* Volume 83, pp. 115-126.

Google Inc., 2014. *Google Maps Javascript API v3.* [Online]
Available at: https://developers.google.com/maps/documentation/javascript/
[Accessed 03 September 2014].

Google Maps, 2014. *Google Maps.* [Online]
Available at: https://www.google.de/maps/
[Accessed October 21 2014].

Grosvenor, T., 2000. *"Qualitative Research in the Transport Sector. Resource paper for the Workshop on Qualitative/Quantitative Methods" Proceedings of an International Conference* *on Transport Survey Quality and Innovation.* Grainau, Germany, Transportation Research E-Circular.

Hensher, D. A. & King, J., 2001. Parking demand and responsiveness to supply, pricing and location in the Sydney central business district. *Transportation Research Part A: Policy and Practice,* 35(3), pp. 177-196.

Hiscock, R., Macintyre, S., Kearns, A. & Ellaway, A., 2002. Means of transport and ontological security: Do cars provide psychosocial benefits to their users?. *Transportation Research Part D: Transport and Environment*, 7(2), pp. 119-135.

Hunecke, M., Hausteina, S., Grischkatb, S. & Böhler, S., 2007. Psychological, sociodemographic, and infrastructural factors as determinants of ecological impact caused by mobility behaviour. *Journal of Environmental Psychology,* Volume 27, pp. 277-292.

Infas, 2009. *Mobilität in Deutschland 2008.* [Online]
Available at: http://www.mobilitaet-in-deutschland.de/pdf/MiD2008_Abschlussbericht_I.pdf
[Accessed 09.06.2014].

Landeshauptstadt München, 2007. *Quantitative Versorgung mit öffentlichen allgemein zugänglichen Grünflächen.* München: Landeshauptstadt München - Referat für Stadtplanung und Bauordnung.

Landeshauptstadt München, 2009. *Schwarzplan Grün- und Freiflächen.* München: Landeshauptstadt München - Referat für Stadtplanung und Bauordnung.

Landeshauptstadt München, 2014. *Lärmkarten EU - München 2007.* [Online]
Available at: http://maps.muenchen.de/laerm/laermminderungsplan.html
[Accessed 17 October 2014].

Lansing, J. B. & Marans, R. W., 1969. Planner's notebook: Evaluation of neighbourhood quality. *Journal of the American Institute of Planners,* Volume 35, pp. 195-199.

LfU, 2014a. *Aktuelle Werte der bayerischen Luftmessstationen.* [Online]
Available at: http://www.lfu.bayern.de/luft/lueb/index.htm
[Accessed 10 October 2014].

LfU, 2014b. *Lärmbelastungskataster Bayern.* [Online]
Available at: http://www.bis.bayern.de/bis/initParams.do?role=laerm
[Accessed 17 October 2014].

LÜB, 2014. *Dokumentation der Luftmessstationen.* [Online]
Available at: http://www.lfu.bayern.de/luft/immissionsmessungen/dokumentation/index.htm
[Accessed 14 October 2014].

Ministerium für Verkehr und Infrastruktur Baden-Württemberg, 2014. *Städtebauliche Lärmfibel.* [Online]
Available at: http://www.staedtebauliche-laermfibel.de/
[Accessed 20 October 2014].

Minnesota Department of Natural Resources, 2014. *DNRGPS Application.* Minnesota: Minnesota Department of Natural Resources.

Moore, G. et al., 2006. Urban environmental quality: perceptions and measures in three UK cities. *WIT Transactions on Ecology and the Environment*, Volume 93.

MVV, 2010. *Mobilität im Landkreis Fürstenfeldbruck,* München: Münchner Verkehrs- und Tarifverbund GmbH (MVV).

Nikolopoulou, M.-H., Kleissl, J., Linden, P. F. & Lykoudis, S., 2011. Pedestrians' perception of environmental stimuli through field surveys: Focus on particulate pollution. *Science of the Total Environment,* 409(13), pp. 2493-2502.

Nilsson, M. & Küller, R., 2000. Travel Behaviour and environmental concern. *Transportation Research Part D: Transport and Environment*, 5(3), pp. 211-234.

Polk, M., 2003. Are women potentially more accommodating than men to a sustainable transportation system in Sweden?. *Transportation Research Part D: Transport and Environment*, 8(2), pp. 75-95.

Porteous, J. D., 1971. Design with people: the quality of the urban environment. *Environment and Behavior,* 3(2), pp. 195-199.

Prillwitz, J. & Barr, S., 2009. *Motivations and Barriers to Adopting Sustainable Travel Behaviour - Working paper 2 for the ProST project.* [Online]
Available at: http://geography.exeter.ac.uk/prost/Downloads/WP2-Motivations-Barrierers.pdf
[Accessed 11 June 2014].

Rodrigue, J. P., 2013. *The geography of transport systems.* 3rd ed. New York: Routledge.

Ryley, T., 2005. Use of non-motorised modes and life stage in Edinburgh. *Journal of Transport Geography*, 14(50), pp. 367-375.

Schneider, A., 2005. *GPS Visualizer.* [Online]
Available at: http://www.gpsvisualizer.com/
[Accessed 22 October 2014^].

Semenza, J. C. et al., 2008. Public perception and behaviour change in relationship to hot weather and air pollution. *Environmental Research,* Volume 107, pp. 401-411.

Silva, J., de Keulenaer, F. & Johnstone, N., 2012. *Environmental Quality and Life Satisfaction: Evidence Based on Micro-Data - OECD Environment Working Papers, No. 44,* Paris: OECD Publishing.

Simons, D. et al., 2013. Factors influencing mode of transport in older adolescents: a qualitative study. *BMC Public Health*, 13(323).

Soltani, A. & Primerano, F., 2005. *The effects of community design.* Australia, 28th Australasian Transport Research Forum (ATRF).

Statistische Ämter des Bundes und der Länder, 2011. *Handbuch zur Erstellung von Erhebungsunterlagen der amtlichen Statistik : Vereinbarungen und Leitlinien,* Wiesbaden: Statistische Ämter des Bundes und der Länder.

Statistisches Amt München, 2014. *Die Bevölkerung in den Stadtbezirken nach der Einwohnerdichte am 31.12.2013.* [Online]
Available at:
http://www.muenchen.de/rathaus/dms/Home/Stadtinfos/Statistik/bevoelkerung/aktuelle-jahreszahlen/jt140102.pdf
[Accessed 2014 September 02].

Transport & Environment, 2014. *EU Transport Policy.* [Online]
Available at: http://www.transportenvironment.org/what-we-do/eu-transport-policy
[Accessed 20 November 2014].

Transport for London, 2012. *Cycle route choice,* London: Transport for London.

TUM-PSU, 2012. *Integriertes Klimaschutzkonzept des Landkreises Fürstenfeldbruck und seiner Städte und Gemeinden (Los 2),* München: TUM-PSU.

U.S. Department of Labor, 2014. *United States Department of Labor.* [Online]
Available at: https://www.osha.gov/dts/osta/otm/noise/images/common_sounds.gif
[Accessed 20 October 2014].

UBA, 2010. *CO2- Emissionsminderung im Verkehr in Deutschland,* Dessau-Roßlau: Umweltbundesamt.

UBA, 2011. *Umweltbewusstsein in Deutschland 2010,* Dessau-Roßlau: Umweltbundesamt.

UBA, 2012. *Traffic Noise.* [Online]
Available at: http://www.umweltbundesamt.de/en/themen/verkehr-larm/verkehrslarm/traffic-noise
[Accessed 10 June 2014].

UBA, 2013. *Umweltbewusstsein in Deutschland 2012,* Dessau-Roßlau: Umweltbundesamt.

UBA, 2014a. *Particulates and nitrogen dioxide still a health burden in 2013.* [Online]
Available at: https://www.umweltbundesamt.de/en/press/pressinformation/particulates-nitrogen-dioxide-still-a-health-burden
[Accessed 06 June 2014].

UBA, 2014b. *Aktuelle Luftdaten.* [Online]
Available at: http://www.umweltbundesamt.de/daten/luftbelastung/aktuelle-luftdaten
[Accessed 2014 October 14].

van Kamp, I., Leidelmeijer, K., Marsman, G. & de Hollander, A., 2003. Urban Environmental Quality and Human Well Being Towards a Conceptual Framework and Demarcation of Concepts; a literature study. *Landscape and Urban Planning,* Volume 65, pp. 5-18.

WestAllianz München GbR, n.d.. *WestAllianz München - Der Standort.* [Online]
Available at: http://www.westallianz-muenchen.de/westallianz/wir/maisach
[Accessed 1st September 2014].

White, M. P., Alcock, I., Wheeler, B. & Depledge, M. H., 2013. Would You Be Happier Living in a Greener Urban Area? A Fixed-Effects Analysis of Panel Data. *Psychological Science*, 24(6), pp. 920-928.

WHO, 2008. *Ambient (outdoor) air quality and health - Fact sheet no 313 - Updated March 2014.* [Online]
Available at: http://www.who.int/mediacentre/factsheets/fs313/en/
[Accessed 2014 November 2014].

WHO, 2008. *Transport, Health and Environment. Trends and development in Europe (1997-2007),* New York and Geneva: WHO/Europe and UNECE-The Pep.

WHO, 2014. *Noise.* [Online]
Available at: http://www.euro.who.int/en/health-topics/environment-and-health/noise/noise
[Accessed 10 June 2014].

Wikipedia, 2010a. *Lage der Gemeinde Maisach im Landkreis Fürstenfeldbruck.* [Online]
Available at: http://de.wikipedia.org/wiki/Datei:Maisach_in_FFB.svg
[Accessed 01 September 2014].

Wikipedia, 2010b. [Online]
Available at: http://de.wikipedia.org/wiki/Datei:Munich_Maxvorstadt.svg
[Accessed 10 September 2014].

Zinemedia Agentur, 2014. *München Maxvorstadt - Alles auf einen Klick.* [Online]
Available at: http://www.maxvorstadt-muenchen.de/
[Accessed 10 September 2014].

ANNEX 1: Questionnaire

Mobility Behaviour and Environmental Quality

Thank you in advance for your time to answer our survey.

The questionnaire will take approx. 10 minutes of your time. Responses to this survey are considered confidential and therefore individual responses will not be released, shared or published. However, we may share the results of this survey with the public in anonymized or aggregated data sets.
The survey ends on 10.10.2014.

<u>Purpose of the questionnaire:</u>

With this questionnaire we aim to find out which aspects related to your most frequent trip affect your mobility decisions.
The results will allow us to give policy recommendations for more sustainable mobility in your area.
Therefore, the time you spend answering this questionnaire is very valuable.

<u>Incentive:</u>

As an incentive we will raffle 2 coupons for Deutsche Bahn, with a value of 50 Euro each. If you wish to participate in the lottery you can leave your contact data at the end.
Your contact data will not be published or shared in any way.

In case you have questions regarding the filling of the survey, please contact:

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www.sv.bgu.tum.de

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Domagkstraße 1a, 80807 München
www.psu-schaller.de

The survey is supported by TUM, PSU GmbH and the community of Maisach.

Information about your transport mode

Do you own a fully functional bicycle?

- Yes
- No

Do you have access to a personal car?

- Yes
- No

Are you a member of a Car-Sharing programme, eg. "Stattauto", "Car2Go", "Drive Now"?

- Yes
- No

In which car-sharing programme are you a member of?

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '3 [Q3]' (Are you a member of a Car-Sharing programme, eg. "Stattauto", "Car2Go", "Drive Now"?)

- Car2go
- CiteeCar
- Drive Now
- Flinkster
- Stadtteil Auto
- Stattauto
- Other

Do you own a monthly public transport ticket (MVV-Abo, Semesterticket, DB-Angebote, etc.)?

- Yes
- No

To which extent are the following criteria influencing your choice of transport mode?

	1 - not at all	2	3	4	5 - fully
Comfort	○	○	○	○	○
Health	○	○	○	○	○
Habit (part of my routine)	○	○	○	○	○
Travel Costs	○	○	○	○	○
Safety	○	○	○	○	○
Environmental Friendliness	○	○	○	○	○
Weather	○	○	○	○	○
Time needed to destination	○	○	○	○	○
Trip purpose (Work, leisure, shopping, etc.)	○	○	○	○	○

Information about your most frequent trip

In this section, we would like to learn about how you perceive the surrounding of your most frequent trip.

According to research made so far, someone's most frequent trip during a week is usually the home-work and work-home trip.
A recent study found that regarding the trip <u>going to work</u>, time is the most important factor that affects mobility behaviour. However, for the trip <u>back to home</u>, other factors seem to be more important than before.

Now, think about your most frequent trip during the week and specifically the part <u>back to home</u> (eg. work-to-home).

What is the purpose of this most frequent trip?

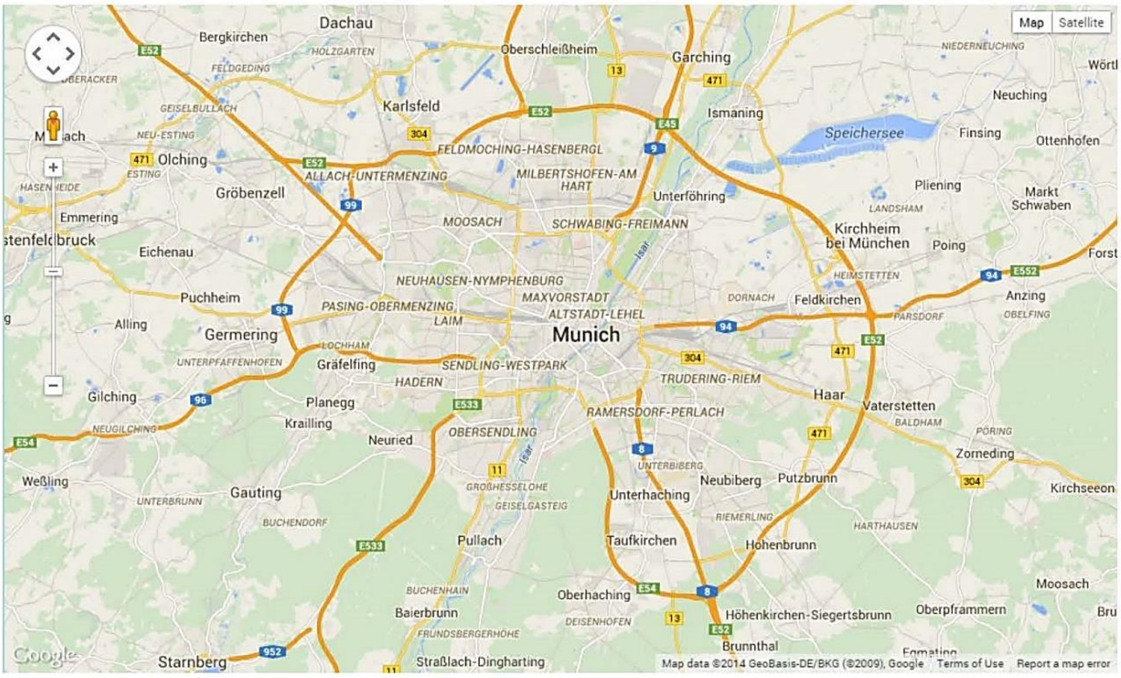
- ○ Work
- ○ Trainee (Ausbildung)
- ○ School / University
- ○ Other [ ]

Please give the Start and End address of this trip and choose the transport mode you usually use for it. Then <u>press</u> the button 'Route'.

In order to represent your route exactly, please change any discrepancies by dragging the blue line at the desired locations (Google does not allow it for transit).

<u>Your Origin and Destination information will not be published or shared in any way, and will be only used for research purposes in aggregated datasets.</u>

Start: Start Address **Ziel:** End Address **Verkehrsmittel:** Car ▼ Route



Please enter then the exact sections of your route in the following table and evaluate air quality, noise and the availability of green areas along your route. The evaluation of these factors may be neglected for parts of the trip made by motorised transport modes.

Examples for the trip 81539 (PLZ) - TUM with different transport modes:

	Strasse / PLZ / Ort / Haltestelle (Start)	Strasse / PLZ / Ort / Haltestelle (Ziel)	Verkehrsmittel	Zeit (min)	Luftqualität	Lärm	Grünflächen
1	81539	Giesing Bhf	Fahrrad	3	gut	mittel	mittel
2	Giesing Bhf	Theresienstrasse	U-Bahn	10	Bitte auswäh	Bitte auswäh	Bitte auswäh
3	Theresienstrasse	TUM	zu Fuß	5	mittel	laut	gar kein grür
4			Bitte auswäh		Bitte auswäh	Bitte auswäh	Bitte auswäh

	Strasse / PLZ / Ort / Haltestelle (Start)	Strasse / PLZ / Ort / Haltestelle (Ziel)	Verkehrsmittel	Zeit (min)	Luftqualität	Lärm	Grünflächen
1	81539	TUM	Fahrrad	26	gut	mittel	eher kein grü
2			Bitte auswäh		Bitte auswäh	Bitte auswäh	Bitte auswäh

	Strasse / PLZ / Ort / Haltestelle (Start)	Strasse / PLZ / Ort / Haltestelle (Ziel)	Verkehrsmittel	Zeit (min)	Luftqualität	Lärm	Grünflächen
1	81539	TUM	Auto (Fahrer	20	Bitte auswäh	Bitte auswäh	Bitte auswäh

	Street / PLZ / Location / PuT Stop (Start)	Street / PLZ / Location / PuT Stop (End)	Transport Mode	Travel Time (min)	Air Quality	Noise	Green Spaces
1			Please choo		Please choo	Please choo	Please choo
2			Please choo		Please choo	Please choo	Please choo
3			Please choo		Please choo	Please choo	Please choo
4			Please choo		Please choo	Please choo	Please choo
5			Please choo		Please choo	Please choo	Please choo

Mobility behaviour and Environmental Quality

Please read the following statements. Check the box that best describes your attitude towards these statements.

***bad air quality: air pollution due to dust, exhaust fumes, etc.**

	strongly agree + +	agree +	neutral + -	disagree -	strongly disagree - -
When I perceive bad air quality, I prefer to use public transport / car than walk/cycle.	○	○	○	○	○
High noise levels along my way, make me walk/cycle less	○	○	○	○	○
I would stop using motorised transport in favour of cycling/walking if there were more green spaces and cycle paths along my way.	○	○	○	○	○
You read in the news that the thresholds for air pollution have been reached in your area. Therefore you change your mode of transport in a more environmental friendly one in order to help reducing pollution.	○	○	○	○	○
When I walk / use the bicycle, I choose my route in such way, that I can pass through open green spaces.	○	○	○	○	○

Personal Information

Before finishing, we have some questions about you.

Age

- ○ younger than 17 years old
- ○ 18 - 29
- ○ 30 - 44
- ○ 45 - 64
- ○ 65 and older

Sex

- ○ Female
- ○ Male

Occupation

- ○ Student (School)
- ○ Student (University)
- ○ Trainee (Ausbildung)
- ○ Working
- ○ Pensioner
- ○ Housewife/-man
- ○ Other [ ]

What is the total monthly net income of your household?

- ○ less than 500 €
- ○ 500 to less than 1000 €
- ○ 1000 to less than 1500 €
- ○ 1500 to less than 2000 €
- ○ 2000 to less than 2500 €
- ○ 2500 to less than 3000 €
- ○ 3000 to less than 3500 €
- ○ 3500 € and more

This survey is conducted in the city of Munich and in the community of Maisach. Please tell us in which area do you belong to.

- ○ City of Munich
- ○ Community of Maisach
- ○ Other [ ]

If you wish to take part in the lottery for the incentives, please leave your contact data below.

Please write your answer(s) here:

First Name / Last Name [ ]

E-mail Address [ ]

Tel. [ ]

Thank you again for your time and effort!

The winners of the lottery, will be informed in October via email.

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psu Fachgebiet für Siedlungsstruktur und Verkehrsplanung TUM

ANNEX 2: Code for Integrating Google Maps in the survey

```
<p>
    Bitte geben Sie Start- und Zielpunkt dieser Strecke ein und wählen Sie aus,
welches Verkehrsmittel Sie dafür normalerweise verwenden. <u><strong>Drücken Sie
</u></strong> dann die Taste "Route".</p>
<p>
    Um Ihre Route exakt darzustellen, verändern Sie bitte eventuelle
Unstimmigkeiten, indem Sie die blaue Linie an die gewünschten Orte verschieben (Für
den ÖPNV ist dies nicht möglich).</p>
<p>
    <u>Ihr Start- und Zielpunkt wird unter keinen Umständen veröffentlicht, sondern
nur für Forschungszwecke in einem Gesamtdatensatz verwendet.</u></p>

<meta name="viewport" content="initial-scale=1.0, user-scalable=no">
    <meta charset="utf-8">
    <style>
      html, body, #map-canvas {
        height: 100%;
        margin-top: 20px;
        margin-left: auto;
        margin-right: auto;
        padding: 0px
      }
    </style>
<script type="text/javascript"
src="https://maps.googleapis.com/maps/api/js?libraries=places&sensor=false&API_KEY"
></script>
<script type="text/javascript" charset="utf-8">

    var map;
    var directionsDisplay;
    var marker;
    var address;
    var geocoder;
    var selectedMode;
    var rendererOptions = {
        draggable: true
    };
    var autocomplete;
    var answer529572X2X62;

    $(document).ready(function(){
        document.getElementById('answer529572X2X62').style.display = 'none';
        function initialize() {
          var mapOptions = {
            zoom: 11,
            center: new google.maps.LatLng(48.1333, 11.5667)
          };
          map = new google.maps.Map(document.getElementById('map-canvas'),
              mapOptions);
        }
        google.maps.event.addDomListener(window, 'load', initialize);
    });

    function codeLatLng1() {
            geocoder = new google.maps.Geocoder();
            var address = document.getElementById("address1").value;
            geocoder.geocode({ 'address': address}, function(results, status) {
                if (status == google.maps.GeocoderStatus.OK)
                {
                    if (results[0])
                    {
                        var startCoords = results[0].geometry.location;
                        codeLatLng2(startCoords);
                    }
                    else
```

```
                        alert("No results found");

                }
                else
                    alert("Geocoder failed due to: " + status);
            });
        }

    function codeLatLng2(startCoords) {
        geocoder = new google.maps.Geocoder();
        var address = document.getElementById("address2").value;
        geocoder.geocode({ 'address': address}, function(results, status) {
            if (status == google.maps.GeocoderStatus.OK)
            {
                if (results[0])
                {
                    var endCoords = results[0].geometry.location;
                    FinishRoute(startCoords, endCoords);
                }
                else
                    alert("No results found");
                }
            else
                alert("Geocoder failed due to: " + status);
        });
    }

    function FinishRoute(start, end){
        if(directionsDisplay != null) {
            directionsDisplay.setMap(null);
            directionsDisplay = null;
        }
        directionsDisplay = new google.maps.DirectionsRenderer(rendererOptions);
        directionsDisplay.setMap(map);
        var selectedMode = document.getElementById('mode').value;
        var directionsService = new google.maps.DirectionsService();
        var request = {
            origin:start,
            destination:end,
            travelMode: google.maps.TravelMode[selectedMode]
        };
        directionsService.route(request, function(response, status) {
            if (status == google.maps.DirectionsStatus.OK) {
                directionsDisplay.setDirections(response);
                save_waypoints();
            }
        });

        google.maps.event.addListener(directionsDisplay, 'directions_changed',
function() {
                save_waypoints();
        });

    }

    function Route(origin, destination, transport_mode) {
        codeLatLng1();
    }

    function Fillin1() {
        autocomplete = new
google.maps.places.Autocomplete(document.getElementById('address1'));
    }

    function Fillin2() {
        autocomplete = new
google.maps.places.Autocomplete(document.getElementById('address2'));
    }
```

```
    function save_waypoints()
    {
        var w = []
        var stepsData = [];
        var pathData = [];
        var wp;
        var rleg = directionsDisplay.directions.routes[0].legs[0];
        var modeData = [];

        //Get the data
        var startAddress = rleg.start_address;
        var endAddress = rleg.end_address;
        var startDataLat = rleg.start_location.lat();
        var startDataLng = rleg.start_location.lng();
        var endDataLat = rleg.end_location.lat();
        var endDataLng = rleg.end_location.lng();
        var wp = rleg.via_waypoints;
        var distanceData = rleg.distance.text;
        var durationData = rleg.duration.text;

        //get the steps
        var allSteps = rleg.steps;

        for (var i = 0; i < rleg.steps.length; i++)
            modeData[i] = [allSteps[i].travel_mode ];

        //get the paths
        for (var i = 0; i < rleg.steps.length; i++)
            pathData[i] = [allSteps[i].path];

        //get the waypoints
        for(var i=0;i<wp.length;i++)
            w[i] = [wp[i].lat(),wp[i].lng()];
        var waypointsData = w;

        var data = {
            travelMode: modeData,
            startLat: startDataLat,
            startLng: startDataLng,
            endLat: endDataLat,
            endLng: endDataLng,
            waypoints: waypointsData,
            paths: pathData
        };

        //Create JSON string from the data
        var str = JSON.stringify(data);
        var inputFieldToSave = document.getElementById('answer529572X2X62');
        inputFieldToSave.value = str;
    }
</script>

<div>
    <b>Start: </b> <input id="address1" type="textbox" style="width: 250px; height:
20px;" placeholder="Start Adresse" oninput="Fillin1()" />
    <b>Ziel: </b> <input id="address2" type="textbox" style="width: 250px; height:
20px;" placeholder="Ziel Adresse" oninput="Fillin2()" />
    <b>Verkehrsmittel: </b> <select id="mode"><option
value="DRIVING">Auto</option><option value="TRANSIT">ÖPNV</option><option
value="BICYCLING">Fahrrad</option><option value="WALKING">zu Fuß</option></select>
    <input type="button" value="Route" onclick="Route()" />
    </div>

<div style="height:600px; width:1000px;">
         <div id="map-canvas"></div>
    </div>
```

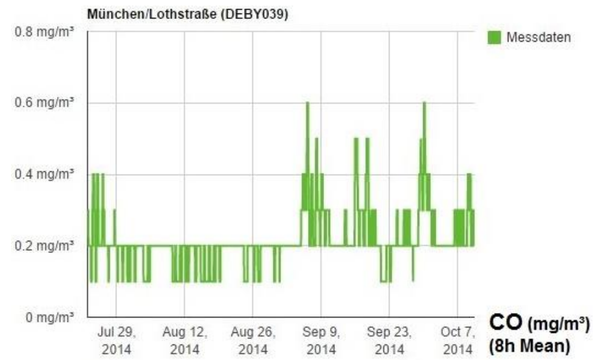
ANNEX 3: Matlab code used for transformation of JSONs to GeoJSONs

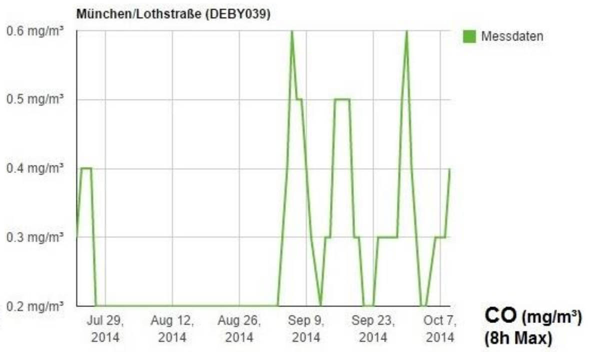
```
function [ result ] = Geojson( json, antwort_id )
%Transformation of JSON to Geojson

    field1 = 'type';  value1 = {'Feature'};
    field2 = 'geometry';
    value2_2='LineString';
    field2_2 = 'coordinates';

    Coordinates = [];
    Coordinates(1,1) = json{1,1}.startLng;
    Coordinates(1,2) = json{1,1}.startLat;
    m = 2;
    for i=1:length(json{1,1}.paths)
        for j=1:length(json{1,1}.paths{1,i})
            for l=1:length(json{1,1}.paths{1,i}{1,j})
                for h=1:length(json{1,1}.paths{1,i}{1,j}{1,l})
                    Coordinates(m,1) = json{1,1}.paths{1,i}{1,j}{1,l}.B;
                    Coordinates(m,2) = json{1,1}.paths{1,i}{1,j}{1,l}.k;
                    m = m+1;
                end
            end
        end
    end
    Coordinates(m,1) = json{1,1}.endLng;
    Coordinates(m,2) = json{1,1}.endLat;

    value2_1 = Coordinates;
    field4 = 'properties';
    fieldMode = 'travel_Mode';
    a = [json{1,1}.travelMode{:}];
    valueMode = sprintf('%s %s ',a{:});
    value3 = struct(fieldMode,valueMode);
    field5 = 'type2';
    geometry = struct(field5,value2_2,field2_2,value2_1);
    s = struct(field1,value1,field2,geometry, field4,value3);
    k = savejson(s);
    geojson = strrep(k,'type2','type' );
    geojson = geojson(2:end-2);
    id = strcat(num2str(antwort_id),'.geojson');
    fid = fopen(id,'w');
    fprintf(fid,geojson);
    fclose('all');
    result = geojson;
end

function [ result ] = RUN( Trip, AntwortID )
result=[];

   for counter=1:length(Trip)
       parsed = parse_json(Trip{counter,1});
       result{counter} = Geojson(parsed,AntwortID(counter));

   end

end
```

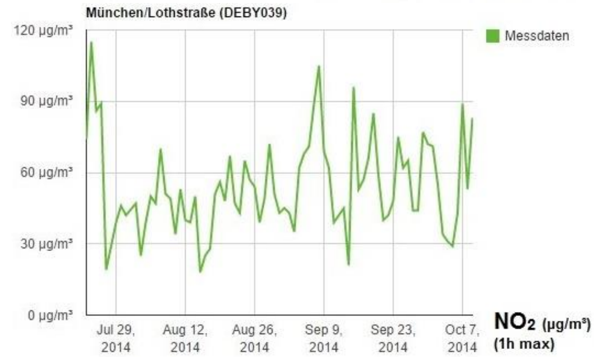
ANNEX 4: Air Pollutants concentrations for all monitoring stations

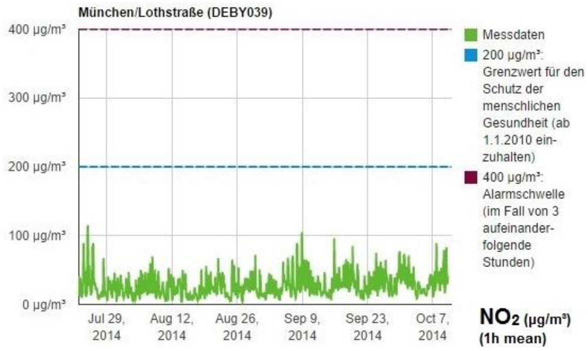
The figures below include all the air pollutants concentrations for all monitoring stations that were used to assess the air quality in the two study areas. The tables with the exact values that are represented in the following figure were too big to be included in this ANNEX, but can be found online here:
http://www.lfu.bayern.de/luft/lueb/index.htm
http://www.umweltbundesamt.de/daten/luftbelastung/aktuelle-luftdaten

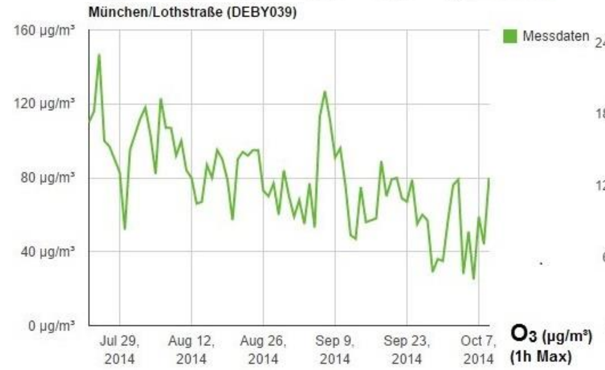
<u>München/Lothstrasse</u>

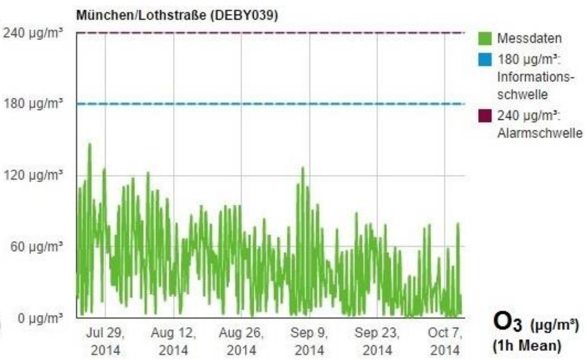


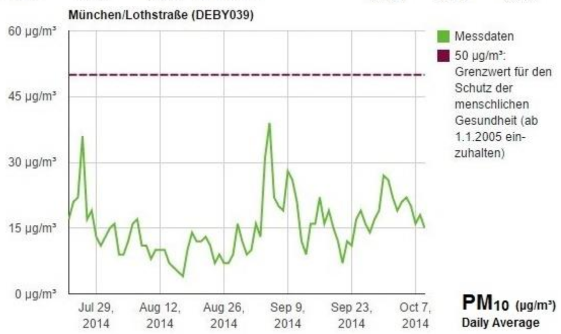




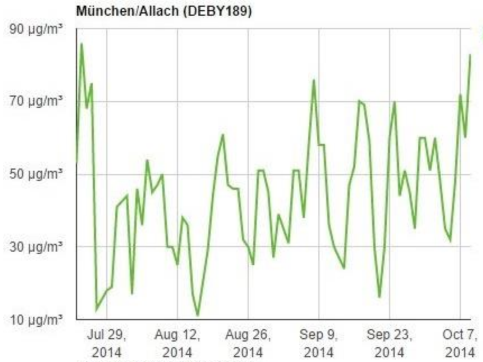




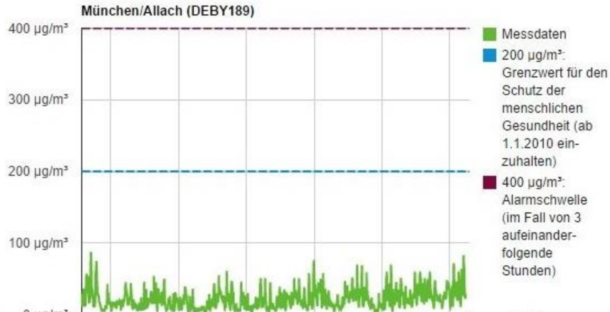




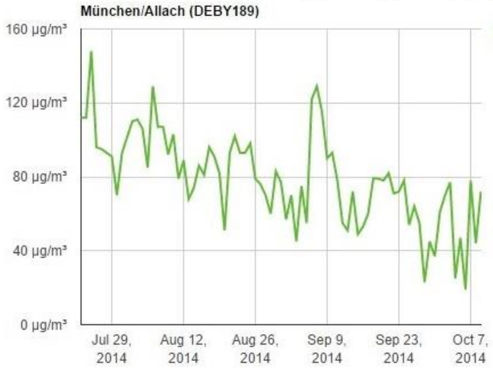
München/Allach



NO2 (µg/m³) (1h Max)



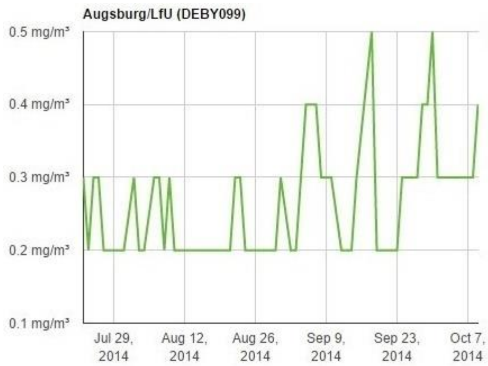
NO2 (µg/m³) (1h Mean)



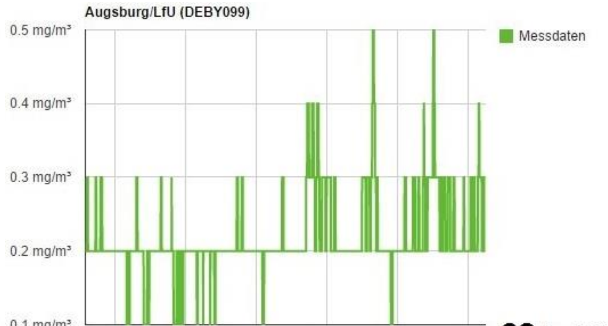
O3 (µg/m³) (1h Max)

O3 (µg/m³) (1h mean)

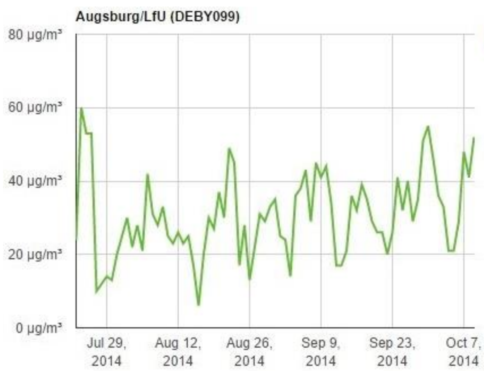
Augsburg/LfU (1)



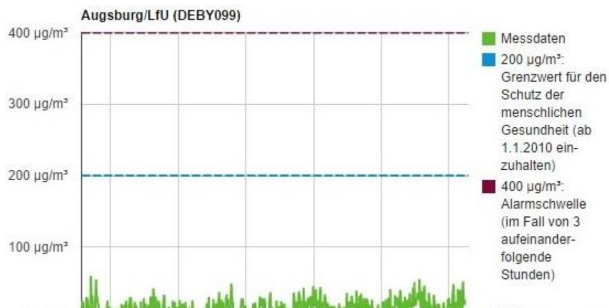
CO (mg/m³) (8h Max)



CO (mg/m³) (8h Mean)



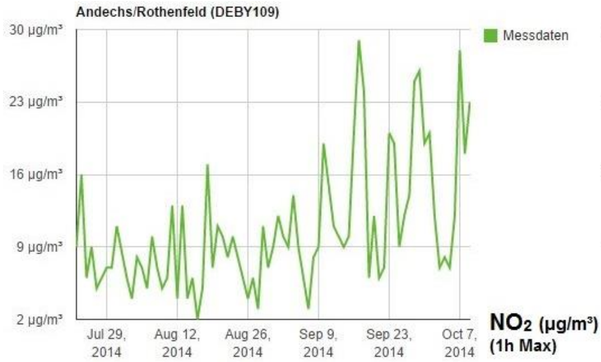
NO2 (µg/m³) (1h Max)

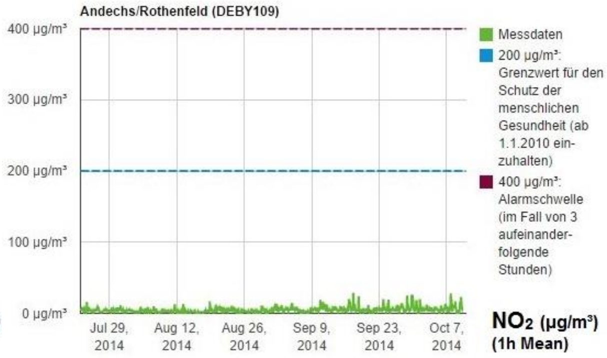


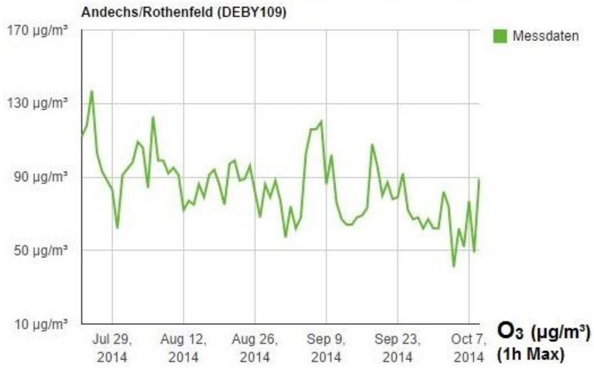
NO2 (µg/m³) (1h Mean)

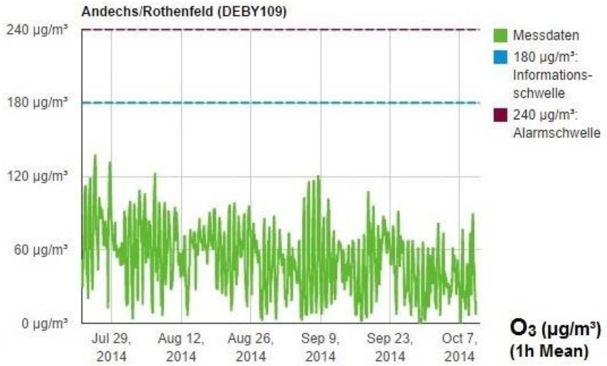
Augsburg/LfU (2)

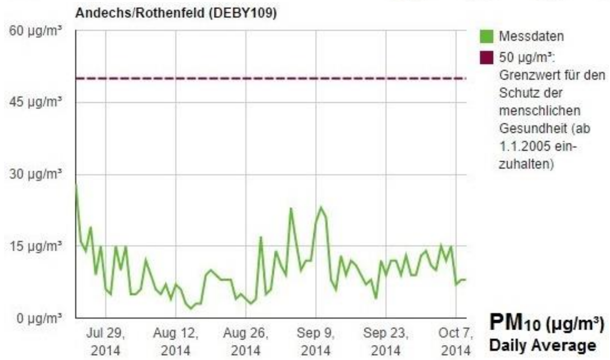
Andechs/Rothenfeld:





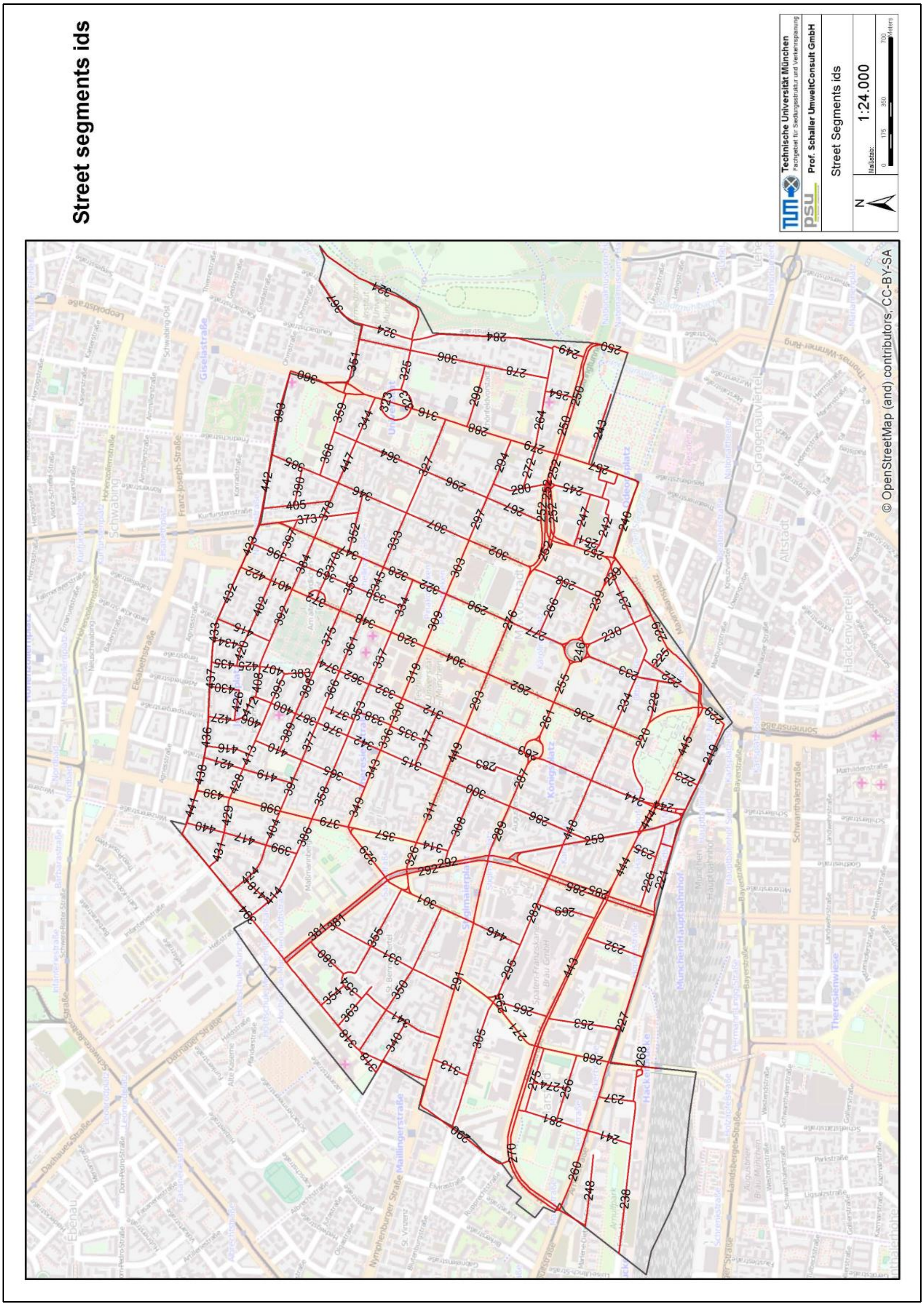




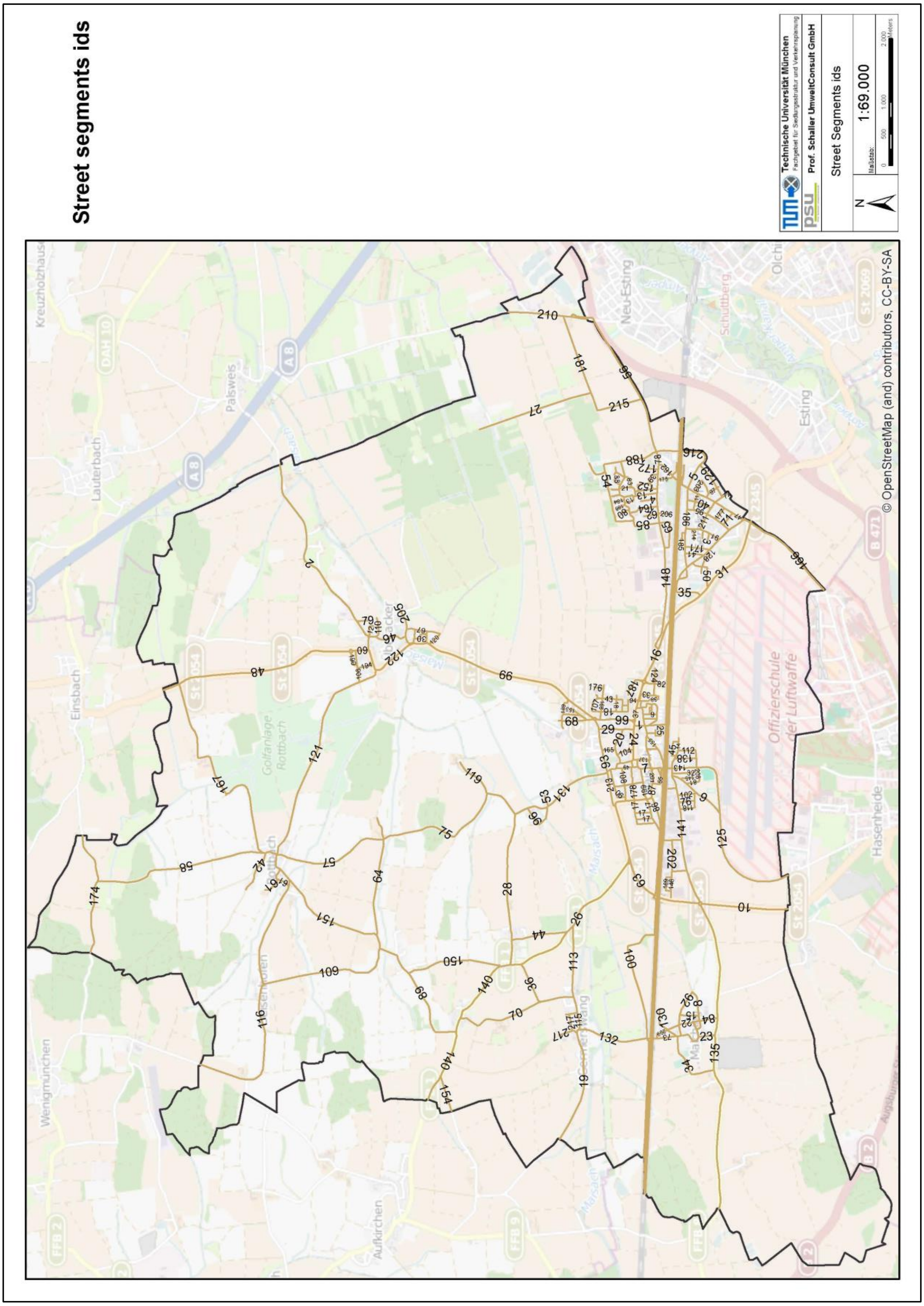


ANNEX 5: Maps of street segments ids

Maxvorstadt



Gemeinde Maisach



ANNEX 6: Comparison between perceived and actual values of environmental quality

Maxvorstadt - Air Quality				
Buff_id	**COUNT**	**AIR (perceived)**	**AIR (actual)**	**Diff**
294	1	1	2	1
297	1	1	2	1
303	1	1	2	1
321	2	1.5	2	0.5
361	6	1.5	2	0.5
374	6	1.666667	2	0.333333
383	6	1.666667	2	0.333333
425	3	1.666667	2	0.333333
395	5	1.8	2	0.2
407	5	1.8	2	0.2
248	1	2	2	0
257	3	2	2	0
270	1	2	2	0
290	1	2	2	0
296	2	2	2	0
301	1	2	2	0
309	3	2	2	0
318	1	2	2	0
362	3	2	2	0
364	1	2	2	0
365	1	2	2	0
366	2	2	2	0
372	2	2	2	0
373	1	2	2	0
378	3	2	2	0
384	2	2	2	0
385	1	2	2	0
392	2	2	2	0
393	3	2	2	0
398	1	2	2	0
401	2	2	2	0
409	1	2	2	0
410	1	2	2	0
411	3	2	2	0
413	5	2	2	0
416	1	2	2	0
419	1	2	2	0
421	1	2	2	0

Maxvorstadt - Air Quality				
Buff_id	**COUNT**	**AIR (perceived)**	**AIR (actual)**	**Diff**
422	2	2	2	0
428	2	2	2	0
429	1	2	2	0
431	1	2	2	0
435	4	2	2	0
436	1	2	2	0
439	1	2	2	0
442	1	2	2	0
326	4	2.25	2	-0.25
279	5	2.333333	2	-0.333333
287	3	2.333333	2	-0.333333
291	3	2.333333	2	-0.333333
311	3	2.333333	2	-0.333333
320	8	2.333333	2	-0.333333
328	4	2.333333	2	-0.333333
337	6	2.333333	2	-0.333333
403	3	2.333333	2	-0.333333
304	8	2.428571	2	-0.428571
223	2	2.5	2	-0.5
268	2	2.5	2	-0.5
283	2	2.5	2	-0.5
300	2	2.5	2	-0.5
322	3	2.5	2	-0.5
345	9	2.5	2	-0.5
386	4	2.5	2	-0.5
445	2	2.5	2	-0.5
312	7	2.571429	2	-0.571429
348	7	2.6	2	-0.6
333	10	2.625	2	-0.625
336	16	2.625	2	-0.625
353	8	2.625	2	-0.625
330	17	2.647059	2	-0.647059
298	5	2.666667	2	-0.666667
323	3	2.666667	2	-0.666667
325	3	2.666667	2	-0.666667
332	3	2.666667	2	-0.666667
334	3	2.666667	2	-0.666667
357	3	2.666667	2	-0.666667
394	3	2.666667	2	-0.666667
414	3	2.666667	2	-0.666667
358	7	2.714286	2	-0.714286
319	18	2.722222	2	-0.722222
316	9	2.75	2	-0.75

Maxvorstadt - Air Quality				
Buff_id	**COUNT**	**AIR (perceived)**	**AIR (actual)**	**Diff**
449	4	2.75	2	-0.75
381	7	2.8	2	-0.8
263	8	2.875	2	-0.875
327	11	2.875	2	-0.875
220	1	3	2	-1
222	4	3	2	-1
227	2	3	2	-1
233	4	3	2	-1
242	1	3	2	-1
245	1	3	2	-1
271	1	3	2	-1
276	3	3	2	-1
277	4	3	2	-1
288	4	3	2	-1
289	1	3	2	-1
315	3	3	2	-1
338	1	3	2	-1
343	2	3	2	-1
344	4	3	2	-1
349	2	3	2	-1
379	2	3	2	-1
387	2	3	2	-1
391	3	3	2	-1
400	2	3	2	-1
447	3	3	2	-1
293	10	3.1	2	-1.1
244	5	3.2	2	-1.2
246	5	3.333333	2	-1.333333
250	4	3.333333	2	-1.333333
342	4	3.333333	2	-1.333333
221	2	3.5	2	-1.5
252	2	3.5	2	-1.5
285	2	3.5	2	-1.5
317	2	3.5	2	-1.5
346	2	3.5	2	-1.5
377	2	3.5	2	-1.5
376	4	3.666667	2	-1.666667
224	1	4	2	-2
226	1	4	2	-2
239	1	4	2	-2
240	1	4	2	-2
255	1	4	2	-2
259	2	4	2	-2

Maxvorstadt - Air Quality				
Buff_id	**COUNT**	**AIR (perceived)**	**AIR (actual)**	**Diff**
261	1	4	2	-2
273	1	4	2	-2
292	3	4	2	-2
329	1	4	2	-2
352	1	5	2	-3

Maxvorstadt - Noise				
Buff_id	**COUNT**	**NOISE (perceived)**	**NOISE (actual)**	**Diff**
220	1	4	4	0
221	2	4	4	0
222	4	2.5	4	1.5
223	2	3	2	-1
224	1	4	3	-1
226	1	4	3	-1
227	2	4	4	0
233	4	2.5	3	0.5
239	1	5	4	-1
240	1	5	5	0
242	1	3	3	0
244	5	3.6	2	-1.6
245	1	3	1	-2
246	5	3.333333	3	-0.333333
248	1	3	1	-2
250	4	4.666667	5	0.333333
252	2	4	5	1
255	1	5	4	-1
257	3	3.5	5	1.5
259	2	5	4	-1
261	1	5	4	-1
263	8	3.75	2	-1.75
268	2	3.5	4	0.5
270	1	3	4	1
271	1	4	4	0
273	1	5	4	-1
276	3	3.666667	4	0.333333
277	4	2.5	3	0.5
279	5	4.333333	5	0.666667
283	2	3	1	-2
285	2	3.5	4	0.5
287	3	3.333333	4	0.666667
288	4	4.5	5	0.5

Maxvorstadt - Noise				
Buff_id	**COUNT**	**NOISE (perceived)**	**NOISE (actual)**	**Diff**
289	1	3	4	1
290	1	3	2	-1
291	3	3.333333	4	0.666667
292	3	4.5	4	-0.5
293	10	3.8	5	1.2
294	1	4	2	-2
296	2	2.5	1	-1.5
297	1	4	4	0
298	5	2.666667	3	0.333333
300	2	3.5	2	-1.5
301	1	3	4	1
303	1	4	4	0
304	8	3.571429	4	0.428571
309	3	3.333333	4	0.666667
311	3	3.666667	5	1.333333
312	7	3.714286	3	-0.714286
315	3	3.333333	2	-1.333333
316	9	3.75	5	1.25
317	2	4	1	-3
318	1	3	2	-1
319	18	3.666667	4	0.333333
320	8	3.333333	4	0.666667
321	2	2	1	-1
322	3	3	4	1
323	3	3.666667	4	0.333333
325	3	3.666667	2	-1.666667
326	4	3.5	4	0.5
327	11	3.75	2	-1.75
328	4	3.333333	4	0.666667
329	1	4	4	0
330	17	3.588235	4	0.411765
332	3	4	2	-2
333	10	3.625	2	-1.625
334	3	3.333333	1	-2.333333
336	16	3.5625	4	0.4375
337	6	3.5	2	-1.5
338	1	4	1	-3
342	4	2.666667	2	-0.666667
343	2	4	4	0
344	4	3	2	-1
345	9	3.5	2	-1.5
346	2	1.5	1	-0.5
348	7	3.2	4	0.8

Maxvorstadt - Noise				
Buff_id	**COUNT**	**NOISE (perceived)**	**NOISE (actual)**	**Diff**
349	2	4	4	0
352	1	1	1	0
353	8	3.625	2	-1.625
357	3	3.666667	2	-1.666667
358	7	3.571429	2	-1.571429
361	6	2.75	2	-0.75
362	3	3.333333	1	-2.333333
364	1	2	1	-1
365	1	2	2	0
366	2	3	2	-1
372	2	2	3	1
373	1	2	1	-1
374	6	3	1	-2
376	4	3.666667	2	-1.666667
377	2	3	1	-2
378	3	2.666667	2	-0.666667
379	2	3.5	4	0.5
381	7	3.8	5	1.2
383	6	3	1	-2
384	2	3	2	-1
385	1	2	1	-1
386	4	3.75	3	-0.75
387	2	4	1	-3
391	3	3	2	-1
392	2	3	3	0
393	3	2.666667	2	-0.666667
394	3	4	2	-2
395	5	2.8	1	-1.8
398	1	3	4	1
400	2	4	1	-3
401	2	2	4	2
403	3	3	1	-2
407	5	3.2	1	-2.2
409	1	2	1	-1
410	1	2	1	-1
411	3	3	1	-2
413	5	2.8	1	-1.8
414	3	4	3	-1
416	1	2	1	-1
419	1	3	1	-2
421	1	2	1	-1
422	2	2	4	2
425	3	3.333333	2	-1.333333

Maxvorstadt - Noise				
Buff_id	**COUNT**	**NOISE (perceived)**	**NOISE (actual)**	**Diff**
428	2	3	3	0
429	1	2	3	1
431	1	2	2	0
435	4	3.5	3	-0.5
436	1	2	1	-1
439	1	4	4	0
442	1	2	1	-1
445	2	3	4	1
447	3	2.333333	1	-1.333333
449	4	4	5	1

Maxvorstadt - Availability of green spaces				
Buff_id	**COUNT**	**GREEN (perceived)**	**GREEN (actual)**	**Diff**
220	1	2	1	-1
221	2	4	3	-1
222	4	3	2	-1
223	2	2	4	2
224	1	5	5	0
226	1	5	4	-1
227	2	4.5	3	-1.5
233	4	3	2	-1
239	1	3	3	0
240	1	3	3	0
242	1	3	2	-1
244	5	2.8	3	0.2
245	1	3	3	0
246	5	3	2	-1
248	1	2	2	0
250	4	3.666667	2	-1.666667
252	2	3.5	3	-0.5
255	1	3	1	-2
257	3	2.5	3	0.5
259	2	5	5	0
261	1	3	2	-1
263	8	2.75	2	-0.75
268	2	3	4	1
270	1	2	1	-1
271	1	2	2	0
273	1	3	2	-1
276	3	3.333333	2	-1.333333

Maxvorstadt - Availability of green spaces				
Buff_id	**COUNT**	**GREEN (perceived)**	**GREEN (actual)**	**Diff**
277	4	3	3	0
279	5	3	4	1
283	2	2	4	2
285	2	3.5	3	-0.5
287	3	2.333333	2	-0.333333
288	4	3.5	4	0.5
289	1	2	2	0
290	1	2	1	-1
291	3	2.333333	2	-0.333333
292	3	5	5	0
293	10	3.5	4	0.5
294	1	2	4	2
296	2	3	4	1
297	1	2	4	2
298	5	2.666667	1	-1.666667
300	2	2.5	3	0.5
301	1	3	3	0
303	1	2	3	1
304	8	3	2	-1
309	3	2	1	-1
311	3	3.666667	4	0.333333
312	7	3.142857	4	0.857143
315	3	3	3	0
316	9	3.875	4	0.125
317	2	3.5	4	0.5
318	1	2	2	0
319	18	3.666667	4	0.333333
320	8	3.333333	2	-1.333333
321	2	1.5	1	-0.5
322	3	2.5	2	-0.5
323	3	5	3	-2
325	3	5	5	0
326	4	3.5	3	-0.5
327	11	4	5	1
328	4	4	5	1
329	1	5	3	-2
330	17	3.882353	5	1.117647
332	3	3.333333	4	0.666667
333	10	4.285714	5	0.714286
334	3	2.5	2	-0.5
336	16	3.8125	5	1.1875
337	6	4	3	-1
342	4	3.333333	2	-1.333333

Maxvorstadt - Availability of green spaces				
Buff_id	**COUNT**	**GREEN (perceived)**	**GREEN (actual)**	**Diff**
343	2	4.5	4	-0.5
344	4	3.5	3	-0.5
345	9	4	5	1
346	2	2.5	3	0.5
348	7	3.8	2	-1.8
349	2	4.5	3	-1.5
352	1	3	5	2
353	8	3	5	2
357	3	4	4	0
358	7	3.833333	5	1.166667
361	6	3.25	4	0.75
362	3	3.333333	4	0.666667
364	1	3	5	2
365	1	3	4	1
366	2	4	5	1
372	2	2	1	-1
373	1	2	4	2
374	6	3	2	-1
376	4	3.666667	3	-0.666667
377	2	4.5	5	0.5
378	3	2.666667	5	2.333333
379	2	4	2	-2
381	7	3.75	3	-0.75
383	6	3.166667	1	-2.166667
384	2	3	4	1
385	1	2	2	0
386	4	3.333333	2	-1.333333
387	2	3	3	0
391	3	4	3	-1
392	2	3	1	-2
393	3	2	2	0
394	3	3.5	3	-0.5
395	5	2.8	2	-0.8
398	1	3	4	1
400	2	3	3	0
401	2	2	2	0
403	3	3.333333	2	-1.333333
407	5	3.4	1	-2.4
410	1	3	2	-1
411	3	2.333333	2	-0.333333
413	5	2.6	3	0.4
414	3	3.5	2	-1.5
416	1	3	2	-1

Maxvorstadt - Availability of green spaces				
Buff_id	**COUNT**	**GREEN (perceived)**	**GREEN (actual)**	**Diff**
419	1	3	2	-1
421	1	3	2	-1
422	2	2	4	2
425	3	3.666667	3	-0.666667
428	2	2	3	1
429	1	3	3	0
431	1	3	3	0
435	4	3.25	3	-0.25
436	1	3	3	0
439	1	1	4	3
445	2	2	2	0
447	3	3	3	0
449	4	3.75	4	0.25

Maisach - Air quality				
Buff_id	**COUNT**	**AIR (perceived)**	**AIR (actual)**	**Diff**
2	1	3	2	-1
3	1	2	2	0
5	6	2.333333	2	-0.333333
7	3	1	2	1
10	2	2	2	0
11	1	1	2	1
14	2	1	2	1
16	17	2.5	2	-0.5
19	1	1	2	1
24	17	2.2	2	-0.2
28	1	1	2	1
30	2	1	2	1
31	15	2.285714	2	-0.285714
35	6	2.5	2	-0.5
37	19	2.363636	2	-0.363636
39	1	2	2	0
40	1	1	2	1
46	1	1	2	1
47	9	2.375	2	-0.375
48	2	3	2	-1
49	6	2	2	0
54	1	1	2	1
55	7	2	2	0
56	2	3	2	-1
59	4	2.5	2	-0.5
60	1	3	2	-1
63	5	2.25	2	-0.25
66	4	2.5	2	-0.5
68	1	2	2	0
69	4	1.75	2	0.25
74	18	2.272727	2	-0.272727
77	19	2.363636	2	-0.363636
78	10	2.111111	2	-0.111111
82	2	2	2	0
85	1	2	2	0
86	1	3	2	-1
87	7	2.5	2	-0.5
91	3	2	2	0
93	1	2	2	0
99	4	2.5	2	-0.5
100	1	2	2	0
105	3	2.333333	2	-0.333333

Maisach - Air quality				
Buff_id	**COUNT**	**AIR (perceived)**	**AIR (actual)**	**Diff**
108	1	2	2	0
112	1	3	2	-1
122	2	2	2	0
123	18	2	2	0
126	4	1.333333	2	0.666667
127	1	3	2	-1
131	2	1.5	2	0.5
132	1	1	2	1
133	8	2.25	2	-0.25
135	5	2	2	0
137	15	2.125	2	-0.125
140	2	1	2	1
141	4	1.666667	2	0.333333
142	1	2	2	0
143	3	1.5	2	0.5
144	1	2	2	0
148	5	2.75	2	-0.75
155	1	3	2	-1
158	1	3	2	-1
160	5	2.333333	2	-0.333333
162	3	1.333333	2	0.666667
163	8	2.375	2	-0.375
166	1	1	2	1
171	1	3	2	-1
172	5	1.2	2	0.8
173	1	3	2	-1
174	1	2	2	0
175	5	1.8	2	0.2
178	4	2.333333	2	-0.333333
182	2	3	2	-1
183	10	1.8	2	0.2
186	2	1.5	2	0.5
189	1	2	2	0
190	1	2	2	0
192	2	1.5	2	0.5
193	5	1.5	2	0.5
194	1	1	2	1
196	7	1.666667	2	0.333333
199	14	2	2	0
201	9	2.5	2	-0.5
203	1	2	2	0
204	4	2.333333	2	-0.333333
205	1	1	2	1

Maisach - Air quality				
Buff_id	**COUNT**	**AIR (perceived)**	**AIR (actual)**	**Diff**
210	2	3	2	-1
212	7	2	2	0
216	8	2	2	0
218	19	2.333333	2	-0.333333

Maisach - Noise				
Buff_id	**COUNT**	**NOISE (perceived)**	**NOISE (actual)**	**Diff**
10	2	2	4	2
16	17	3.4	4	0.6
24	17	2.818182	3	0.181818
31	15	3	4	1
37	19	3.090909	3	-0.090909
48	2	3	3	0
60	1	3	3	0
63	5	2.25	4	1.75
66	4	2.666667	3	0.333333
74	18	2.916667	3	0.083333
77	19	3.090909	4	0.909091
87	7	2.833333	3	0.166667
99	4	2.666667	3	0.333333
122	2	2.5	3	0.5
135	5	2.25	3	0.75
137	15	2.777778	3	0.222222
140	2	2	3	1
160	5	2.75	3	0.25
182	2	3	3	0
201	9	2.571429	3	0.428571
212	7	2.2	4	1.8
218	19	3.076923	4	0.923077

Maisach - Availability of green spaces				
Buff_id	**COUNT**	**GREEN (perceived)**	**GREEN (actual)**	**Diff**
2	1	1	1	0
5	6	2.833333	2	-0.833333
10	2	1	1	0
16	17	2.1	1	-1.1
19	1	1	1	0
24	17	2.333333	2	-0.333333
28	1	1	1	0
31	15	1.714286	1	-0.714286
35	6	2	2	0
37	19	2.454545	1	-1.454545
47	9	2.375	1	-1.375
48	2	1	1	0
54	1	1	1	0
56	2	1	1	0
60	1	1	1	0
63	5	1.25	1	-0.25
66	4	1.5	1	-0.5
74	18	2.3	2	-0.3
77	19	2.454545	1	-1.454545
78	10	2.444444	1	-1.444444
85	1	1	1	0
87	7	2	1	-1
99	4	1.5	1	-0.5
100	1	2	1	-1
122	2	1.5	1	-0.5
123	18	2.294118	1	-1.294118
126	4	2.666667	3	0.333333
131	2	2	1	-1
132	1	1	1	0
133	8	2.625	2	-0.625
135	5	1.25	1	-0.25
137	15	2.571429	3	0.428571
140	2	1	1	0
141	4	2.666667	3	0.333333
148	5	2.5	2	-0.5
160	5	1.666667	1	-0.666667
163	8	2.375	2	-0.375
166	1	1	1	0
182	2	1	1	0
183	10	2	3	1
186	2	3	2	-1
199	14	1.5	1	-0.5

Maisach - Availability of green spaces				
Buff_id	**COUNT**	**GREEN (perceived)**	**GREEN (actual)**	**Diff**
201	9	2.833333	2	-0.833333
212	7	1.2	1	-0.2
216	8	2.375	1	-1.375
218	19	2.916667	3	0.083333

Statutory Declaration

I herewith formally declare that I have authored the submitted thesis independently. I did not use any outside support except for the declared literature and other sources mentioned in the paper.

I clearly marked and separately listed all of the literature and all of the other sources which I employed when producing this academic work, either literally or in content.

I am aware that the violation of this regulation will lead to failure of the thesis.

München, den 1. Dezember 2014

Anastasios Koutsogiannis