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Mixed Methods Approach to Assess Equity in Temporal Accessibility by Rail Public Transport (RPT) Stations

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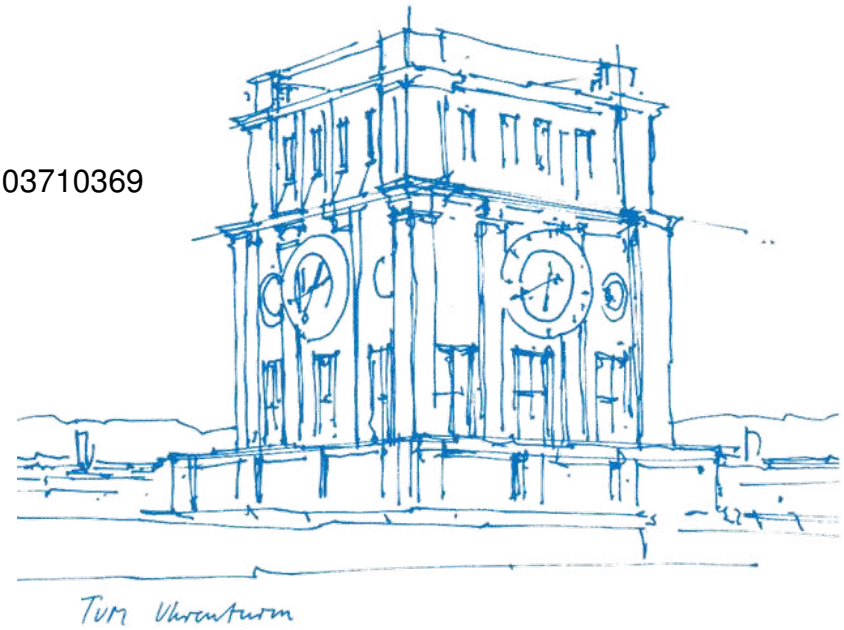

Abstract

To achieve a sustainable future of both urban and rural areas while meeting the rising mobility needs, there is a need to shift towards sustainable modes such as public transportation. Rail public transport (RPT) is commonly known as a catalyser for Transit Oriented Development, thus particularly effective in improving the access to goods, services and socio-economic opportunities. However, access by RPT is not equitable across urban populations, and disparities become even more prominent when the temporal dimension of accessibility is being considered, as service levels vary significantly across locations and times of the day. These disparities are also visible within the metropolitan region of Munich, in which inner-cities benefit from much higher service frequencies in comparison to suburban and rural areas, particularly during off-peak hours. Therefore, ensuring strong temporal accessibility by RPT is essential in order to provide underprivileged individuals equitable socio-economic opportunities. In return, this highlights the need to assess how equitable temporal accessibility by RPT is, as such evidence is needed to plan an inclusive and sustainable public transport network, allocating a higher level of temporal accessibility to those who need it the most. Despite a growing interest in temporal accessibility analysis, social equity implications are scarcely included, while mixed-methods approaches are rarely utilized. This is why a mixed-methods approach has been proposed, combining quantitative and qualitative research methods in order to capture both large-scale temporal accessibility (in)equity patterns as well as local subjective perspectives, as both methods were expected to cross-validate and complement each other. This research disclosed a widely fair temporal accessibility to POIs, yet an inequitable temporal accessibility to offices, as both quantitative and qualitative methods suggested. Moreover, an in-depth assessment of specific socio-economic and -demographic characteristics disclosed equity gaps for women, individuals with lower educational backgrounds and lower-income households as well. These findings have been cross-validated by qualitative interviews, which complemented them with smaller-scale observations such as migration related issues for refugees in rural areas or temporally induced physical accessibility barriers. Therefore, the chosen mixed-methods approach has proven itself to be highly successful, as it did not only set a new standard for equity assessments in temporal accessibility, but also aspires to support decision-makers to strive towards a sustainable future of metropolitan regions.

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Chapter 1

Introduction

As urban areas grow and expand, the transportation demand of residents rises consequently [Bundesregierung, 2018]. To tackle present challenges such as climate change without compromising the quality of life in inner cities, it is relevant to strive towards a sustainable future of urban areas. Therefore, this multi-dimensional process also involves and requires changes in the individual's travel mode choice, in which a modal shift towards more sustainable modes such as public transportation is necessary [United Nations, 2016].

In addition to the sustainability aspect, particularly faster modes such as rail based public transportation also strongly increase the access to goods, services and opportunities in comparison to private cars in urban areas, as they do not only offer higher capacity and speeds but are also renowned catalyzers of transit-oriented development [Benenson et al., 2011, Culver, 2017]. However, access to and by rail-based transportation is not equitable across urban populations, and disparities become even more prominent when considering the temporal dimension of accessibility [Eckwert, 2023].

Geurs and van Wee [2004] identified four dimensions of accessibility, one of which being the temporal component. Since public transport is characterized by fixed departure times and headways, different parts of the population might have a restricted access to destinations and specific times of the day. This temporal perspective is critical, as not all destinations can be accessed at all times of the day. For instance, the greater metropolitan region of Munich in the south of Germany illustrates this issue well. While the inner city benefits from a higher temporal accessibility even at night time, public transport services on its outskirts become scarce in the evening, with some areas completely disconnected late at night [Kentner, 2017]. Furthermore, daytime accessibility gaps persist in areas with low public transport patronage, where reduced levels of service have been implemented in recent years [Pfadenhauer, 2022].

This lack of temporal accessibility intensifies car dependency in underserved neighborhoods or forces individuals to rely on costly alternatives such as taxis or overnight stays outside of their place of residence [Kentner, 2017]. However, individuals might not always have the financial means to afford these solutions, which discloses an equity gap in temporal accessibility to basic services by RPT. This raises the central question of this research: How equitable is the temporal accessibility from rail station to destinations in the greater metropolitan region of Munich? Addressing this issue is essential for promoting social inclusion, as improving temporal accessibility could provide disadvantaged residents a stronger access to goods, services and opportunities at all times of the day. Therefore, tackling this issue is a critical step towards achieving sustainable urban mobility by fostering an equitable access for all individuals.

Equity in accessibility to public transport is commonly being assessed with a sole focus on spatial

aspects, such as access to goods, services and opportunities, without taking time dependency into consideration [Bartzokas-Tsiompras and Photis, 2019, Delbosc and Currie, 2011, Hesse and Scheiner, 2010]. However, as past research suggested, its temporal variation significantly impacts overall accessibility and its social equity dimensions [Geurs and van Wee, 2004]. Therefore, the aim of this thesis is to develop a mixed-methods approach to assess potential equity gaps of temporal accessibility to services by RPT and apply the method in the case study of the greater metropolitan region of Munich. By incorporating both quantitative and qualitative methods, this research contributed to a deeper academic and practical understanding of equity in accessibility planning, emphasizing the commonly overlooked temporal dimension. Hence, this study will not only help to identify potential equity gaps, but also serve as a foundation for integrating mixed-methods temporal equity assessments into state-of-the-art transport planning practices, encouraging solutions to make transportation more accessible at all times of the day and equitable for those who need it the most.

To address the lack of equity assessments in temporal accessibility a mixed-methods approach has been proposed. While a temporal accessibility indicator has been developed as part of the quantitative section in order to measure temporal accessibility, a qualitative method explored resident's perception and coping mechanism on temporal accessibility. The combination of both provided a comprehensive understanding of equity in temporal accessibility in the metropolitan region of Munich, by balancing both large-scale patterns with individual experiences.

In a first term, a both systematic and exploratory literature review will be provided, by defining and linking key concepts necessary for this research, as well as presenting state-of-the-art methods to assess temporal accessibility. After that, the developed methods will be elaborated, and their results will be showcased subsequently. The results will then be discussed, by linking both methods with state-of-the-art literature, to understand how equitable temporal accessibility by RPT in the metropolitan region is so that policy recommendations for planning practices can be formulated.

The metropolitan region of Munich located in southern Germany provides a compelling case for examining equity in temporal accessibility. As one of Europe's most economically dynamic regions, it is characterized by a dense urban core with a wide public transport coverage, while its surrounding suburban and rural areas have varying service levels [EMM e.V., MVG mbH]. The region's public transport network offers higher service frequency within the city but faces challenges in maintaining consistent temporal accessibility in its outskirts, especially in off-peak hours [MVG mbH, Kentner, 2017]. By focusing on the metropolitan region of Munich, this research can address temporal accessibility disparities and potential resulting equity gaps. Contrasting urban, suburban and rural areas provides an ideal context to investigate temporal accessibility and its social equity implications. Moreover, an overview of Munich's metropolitan region can be found on map provided by EMM e.V. in Fig. 1.1 on the following page.

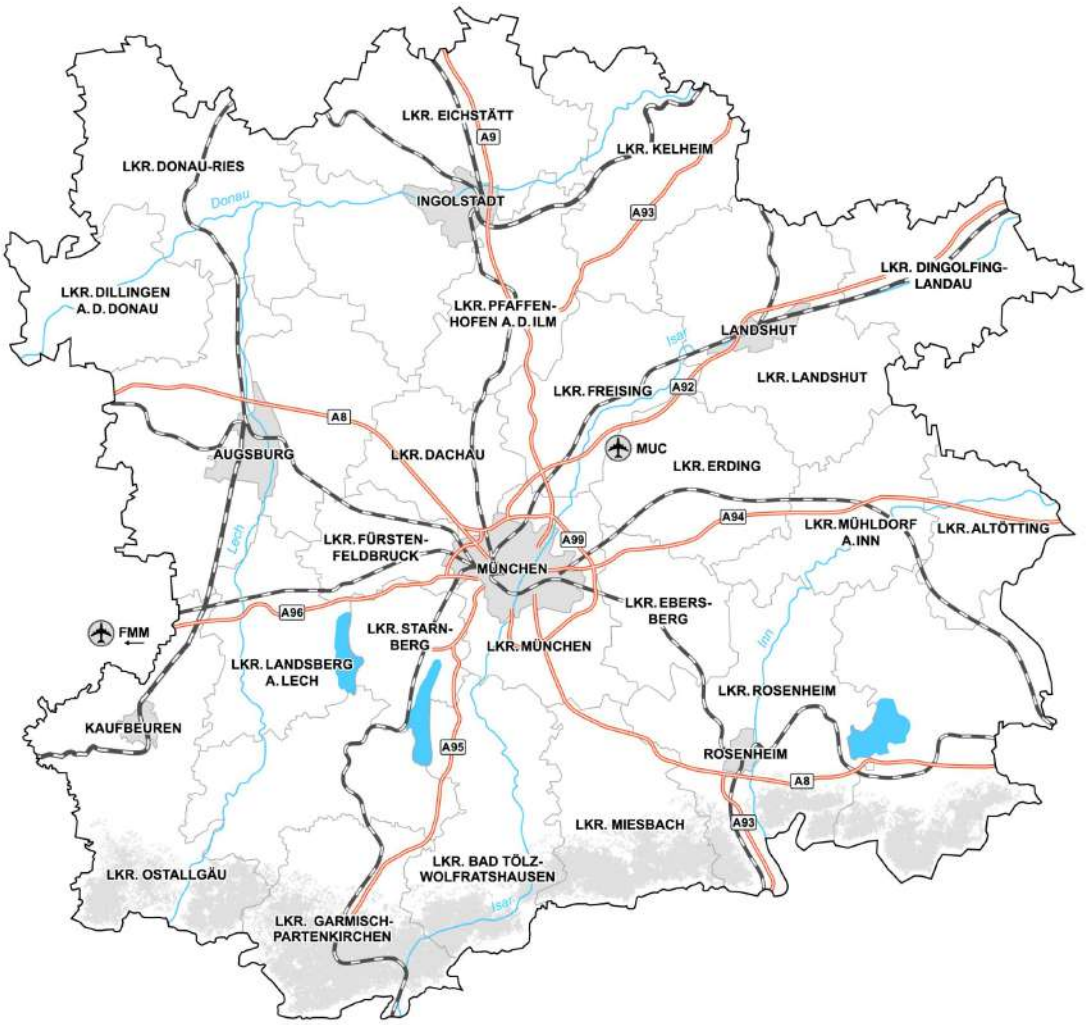


Figure 1.1: Map of the Metropolitan Region of Munich

Chapter 2

Literature Review

"Accessibility is of key importance as it enables participation in a range of activities" [Stepniak et al., 2019]. This quote of Stepniak et al. [2019]'s review paper highlights the main motivation of accessibility-related research, since improving the participation in activities reduces the chances of mobility-related social exclusion. However, as Fransen et al. [2015], stated in his research, that social disparities are mainly assessed to public transport, yet not by the system itself. The reason behind this differentiation is that an accessibility analysis by the transit system, as Kwan [2013] stated, is also influenced by other factors such as the frequency of the services. Therefore, combining these three quotes underline the direct impact and relevance of temporal accessibility in equity-related issues.

To better understand how equity can be assessed by measuring temporal accessibility, this chapter provided a broader understanding of state-of-the-art methods that are being used. Hence, the goals of this chapter were to (1) conceptualize temporal accessibility, by exploring which accessibility measurements exist, how time variation is being represented and to what extend methods are adequate to assess equity, as well as (2) to highlight state-of-the-art method to identify potential gaps in the research landscape. In a first term, the framework of this research has been presented and key concepts have been defined. After that, the methodology of the literature review has been explained and the results have been given and discussed subsequently, so that a conclusion could have been drawn.

2.1 Framework and Key Concepts

To be able to grasp the interdependency of (A) accessibility, (B) its temporality and (C) equity, the key concepts have been defined in this section. The following section presented key research articles from which state-of-the-art definitions originated. Based on these findings, own definitions relevant for the proposed mixed-methods approach have been provided.

Today, a wide range of definitions of accessibility can be found. Thus, this research has been focusing on the most significant ones, and pointing out the ones relevant in the context of this research. In his research on how accessibility shapes land use, Koenig [1980] defined accessibility as "the potential of opportunities for interaction", a definition which has evolved over time, yet still widely used today. This definition has also been extended by Koenig [1980], which set a focus on the ease of reaching rather than the potential. In his research, he assessed both the matter of reaching and the level-of-service of the mode used to complete the trip [Koenig, 1980]. Moreover, only a few years earlier, Vickerman [1974] conducted his research making use of a so-called "cumulative" measurement method, in which

the number of reachable opportunities within a given travel time are being counted, a base for most quantitative accessibility measurement tools today. A first attempt to dismantle the term of accessibility has been made by Kwan [2013], who separated people from places, by including a personal or subjective perception to the term. This early distinction can be found in nowadays's widely used definition provided by Geurs and van Wee [2004]. Geurs and van Wee [2004] defined accessibility as

> "the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s)"

Following this definition, Geurs and van Wee [2004] identified four main components of accessibility. First, the land-use component, which stands for the distribution of opportunities at both origins and destinations, followed by the transport component, which includes the aspects of (dis)utility or costs. Moreover, the temporal aspect, which reflects temporal limitations (e.g. opening times) as well as the individual component, which reflect the needs based on personal socio-economic or -demographic backgrounds, can be found as well [Geurs and van Wee, 2004]. Therefore, based on the showcased definitions, the definition that has been used in own past research as well as in the present one, is that accessibility defines itself as the ease of reaching goods, services and opportunities.

As Geurs and van Wee [2004] insinuated in his distinction of components of accessibility, the temporality is not to neglect. Research specifically on temporal accessibility is less common than (spatial) accessibility in its broader sense, yet highly important as also Farber et al. [2014] suggested:

> "It is therefore a more nuanced and valid measure of accessibility." [Farber et al., 2014]

In this section, two core review papers have been showcased. A first review has been conducted by Tomasiello et al. [2019], in which he developed a cumulative multi-temporal measurement method for accessible jobs. In his research, he also conducted an extensive systematic literature review on the type of accessibility measurement that has been used, a potential cost function and whether temporality has been included or not [Tomasiello et al., 2019]. His literature review also assessed the versatility of implementation of state-of-the-art methods, in which according to him, most cumulative and absolute-potential measurements can be used with any temporal granularity at any location, making them suitable for policy- and decision makers [Tomasiello et al., 2019]. Another extensive review and method has been proposed by Stepniak et al. [2019], in which he analyzed temporal accessibility to public services in Poland. Both his literature review and his proposed methodology assessed the temporal resolution of diverse accessibility analysis methods, and came to the conclusion that smaller resolutions are more precise [Stepniak et al., 2019]. However, he stated that a 15 min. resolution is a good middle ground, as it strongly reduces computational efforts while delivering high-quality results [Stepniak et al., 2019]. Temporal variation can be measured in any resolution across any period of time, which is why it is important to note that this research has been using the definition of temporal accessibility as the variation of the number of accessible places (e.g. POIs) in a specified time frame (here at different times of the day).

The last key concept that needs to be elaborated is the concept of equity. Equity can be defined in various context and finds different definitions, which underlines the importance of showcasing in which context this research will be conducted. Commonly, three main rules of distribution can be distinguished, namely efficiency, equality and equity. Leventhal [1980] and Talen [1998] conceptualized and defined

these types of resource allocations. While an efficient resource allocation insinuates its dependency towards people's contribution, equality stands for an equal distribution, regardless of one's contribution or need [Leventhal, 1980][Talen, 1998]. However, an equitable distribution of resources implies an allocation according to the individual's need [Leventhal, 1980][Talen, 1998]. The distinction can be pushed even further, as equity-related research commonly addresses both spatial and social equity [Leventhal, 1980][Talen, 1998]. While spatial equity tackles a fair geographical distribution of a resource, social equity emphasizes a fair treatment and equitable opportunities within those spaces [Duran-Rodas et al., 2020]. Therefore, this research has been focusing on social equity.

Moreover, it is also important to bridge both equity and accessibility. The reason why the emphasis on equitable planning is so strong in accessibility analysis, is that the worst-case scenario of a lack in accessibility to and by public transport, is mobility-related social exclusion. This term has been defined by Preston and Rajé [2007] as follows:

> "Social exclusion is a constraints-based process which causes individuals or groups to not participate in the normal activities of the society in which they are residents and has important spatial manifestations." [Preston and Rajé, 2007]

This definition has been elaborated in their research about a potential rise of the issue of social-exclusion in public policy planning paradigms, in which they undoubtedly stated that social exclusion is caused by a lack of access to social opportunities rather than their existence itself [Preston and Rajé, 2007]. The matter of social-exclusion has also been further explored by Wixey et al. [2005], who identified seven different types of mobility-related social exclusion. Some of the aspects can also be found in Geurs and van Wee [2004]'s four components of accessibility. First, the spatial aspect has been defined by the general lack of spatial accessibility, which is closely followed by the temporal related social-exclusion, as accessibility might be limited at certain times of the day [Preston and Rajé, 2007]. Moreover, one can also find a personal aspect, related to potential impairment or other physical (dis)abilities, a financial aspect which involves accessibility-induced costs, an environmental aspect that involves pollution or other dangers, an infrastructural as well as an institutional aspect [Preston and Rajé, 2007]. More modern definitions can be found by Pooley [2016], who defined social-exclusion as a "multi-dimensional process". He clustered for dimensions, namely resource and income, labour market, services and social relations [Pooley, 2016]. As these given researches have shown, multiple definitions of social-exclusion exist, while all of them are to the least partly related to the accessibility to goods, services and opportunities. Thus, this research focused on accessibility-based social equity-related gaps and issues, as this research aimed to identify and avoid the phenomenon of social-exclusion, hence striving towards a sustainable future of urban and rural areas.

In the following section, the systematic literature review will be presented. First, its overall method and workflow will be provided, while the results will be presented and discussed subsequently. Lastly, an additional section about mixed-methods approaches will be provided to complement findings of the systematic literature review.

2.2 Systematic Literature Review

The aim of this literature review, was to both conceptualize temporal accessibility and highlight state-of-the-art methods to identify potential research gaps. Therefore, after a definition of the key concepts

used throughout this research had been given, a systematic literature review has been conducted. The systematic literature review has been performed with the help of the WebOfScience® database using a set of five keywords. The keywords have been gathered based on the papers selected by Stepniak et al. [2019] and Tomasiello et al. [2019]. All their respectively cited research paper's keywords have been screened and highest recurrences have been chosen. Therefore, the results were the following keywords: "Accessibility", "Public Trans*", "Time", "Temporal". The first query with the given keywords returned a sample of n=176 research papers. After a first screening of their titles, a total of 58 papers have been excluded as their topic did not revolve around temporal accessibility. With the remaining n=118, a more in-depth screening has been conducted, including both abstracts and proposed methods. Using the same exclusion criteria, n=73 papers have been excluded, thus n=45 research papers have been retained in the systematic literature review. The entire flow-chart of the conducted systematic literature can be found in Fig. 2.1.

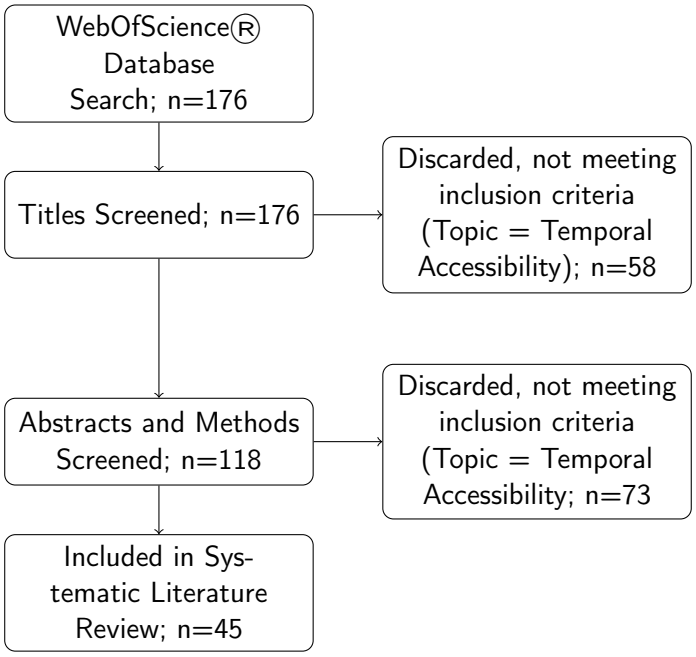


Figure 2.1: Flowchart of the conducted Systematic Literature Review

The papers have then been classified and analysed following the given 3 key concepts of (A) Accessibility, (B) Temporality and (C) Equity. For (A) accessibility, the type of measurement or indicator has been identified. As for (B), the research papers have been analysed based on the way in which time variation has been represented, as well as the assessed time span and the used resolution. Lastly the papers have also been classified based on whether equity-related issues have been addressed in their methodology and, if so, which socio-economic/ and -demographic characteristics were included. This in-depth analysis has then been simplified and sorted in sub-categories based on the given results. In a first term, this involved whether the travel time, the number of point of interests (POI)s or other indicators have been used to measure (A) accessibility. In terms of (B) temporal accessibility, the papers have been classified based on their type of time variation representation. Here, they have been categorized in continuous- or discontinuously methods (e.g. comparison of peak and off-peak, in contrary to a 24h span and a 5 min. resolution.). Lastly, (C) verified the presence of social equity impact assessments. In addition to that, both the journal topics and the release year of the selected papers have been included and plotted

in bar-charts, in order to disclose potential patterns.

Moreover, due to a scarcity of qualitative and mixed-methods approaches, an additional brief exploratory literature review has been added to highlight other adequate methods to assess temporal accessibility and equity. With the help of these in-depth results, the findings have been discussed and the position of this research in the research landscape of mobility justice has been pointed out before conclusions were drawn.

After the methodology of the proposed literature review has been highlighted, results of the systematic literature review can be found in form of a summary in Table 2.1 on the following page. The detailed assessment of all research articles can be found in a table in the appendix. Moreover, the publication years as well as the different journals have also been plotted and can be found in Fig. 2.2 and 2.3 below.

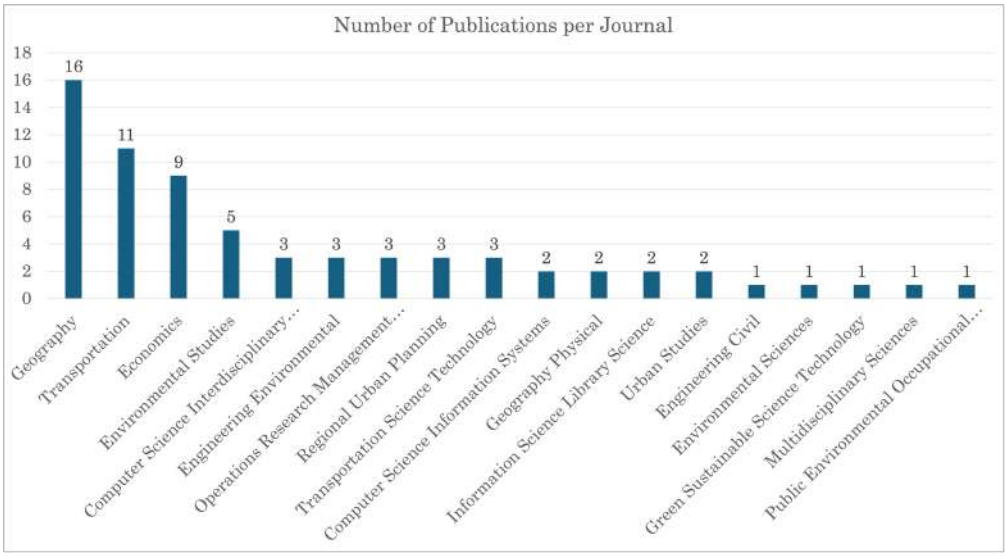


Figure 2.2: Number of Publications per Journal

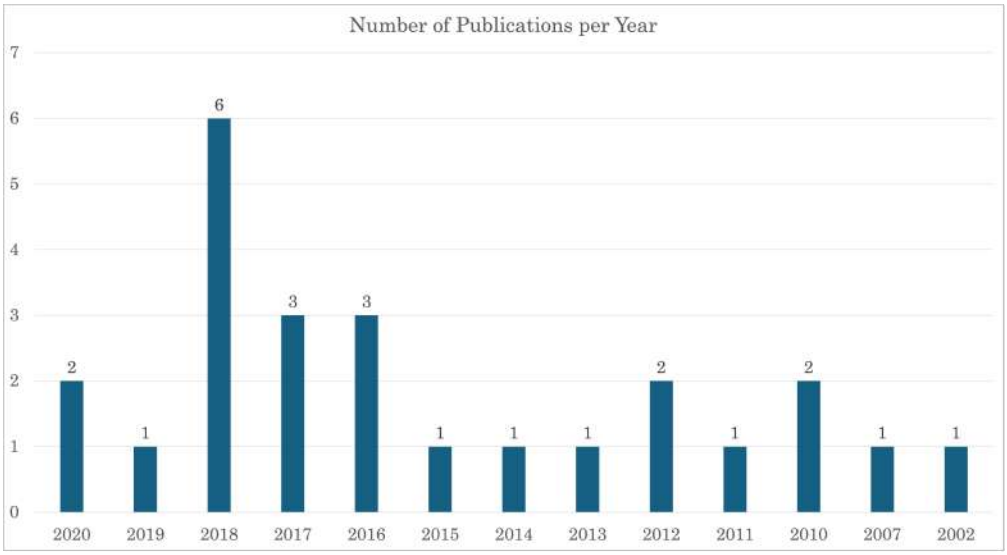


Figure 2.3: Number of Publications per Year

Authors	(A) Accessibility Measurement			(B) Temporal Accessibility Measurement		(C) Equity Assessment
	Travel Time	POI	Other	Discontinuous	Continuous	Equity Impact
Farber et al. (2014)	✓				✓	✓
Lei et al. (2010)	✓	✓		✓		
Dubé et al. (2013)	✓				✓	
Järv et al. (2018)	✓				✓	✓
Farber & Fu (2017)	✓				✓	
Kamruzzaman & Hine (2012)			Survey	✓		✓
Lee & Miller (2018)		✓		✓		
Tribby & Zandbergen (2012)	✓			✓		✓
Polzin et al. (2002)			Weighted		✓	✓
Kamruzzaman et al. (2016)			Survey	✓		✓
Stepniak et al. (2019)		✓			✓	
Xu et al. (2015)			Transit Accessibility Index	✓		
Delafontaine et al. (2011)			Opening Hours		✓	✓
Liao et al. (2020)	✓				✓	
Kujala et al. (2018)	✓				✓	
Tenkanen et al. (2016)		✓		✓		
Fayyaz et al. (2017)	✓				✓	
He et al. (2018)			Number of Trips	✓		✓
Neutens et al. (2010)		✓			✓	✓
Benenson et al. (2017)		✓			✓	
Aman & Smith-Colin (2020)			Multiple	✓		✓
Farber et al. (2016)	✓				✓	✓
Wang et al. (2018)			Activity Intensity		✓	
Moyano et al. (2018)		✓			✓	
Stepniak & Goliszek (2017)			Number of Trips		✓	✓
Guan et al. (2020)		✓			✓	
Chen et al. (2020)		✓			✓	✓
Lee et al. (2013)			Land-Use		✓	
Niedzielski et al. (2020)			Excess Commute Time		✓	
Xiong et al. (2022)			EMS Performance		✓	
Tomasiello (2019)		✓		✓		
Tasic et al. (2014)		✓			✓	
Cheng et al. (2018)			Timetable Network Graph	✓		
Yan et al. (2022)		✓		✓		✓
Dong et al. (2021)		✓			✓	
Murphy & Owen (2019)		✓			✓	
Ryan et al. (2023)			Number of Trips	✓		✓
Fatima et al. (2021)	✓				✓	✓
Langford et al. (2022)		✓		✓		
Henriksson et al. (2021)			MIXED-METHODS			
Robbennolt & Witmer (2023)			Accessible Area	✓		✓
Vitrano & Mellquist (2023)			Accessible Area + MM	✓		✓
Pinelli et al. (2009)		✓		✓		
Gan et al. (2024)		✓		✓		
Price et al. (2023)		✓		✓		

Table 2.1: Summary of the Systematic Literature Review

2.2.1 Accessibility Measurements (A)

The conducted systematic literature review has shown that, while a multitude of temporal accessibility measurement methods exist, cumulative measures remain the most commonly used. In other words, most research papers focus on counting the number of accessible opportunities such as workplaces, POIs, or the travel time to reach them [Farber et al., 2014],[Benenson et al., 2017],[Kamruzzaman and Hine, 2012]. Fewer articles also counted the number of trips [Polzin et al., 2002], the land use [Lee et al., 2013], the accessible area [Vitrano and Mellquist, 2023] and lastly the intensity of activity (utility-based) [Wang et al., 2018]. Yet, a more detailed insight of selected research papers will be given below.

A first example that can be cited is the research conducted by Farber et al. [2014], in which he attempted to understand where and what kind of individuals are particularly affected by food deserts [Farber et al., 2014]. To achieve the goal of his research, he calculated the variation of travel times from centroids in residential areas to their nearest supermarkets [Farber et al., 2014]. By overlaying this data with socio-economic and -demographic data, he could categorize which type of resident (divided by ethnicity, age and economical status) had lower or higher travel times, thus suffering from potential temporal accessibility gaps in a span of 24 hours [Farber et al., 2014]. While it was difficult to disclose patterns for the ethnicity based assessment, economical status assessment suggested a slightly higher level of temporal accessibility for those living below poverty line [Farber et al., 2014]. Therefore, his research resulted in a successful quantitative equity in temporal accessibility analysis [Farber et al., 2014].

Another POI accessibility-based assessment has also been elaborated by Lee and Miller [2018]. In their research, they investigated how temporal accessibility changed after the implementation of a new BRT service in the city of Columbus, OH [Lee and Miller, 2018]. For 4 different times of the day, they compared the number of jobs and healthcare facilities [Lee and Miller, 2018]. Thus, they successfully pointed out, that the new BRT system was indeed beneficial, as temporal accessibility improved [Lee and Miller, 2018]. While the main focus of this research was not social equity impacts, they did point out that the planned improvement in temporal accessibility would be beneficial especially for lower-skilled employees, who have to travel during non-core service hours such as early mornings or late evenings [Lee and Miller, 2018].

A more unique approach can also be found within Wang et al. [2018], in which he measured the activity intensity. This measurement is commonly known as a space-time utility temporal accessibility measurement method, which combines multiple elements such as travel time data, temporal patterns of availability at destinations or spatial distribution of opportunities [Wang et al., 2018]. This measurement allows a very precise estimation on the level of temporal accessibility [Wang et al., 2018]. By carrying out his method in Wuhan, he noted that, besides the fact that central urban locations benefit from stronger temporal accessibility much more than suburban places, state-of-the-art research methods and policy makers should distinguish the utility of different destinations at different times of the day [Wang et al., 2018]. Overall, he clearly advocates the use of temporal constraints in today's accessibility assessment practices [Wang et al., 2018].

This section has shown that a multitude of accessibility measurements exist. However, commonly used ones such as the cumulative measurement of POIs use these indicators as such. This is why the proposed mixed-methods approach will push common cumulative measurement methods further by elaborating an indicator. In the following section, the methods in which temporal variation can be measured have been detailed.

2.2.2 Measurement of Temporal Variation (B)

The time variation assessment of accessibility measurement methods finds different scopes and resolutions. While most papers assessed a period of 1 day (24 hours), others either assessed time periods of activity or high-intensity (peak-hours) [Lei and Church, 2010],[Kamruzzaman and Hine, 2012],[Lee and Miller, 2018].

For instance, a research conducted by Farber and Fu [2017] assessed travel time variations between population weighted centroids and jobs by using employment counts [Farber and Fu, 2017]. For multiple Origin-Destination pairs, he computed the travel time for every minute of the day in a span of 24 hours [Farber and Fu, 2017]. This level of resolution offers the highest level of precision, however is also the most tedious to compute [Farber and Fu, 2017, Stepniak and Goliszek, 2017].

A more common and more simple approach is to select different times in one day and compare them. This is also what Ryan et al. [2023] has proposed, in their research about different time of travel choices of different groups of individuals [Ryan et al., 2023]. By comparing the number of work-related trips during pre-peak-, peak- and post-peak time, they could identify how travel patterns differ by different socio-economic groups, especially in regards of their employment status [Ryan et al., 2023].

Yet, only two articles compared 2 different days [Xu et al., 2015],[Vitrano and Mellquist, 2023], two articles assessed a period of one week [Pinelli et al., 2009, Delafontaine et al., 2011] while another one assessed multiple years in a row [Dube et al., 2013]. Depending on the destination that needs to be reached and time spans that are being assessed, a much lower resolution can be chosen [Stepniak and Goliszek, 2017]. This is also what Delafontaine et al. [2011] advocated in his research, in which he assessed the opening times on equity of individual space-time accessibility [Delafontaine et al., 2011]. By using libraries as an example, he mapped the opening times of 16 different libraries in the city of Ghent at every day of the week [Delafontaine et al., 2011]. Here, it becomes visible that a higher resolution can probably be omitted, while a time span of multiple days is of much higher importance [Delafontaine et al., 2011].

As observed in the given research articles, the resolutions and chosen time spans widely differ, as some papers focused on the comparison of specific times of the day such as peak or off-peak, while others conducted a continuous assessment in commonly an hourly or 15-mins. resolution [Jarv et al., 2018],[Stepniak and Goliszek, 2017]. Choosing the most suitable scope and resolution depends widely on the type of destination that needs to be accessed and whether it is expected to vary across multiple days of a week. However, social equity implications are just as important, yet sometimes only implicitly considered in the cited research articles, which is why the next section will further elaborate this matter.

2.2.3 Social Equity Implications (C)

A noticeable result is, that approximately half of the research articles in the sample address equity related issues [Farber et al., 2014],[Lee and Miller, 2018],[Tribby and Zandbergen, 2012]. In the equity-related articles, mainly the temporal accessibility by disadvantaged group of residents as stated in the sections above has been assessed. Commonly assessed groups of individuals for equity analysis were income, gender, age and occupation [Farber et al., 2014],[Neutens et al., 2010]. Only a very little number of articles tackled car ownership, home ownership or used the GINI coefficient as an indicator [Kamruzzaman and Hine, 2012],[Vitrano and Mellquist, 2023].

One of a very few mixed-methods approaches has been proposed by Kamruzzaman and Hine [2012]. In his research about activity spaces and transport disadvantage in rural areas, he included almost all type of potential indicators of transport disadvantage. These included for example age, gender, economical status, occupation, or home and car ownership. While he found out that especially gender, income and car ownership were significant in his developed models, he noted for example that women had smaller activity spaces while lower-income or non-motorized households were more likely to participate in local activities. While the distribution of trips (temporal accessibility) and the size of activity space per socio-economic or demographic characteristic has been considered separately, he could successfully distinguish potentially disadvantaged group of residents.

A more unique approach of measuring equity in temporal accessibility has been developed by Jarv et al. [2018]. In addition to the calculation of the temporal variation of the accessibility in an hourly resolution, he calculated the hourly level of spatial equity, resulting in a temporal variation of a GINI coefficient [Jarv et al., 2018]. While his research did not specifically focus on specific group of residents, he was more interested in the fact that certain destinations such as grocery stores should be equally distributed among the population in the city of Tallinn [Jarv et al., 2018]. What seems to be rather an equality than equity analysis, is still worth to showcase as it is the only research in the sample that assessed the variation of its GINI coefficient.

A recent study that is supposedly more in line with the proposed research method in the following chapter, is for example a research led by Robbennolt and Witmer [2023]. In his research, he assessed the accessible area in square meters by income, residents below poverty line and non-motorized households, as well as the population density, by comparing 7 times of a day [Robbennolt and Witmer, 2023]. His research disclosed no significantly inequitable access to opportunities by lower-income or non-motorized households, however, no equitable temporal accessibility either [Robbennolt and Witmer, 2023]. His findings suggested a highly equal temporal accessibility, which stayed in contrary of what both his research and his local government advocate: the need for more equity - allocating the resource to those who need it the most [Robbennolt and Witmer, 2023].

Lastly, only 3 mixed-methods approach have been identified in the sample of selected articles including mainly interviews, hence the necessity of an exploratory literature review to tackle qualitative methods in equity and accessibility assessments, which will be detailed in the following section.

2.2.4 Mixed-Methods Approaches and Qualitative Methods

This section aimed to complement the findings of the conducted systematic literature to bridge the lack of qualitative research methods in the previously cited articles. This section followed the same patterns as the previous sections, by first showcasing both sole qualitative and mixed-methods assessments for (A) Accessibility analysis, (B) Temporal accessibility analysis and lastly (C) Equity assessments.

The first qualitative tool that has been showcased had been developed by Jones [2011], which is visually interactive and supports in accessibility planning for mobility disadvantaged groups. According to Jones [2011], making use of sole quantitative tools is "narrowly focused", as subjective aspects are left out. By conducting workshops with residents and professionals of his assessment area, he identified specific needs, which helped to tailor accessibility planning policies to local specificities [Jones, 2011]. Tiznado-Aitken et al. [2020] shares the same opinion, as he believes that a "one-dimensional" analysis lacks in the individual's perception, since own needs, preferences and abilities differ from own neighbors

[Miller, 1982]. Tiznado-Aitken et al. [2020] highlights the complementary function of mixed-methods, as while larger-scale observations are well covered by quantitative methods, qualitative research methods complement and cross-validate those findings with much richer yet smaller-scale data. In addition to traditional accessibility measurement methods, he decided to enrich and complement his findings with unstructured interviews, in which interviewees had the opportunity to reflect about their own experiences and circumstances in public transport accessibility [Tiznado-Aitken et al., 2020].

While Kamruzzaman and Hine [2012] was allegedly the first to make use of a mixed-methods approach to assess the temporal changes in accessibility, Vitrano and Mellquist [2023] is a much more recent research and is much more in line with what has been proposed in the following chapters. In their research about temporal accessibility in the city of Malmö, they pointed out how equitably residents felt treated in terms of time wealth and accessibility through a mixed-methods approach [Vitrano and Mellquist, 2023]. She successfully pointed out that residents with irregular work hours were particularly affected by off-peak service gaps, but also that peak hours were unevenly distributed throughout the society [Vitrano and Mellquist, 2023]. Moreover, they also highlighted the success in the use of the mixed-methods approach, and distinguished perceived and actual accessibility [Vitrano and Mellquist, 2023]. Their respondents were allegedly complaining about infrequent services, crowdedness or delays, findings that her quantitative methods cannot capture [Vitrano and Mellquist, 2023]. Therefore, their research was a valuable insight, while following chapters will reveal how similar observations can be made.

Lastly, qualitative methods as equity assessment methods have been showcased as well. To better understand potential equity gaps, Shay et al. [2016] made use of interactive workshops as well, in which local informants were asked to identify areas of potential transport disadvantage. Those areas were identified by map drawings and open discussions [Shay et al., 2016]. In a second step, other groups have been gathered as they have been asked to exchange their knowledge and discuss local equity conditions [Shay et al., 2016]. This type of method presented by Shay et al. [2016] has been well perceived by their key informants, and has proven to be a successful method to assess potential disadvantage, as even street-scale population differences can be observed. Also mixed-methods tools can be found in the equity assessment landscapes. Fairness assessments can be subjective, as stated by Duran-Rodas et al. [2020], who conducted research about the fairness aspect in bike-sharing infrastructure allocation. He made use of a lexicometric analysis in the city of Strasbourg to understand the feeling of inhabitants about an implemented bike-sharing-system [Duran-Rodas et al., 2020].

Another method can also be found by Thomopoulos and Grant-Muller [2013], with their aim to bridge a gap between widely used cost-benefit and multi-criteria analysis practices. Thus, they developed the SUMINI ("SUstainable Mobility INequality Indicator") tool, which allows decision makers to weigh project and scheme alternatives through a scoring system, hence allow them to quantify subjectivity [Thomopoulos and Grant-Muller, 2013]. Thus, the showcased qualitative and mixed-methods approaches have shown that a multitude of methods exist, but more importantly highlighted the necessity of both quantitative and qualitative methods in state-of-the-art equity assessments.

2.2.5 Relevance of Mixed-Methods Approaches to Assess Equity in Temporal Accessibility

Therefore, these researches have shown that including qualitative research methods is crucial to complement quantitative methods through mixed-methods approaches, since equity and accessibility both

can be strongly subjective and dependent on the individual's circumstances and needs. While most researches have been focusing on spatial aspects in accessibility from/to RPT, only recent ones have started incorporating the dimension of temporal variation in accessibility over a predefined time span, as observed throughout the showcased research articles and the Fig. 2.3. Despite a rise in accessibility related papers including temporal aspects, most equity related issues remain implicit and are not always addressed. Moreover, this literature review has also highlighted the great lack in qualitative- and mixed-methods, despite the subjectivity in equitable accessibility related issues. However, this literature review has also highlighted the significance of the temporal assessment in state-of-the-art accessibility analysis. Most studies strongly emphasize that assessing accessibility at a single point in time is insufficient and inadequate, as individual's travel patterns and destinations, as well as the transport services vary throughout the day or a week. Therefore, this literature review has proven that temporal accessibility is much more advanced and precise than common spatial accessibility measurement methods, hence reinforcing its suitability for the goals of this research.

As previously observed, cumulative measurement methods are widely used, yet mostly as an indicator on their own. Therefore, this research will push them further and focused on the creation of a cumulative measurement-based Temporal Accessibility Indicator. Moreover, and to the best of our knowledge, this research has been among the first to adopt a mixed-methods approach to address social equity in temporal accessibility, hence addressing the lack of such methods in the current research landscape. By incorporating perceived temporal accessibility and fairness, it aimed to advance the understanding of subjectivity in accessibility and equity, thereby strongly contributing to the research landscapes of accessibility planning and mobility justice.

Chapter 3

Mixed-Methods Approach

The objective of this research was to assess how equitable the temporal accessibility from rail-based public transport station is, by applying the proposed method onto the greater metropolitan region of Munich. This assessment provided an understanding of the level of temporal accessibility in both rural and urban areas while highlighting potential social equity gaps in terms of temporal accessibility that might arise. To achieve the objective of this research, a mixed-methods approach has been proposed and applied onto the greater metropolitan area of Munich.

This section first disclosed how a Temporal Accessibility Indicator has been developed, capturing both the strength and the overall time variation of accessibility for every station in a time span of 24 hours. To back up this newly developed indicator, a complementary quantitative assessment has been proposed, in which RPT stations have been clustered based on their temporal accessibility. In addition to that, a qualitative temporal equity assessment critically validated and complemented quantitative findings, in order to achieve a mixed-methods approach. The exact structure summarizing the proposed mixed-methods approach can be found in the flowchart in Fig 3.1 below:

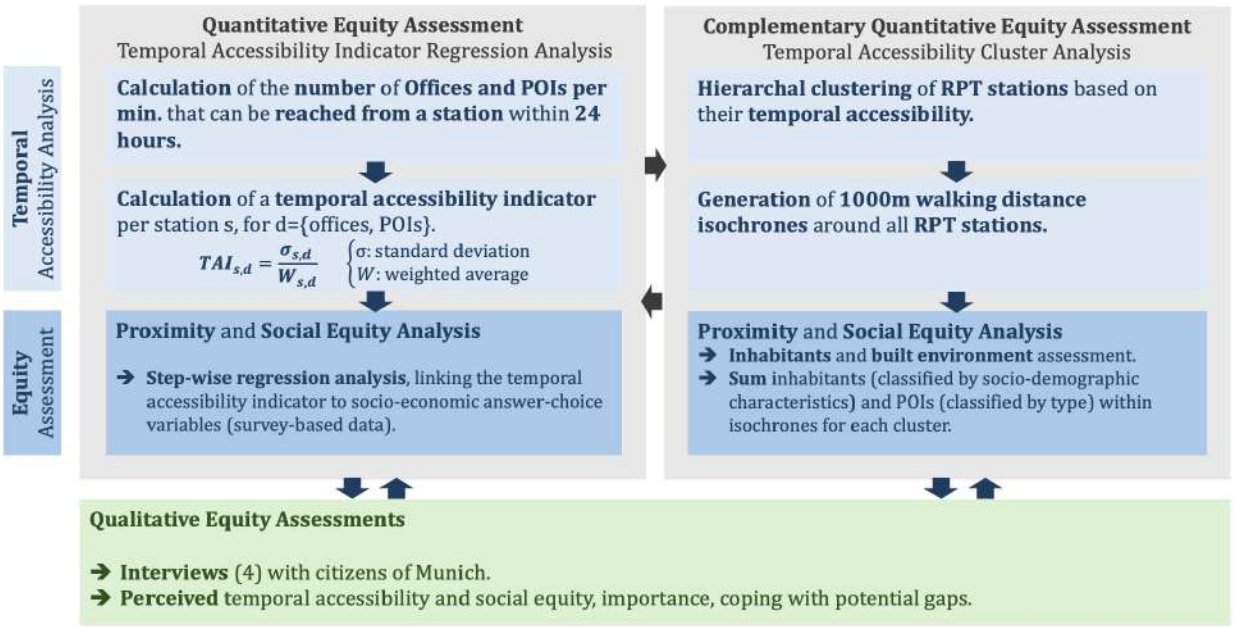


Figure 3.1: Flowchart of the Proposed Mixed-Methods Approach

The proposed methodology has been selected as it pushed standard reliable tools and practices such as the cumulative measurement or linear regression analysis further, thus aiming that the output of this research provides to the least an identical or higher standard than past research conducted on similar topics. Moreover, the indicator as well as the simple nature of the complementary method emphasize the versatility of application of these tools, as they are not tailored on the Munich's metropolitan region, hence making them applicable on any region on this planet. Lastly, the mixed-methods nature of this assessment pushed standard sole quantitative/qualitative methods forward, by complementing large-scale patterns with small scale subjective perspectives. Both the cross-validation and complementing of each other results in much richer results, and can be considered indispensable when subjective issues such as equity and accessibility are being assessed.

Therefore, the proposed mixed-methods will provide a Temporal Accessibility Indicator, a total of four linear models describing socio-economic and -demographic characteristic, as well as the used correlation coefficients. Moreover, the complementary method will provide bar charts disclosing potential disparities in temporal accessibility by socio-demographic characteristics. Lastly, the qualitative method will not only provide individual's perception on equity in temporal accessibility, but also complement and critically validate quantitative results. In the following sections, an in-depth explanation of the developed methods has been given, by starting with the quantitative assessment, followed by the qualitative assessment and ending with the mixed-methods approach.

3.1 Quantitative Temporal Accessibility Equity Assessment

3.1.1 Temporal Accessibility Indicator and Linear Regression Analysis

Aim and Expected Outcome

The aim of this first method was to develop an indicator that included both the overall strength of accessibility and a temporal variation component, which can be subsequently used to assess equity quantitatively, by conducting a regression analysis with independent socio-economic and -demographic variables. This linear model won't be used as an estimator, but help with a relationship analysis to disclose which socio-economic or -demographic factors are associated with a higher temporal accessibility. This section will first showcase the type of data that has been collected, how the data has been prepared and assessed, how the indicator has been calculated and lastly how it has been used in combination with socio-economic/-demographic data to conduct an equity analysis.

Used Data Sources

In a first term, static GTFS data has been collected from DELFI e.V. [2024]. This dataset has been cropped to fit not only the metropolitan region of Munich, but also an empirically chosen much larger part outside of it, so that stations bordering this area will still find significant temporal accessibility results. The exact bounding box coordinates in which the GTFS dataset has been cropped to can be found in the appendix. Moreover, the rail public transport stations of the dataset have been extracted for the metropolitan region of Munich. In a second term both generalized offices and generalized POIs have been gathered from OpenStreetMap (OSM) data, in which only the location coordinates and IDs as point layers, yet not further information has been retained [OpenStreetMap Contributors, 2017]. Socio-

economic and -demographic data has been gathered by the "Mobilität in Deutschland 2017" (MiD 2017) survey, containing answer choice variables in a grid cell format, following the German national grid cell standard format with cell sizes ranging from 5km2 (low density areas) to 500m2 (high density areas) [BMVI, 2017].

Data Preparation

To measure the temporal accessibility from RPT stations towards offices or POIs respectively, the r5r rapid routing algorithm has been used, and looped in a time period of 24 hours on a Monday outside of public holidays, as most services are expected to run on a weekday [Pereira et al., 2021]. To run this algorithm, the stations extracted from the GTFS data-set have been used as origin points, while the POIs and offices have been respectively set as the destinations. Moreover, the mode has been set to Walk and Transit, as this analysis does not include other modes such as (non-)motorized individual traffic. The walking speed has been set to an average value of 5kph, commonly used in accessibility analysis [Pajares et al., 2021]. Moreover, the maximum trip duration has been set to 30 min., as this value is the average measured commuting time in the state of Bavaria, in which Munich is located [BMVI, 2017]. The exact used and modified/looped r5r script can be found in the appendix. Therefore, r5r generated a travel time matrix for every minute of the day for the office-based analysis. However, due to a much higher number of POIs, a cumulative resolution of 30 min has been chosen to improve computing efficiency. The travel time matrix were then merged and sorted by stations in a larger table to prepare the number of accessibility POIs and offices for future assessments. However, in the further assessment steps, a 24hrs analysis time span will be considered only for POIs, whereas 13hrs (from 6:00 to 18:59) will be empirically retained for the office-related analysis, as they typically represent the outer boundaries of the peak hours in Germany.

Moreover, for further assessments and the creation of the indicators, it was also necessary to gather the number of departures per hour and stations. This data has been extracted from the same GTFS data-set used for the cumulative measurement of offices and POIs [DELFI e.V., 2024].

In the mean time, the "MiD 2017" survey dataset has been adapted as well. Each answer has been broken down by all its possible choices and aggregated per cell, to gain a data structure that describes the percentage of respondents per category and cell. Moreover, all different cell sizes have been included in one dataset, to allow more precision in higher density urbanized areas and broader data structures in less populous more rural areas.

Indicator Creation

After the data has been successfully aggregated, the number of POIs and offices were summed per hour, to match the data structure of the departures per hour. Using these two data-sets, two different values have been calculated. In a first term, the weighted average value W_s of POIs for $t \in [0; 24]$ (24) hours and offices for $t \in [6; 18]$ (13) hours has been respectively calculated for every station s, by using the formulas below:

$$W_{s,Offices} = \sum_{t=6}^{18} D_{t,s} \cdot A_{t,s}$$

$$W_{s,POIs} = \sum_{t=0}^{23} D_{t,s} \cdot A_{t,s}$$

where:

- t: Hour of the day (6 to 18 or 0 to 23).
- s: Station index.
- $D_{t,s}$: Number of departures at hour t and station s.
- $A_{t,s}$: Number of accessible places at hour t and station s.

In a second term, the variation of accessibility over the assessed time spans has been calculated by using the standard deviation of the hourly cumulated destinations. Thus, the standard deviation of the number of accessible places over time t for each station s has been calculated as followed:

$$\sigma_{s,Offices} = \sqrt{\frac{1}{T} \sum_{t=6}^{18} \left(A_{t,s} - \bar{A}_s\right)^2}$$

$$\sigma_{s,POIs} = \sqrt{\frac{1}{T} \sum_{t=0}^{24} \left(A_{t,s} - \bar{A}_s\right)^2}$$

where:

$$\bar{A}_{s,Offices} = \frac{1}{T} \sum_{t=6}^{18} A_{t,s}$$

$$\bar{A}_{s,POIs} = \frac{1}{T} \sum_{t=0}^{24} A_{t,s}$$

- T: Total number of time periods.
- $A_{t,s}$: Number of accessible places at hour t and station s.
- $\bar{A}_s$: Mean number of accessible places at hour t and station s.

After that, the standard deviation has been divided by the weighted average mean, resulting in the desired indicator. This indicator called TAI_s has been calculated for every station s in the entire metropolitan region of Munich and is expressed as followed:

$$TAI_{s,Offices} = \frac{\sigma_{s,Offices}}{W_{s,Offices}}$$

$$TAI_{s,POIs} = \frac{\sigma_{s,POIs}}{W_{s,POIs}}$$

where:

- σ_s: Standard deviation of the number of accessible places for every station s.
- W_s: Weighted average value of the number of accessible places for every station s.

Spatial analysis

After the temporal accessibility indicator has been calculated for every station within the metropolitan region of Munich, it has been combined with socio-economic and -demographic variables from the "MiD 2017" survey. For that, an inverse-distance-weighted (IDW) raster has been generated using the borders of the metropolitan region of Munich, and an empirically optimal resolution of px = 0.001, to approximate an average temporal accessibility indicator value between stations [OpenStreetMap Contributors, 2017]. For every cell of the grid of "MiD 2017"'s dataset, the mean indicator value has been calculated using QGIS's zonal statistics tool [QGIS]. This step then helped to obtain for every cell all socio-economic/-demographic characteristics as well as the mean temporal accessibility indicator value, which can be used for the subsequent regression analysis.

Linear Regression Analysis

The "MiD 2017" is a large dataset containing not only socio-economic/-demographic variables but also highly detailed travel behavior information [BMVI, 2017]. The latter has been omitted, and mainly 6 categories of potential variables have been kept. Based on the conducted systematic literature review in chapter 3.3 and based on the most commonly assessed socio-economic/-demographic characteristics of individuals in equity analysis, the motorization of household, the age, gender, education, occupation and the economical status have been considered. Using these categories, two approaches have been followed to understand and create the best fitting linear model. In a first approach, a Pearson correlation has been conducted for all available variables, and a linear model has been created with all the highest correlating variables of each category. This could help in a first step to understand which characteristics or categories have potential dependencies with higher temporal accessibility. However, a second more systematic approach has been followed, by making use of a step-wise linear regression model using BIC due to its smaller and more precise selection of variables in its output, to not only generate the best-fitting model, but also understand which variables of each category have a significant impact on - or are impacted by temporal accessibility. Lastly, to avoid multicollinearity between independent variables, all models' variables underwent a VIF-test (Variance Inflation Factors). As VIF thresholds widely differ, an empirical threshold of 3 has been set [O'brien, 2007].

Therefore, this method provided an overview on the temporal accessibility situation in the metropolitan region of Munich, depicted on maps in the following chapter. In addition to that, four linear models have been generated, describing socio-economic and -demographic characteristics or residents having very high or low temporal accessibility by RPT stations. Before the results will be showcased, the following section will elaborate how the complementary analysis has been conducted.

3.1.2 Complementary Temporal Accessibility Cluster Analysis

Aim and Expected Outcome

As an addition of the findings in the first quantitative equity analysis, the RPT stations have been clustered, and an accessibility analysis has been conducted. In this part of the assessment, the main aim was to disclose which type of individuals have access to which cluster/type of RPT stations, within a 1000m walking distance range while understanding potential relations to the built environment. This method will provide both tables and bar charts in which it will be possible to visualize the ratio and deviation of

the mean of different types of individuals within a same category (age, gender and migration background) and POI categories (recreational, commercial, educational, medical) per RPT station station cluster. The following sections will provide an in-depth explanation on how this analysis has been conducted.

Used Data Sources

The dataset used as an input for the clustering algorithms are the aggregated outputs of the r5r algorithms, over a time span of 24 hours for the POI-based temporal accessibility data and 13 hours for office-based temporal accessibility data. The age, migration and gender related information is provided by the German "Zensus 2011" data-set, which provides an exact count of inhabitants per category in small 100m-2 cells [Zensus, 2011]. Moreover, the POIs have been gathered by "OSM" data [OpenStreetMap Contributors, 2017]. Both data-sets have been cropped onto the metropolitan region of Munich to fit the scope of the analysis.

Isochrone Generation

In addition to the collected socio-demographic data, isochrones have been built using OpenRouteService plugin in qGIS software around every RPT station in the metropolitan region of Munich [ORS]. For this Isochrone generation, the mode has been set to walking, with a walking speed of 5km/h and a walking distance of 1000m. Statistics on the average walking distance in Munich widely differ, while this value has been set after Sarker et al. [2019]'s research, pointing out a common 1000m walking distance from/to subway stations in this region [Sarker et al., 2019].

Cluster Generation

In a second step, RPT station clusters have been generated using the R-based hierarchical clustering method, as results were found to be more precise than the k-means clustering algorithm. To identify the ideal number of clusters, a heatmap has been generated for both the POI and the office-based accessibility data respectively using the pheatmap package, using the original temporal accessibility datasets in their original resolution as an input [Raivo Kolde, 2010]. The heatmaps of the hierarchical clustering results for both offices and POI based temporal accessibility data have been depicted in fig. 3.2 and 3.3 below. As depicted, the horizontal x axis indicates the stations, while the vertical y axis stands for every minute of the day. Moreover, the scale on the right side of the heatmap indicates the scaled number of offices or POIs accessible in each minute per station in 24 hours. Hence, supported by a visual analysis of the heatmaps, the number of clusters has been set to 5 for the office-based and 6 for the POI-based analysis.

Data Analysis

Lastly, the analysis has been conducted. For each cluster, the number of individuals living within the respective isochrone of the stations as well as the POI types have been calculated. In other words, an exact count of e.g. females, males, or residents with migration background as well as the number of recreational, commercial, educational or medial POIs per cluster has been identified. With the help of this data, visual representations such as the deviation to mean values could have been depicted.

Therefore, the complementary temporal accessibility analysis provided bar-charts depicting different socio-demographic group's accessibility to different clusters in the following chapter, in order to

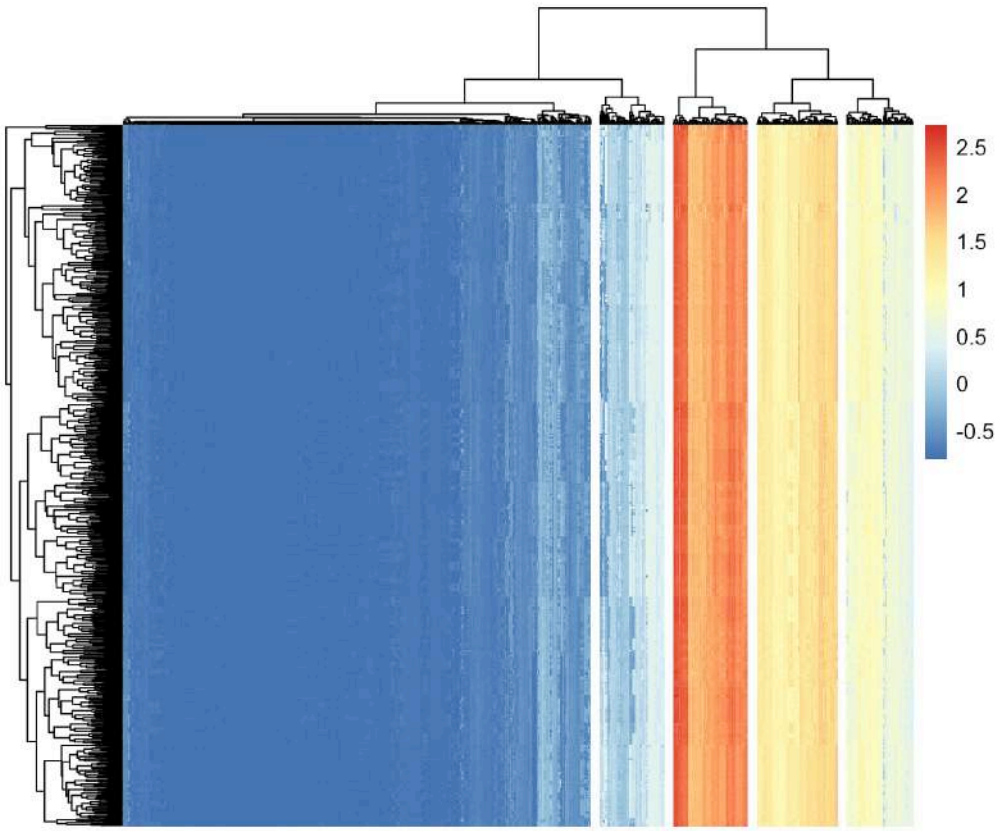


Figure 3.2: Heatmap of the Hierarchical Station Clustering Analysis based on their Temporal Accessibility to Offices

understand who is privileged in terms of temporal accessibility by RPT. Yet, in order to conduct this mixed-methods approach, the following section will detail the employed qualitative methodology which are indispensable for this assessment.

3.2 Qualitative Temporal Accessibility Equity Assessment

Aim and Expected Outcome

After the quantitative analysis has been proposed, the qualitative approach will be further elaborated. This method consisted in primary data that has been collected within interviews, and explored resident's perception on fairness and equity in temporal accessibility by RPT and aimed to enrich larger quantitative results, as local specificities tend to be overseen. Therefore, this interview will furnish an understanding on whether needs in terms of temporal accessibility have been satisfied, understand the perception on fairness of temporal accessibility across the area the interviewee is familiar with, deepening the understanding and critically validate quantitative method results as well as potentially explore improvements in temporal accessibility or planning policies to ameliorate equity in temporal accessibility by RPT.

Participant Selection and Choice of Interview Guide

To conduct the interviews, a number of 4 participants have been selected, each with a different socio-economic and -demographic background and living in different parts of the city. To conduct a qualitative

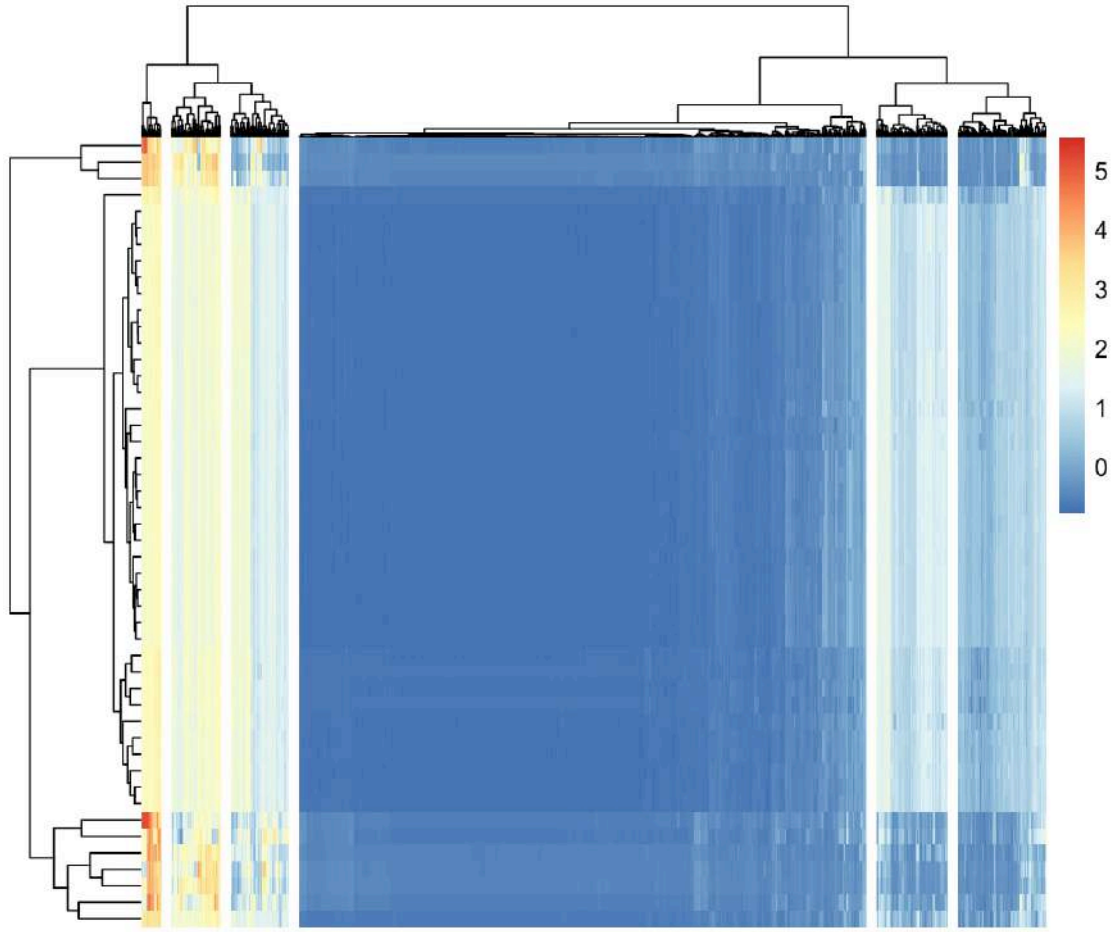


Figure 3.3: Heatmap of the Hierarchical Station Clustering Analysis based on their Temporal Accessibility to POIs

equity analysis, a semi-structured interview guide has been preferred, as respondents tend to be unfamiliar with equity in temporal accessibility related topics, while allowing them to express their opinions freely and independently [Wholey et al., 2010]. Moreover, this type of interview structure allows potential extensions and adjustments, deepening specific topics and observations while ensuring it stays within the topic boundaries [Wholey et al., 2010].

Interview Guide

In a first time, interviewees were asked to reflect on their own travel behavior and circumstances, as well as potential challenges over the span of a day. This general first step helped to draw an image of their overall satisfaction in terms of mobility needs and served as an introduction to the following questions. After this general introduction, it has been identified whether the interviewee had a general awareness of the impact of temporal variation in accessibility. In case of unfamiliarity of the interviewee with these kind of topics, it helped him to gain a broader understanding and raise awareness about subjects they had not yet put a thought to. The interviewee has been asked to reflect on potential changes and experienced difficulties in accessibility due to potential gaps at specific times of the day. Moreover, they have also been asked to reflect if different types/groups of individuals are affected by those differences in diverse ways. By slowly guiding the interviewee throughout potential equity thoughts through the 2 first section,

the interviewee had to reflect on general social equity, and link this matter to accessibility. Here, the interviewee shared its own perception on equity in terms of temporal accessibility in the environment he is familiar with.

The first part of the interviews marked the sole qualitative aspect of it. However, in a last section, the mixed-methods nature of this approach will be further elaborated. While this section is also part of the conducted interviews, it has been detailed in a separate section due to its core role in this assessment.

3.3 Mixed-Methods Assessment

Lastly, as part of the qualitative interviews and with the aim to bridge both quantitative and qualitative data to allow a mixed-methods approach, the interviewee has been asked to validate or critically question quantitative results of the equity assessment. This did not only help to determine to what extent the quantitative results are applicable, but also added depth to the meaning of them, in order to ease future interpretation steps. Moreover, they have been asked to identify potential group of (dis-)advantaged residents, as well as to put the quantitative results in relation to their own circumstances. With these questions, respondents were asked to reflect on the quantitative results, as their opinions helped and reinforced the interpretation of the results from a local perspective. Lastly, respondents were also asked to judge the overall equity situation in terms of temporal accessibility by RPT. Such question opened the possibility to compare and disclose to what extent their opinion shifted after the results have been shown. The final section of the qualitative interviews can also be seen as a core element of this mixed-methods approach, as it aimed to bridge both methodologies, by complementing each other's findings, critically validate or disagree and ease future interpretation steps.

Therefore, this section briefly described the contents of the interview guide. Yet, the entire and more detailed guide can be found in the Appendix. After the proposed mixed-methods approach has been highlighted throughout its multiple steps, its results will be detailed in the following chapter.

Chapter 4

Results

4.1 Quantitative Temporal Accessibility Equity Assessment

4.1.1 Temporal Accessibility Indicator and Linear Regression Analysis

Temporal Accessibility Indicator

After the routing algorithm has been run and the data has been aggregated, the described indicator has been calculated and visually represented in a map of Munich's metropolitan area for respectively Offices and POIs. Both maps can be found in Figure 4.1 and 4.3 below. Moreover, a close-up on the city of Munich can be found in Figures 4.2 and 4.4 respectively. In addition to the maps and to provide an in-depth understanding of temporal variation characteristics of each indicator category shown in the legend, 5 random stations have been chosen per legend category and their temporal accessibility to offices has been plotted and can be found in Figure 4.5 (a) - (c) and 4.6 (a) - (b). Moreover, 4 maps at different times of the day have been added in Fig. 4.7 which depicts the accessibility to POIs. However, this map has only been added to support the significance of temporality in accessibility assessments at later stages of the discussion.

As the station's indicator of both maps have been visually represented using the same scale, higher values for the POI-based assessment can be found. In the office-based assessment, lower indicator values can be found in Munich's urban area as well as other sub-center cities such as Augsburg, Ingolstadt or Rosenheim, while the eastern part shows a higher number of stations with a higher indicator value. The office-based assessment depicts higher indicator values in most areas, with mid-range values in Munich. Low indicator values can be found for stations in more disperse/rural areas.

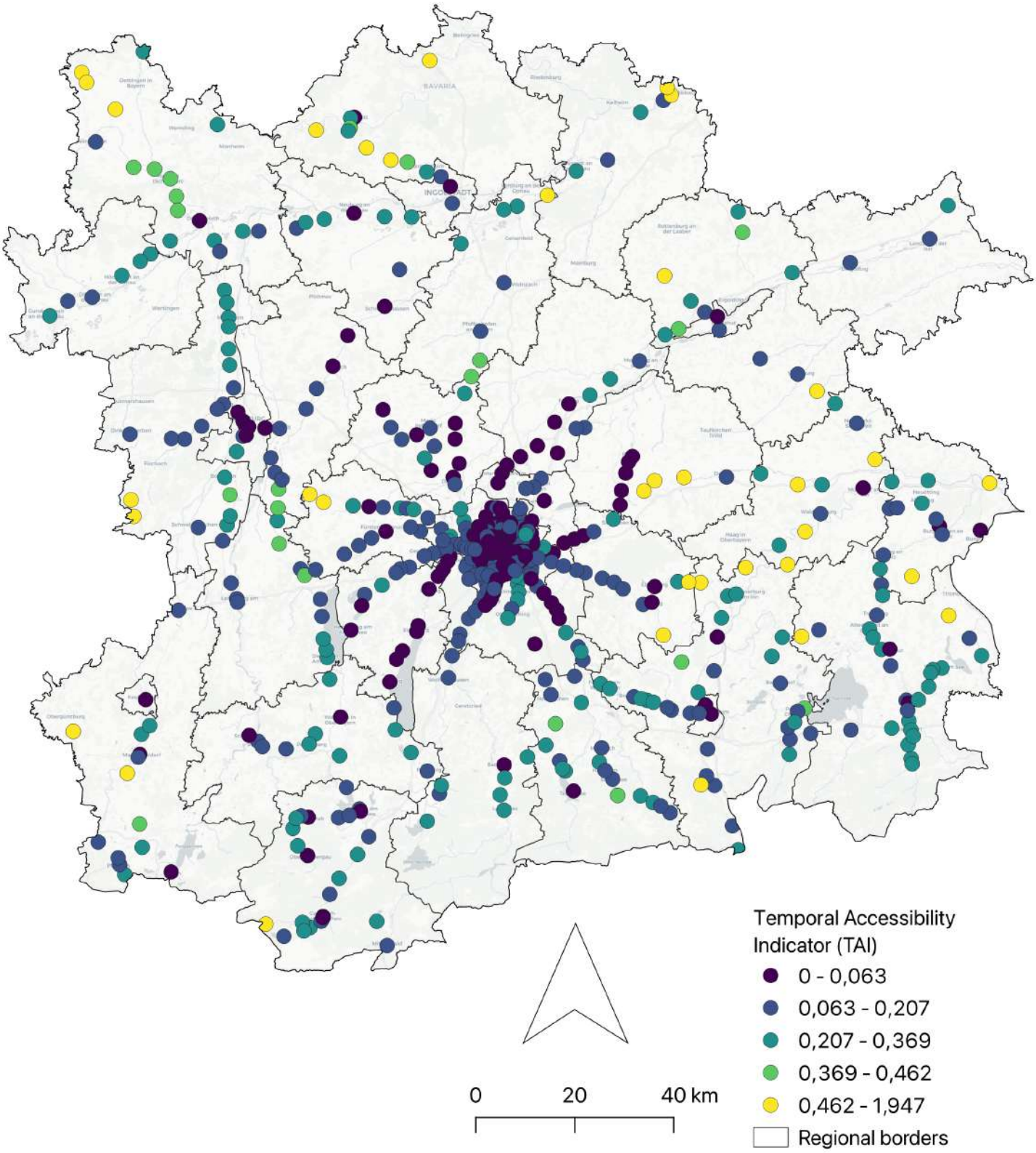


Figure 4.1: Temporal Accessibility to Offices in Munich's Metropolitan Region

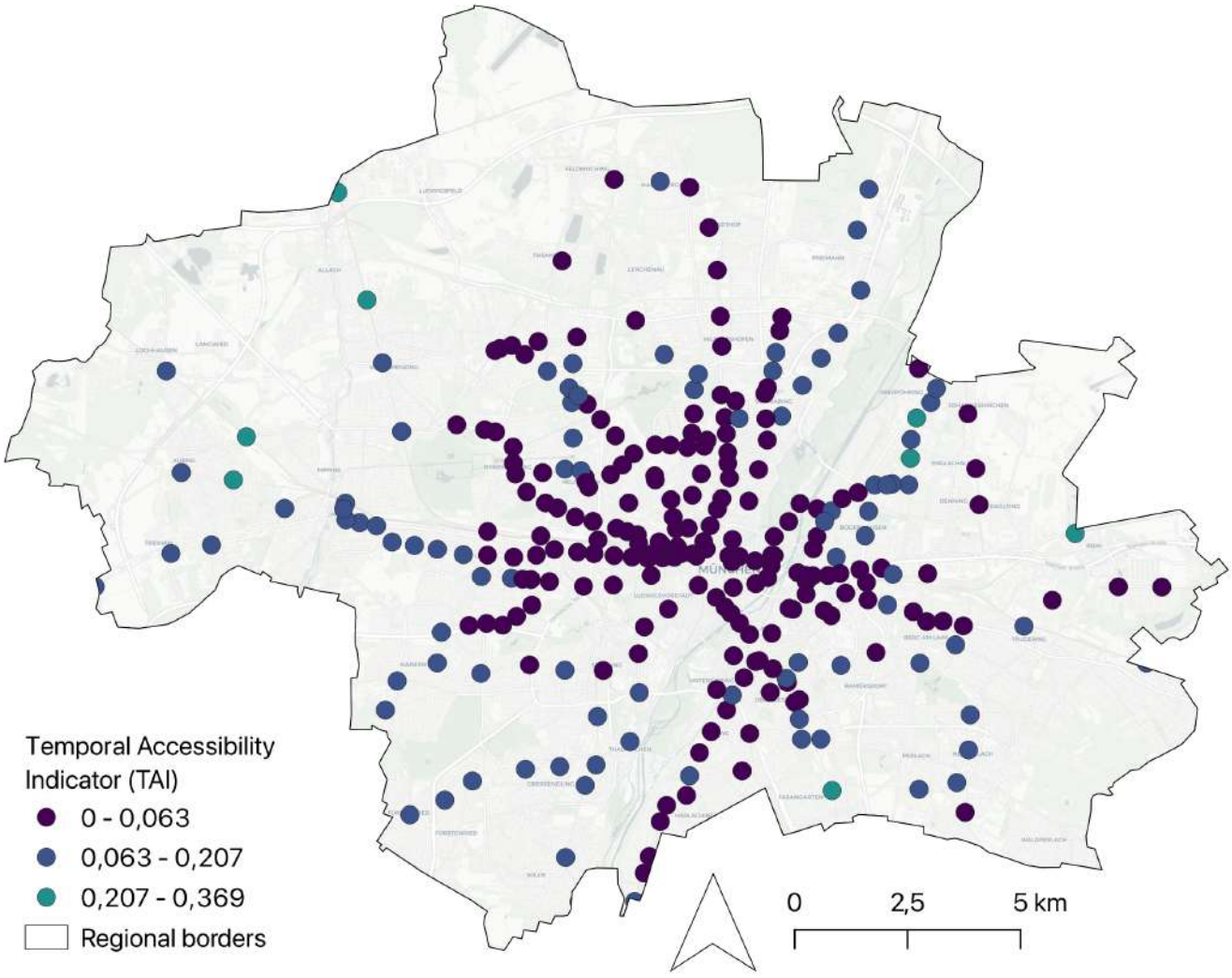


Figure 4.2: Temporal Accessibility to Offices in the City of Munich

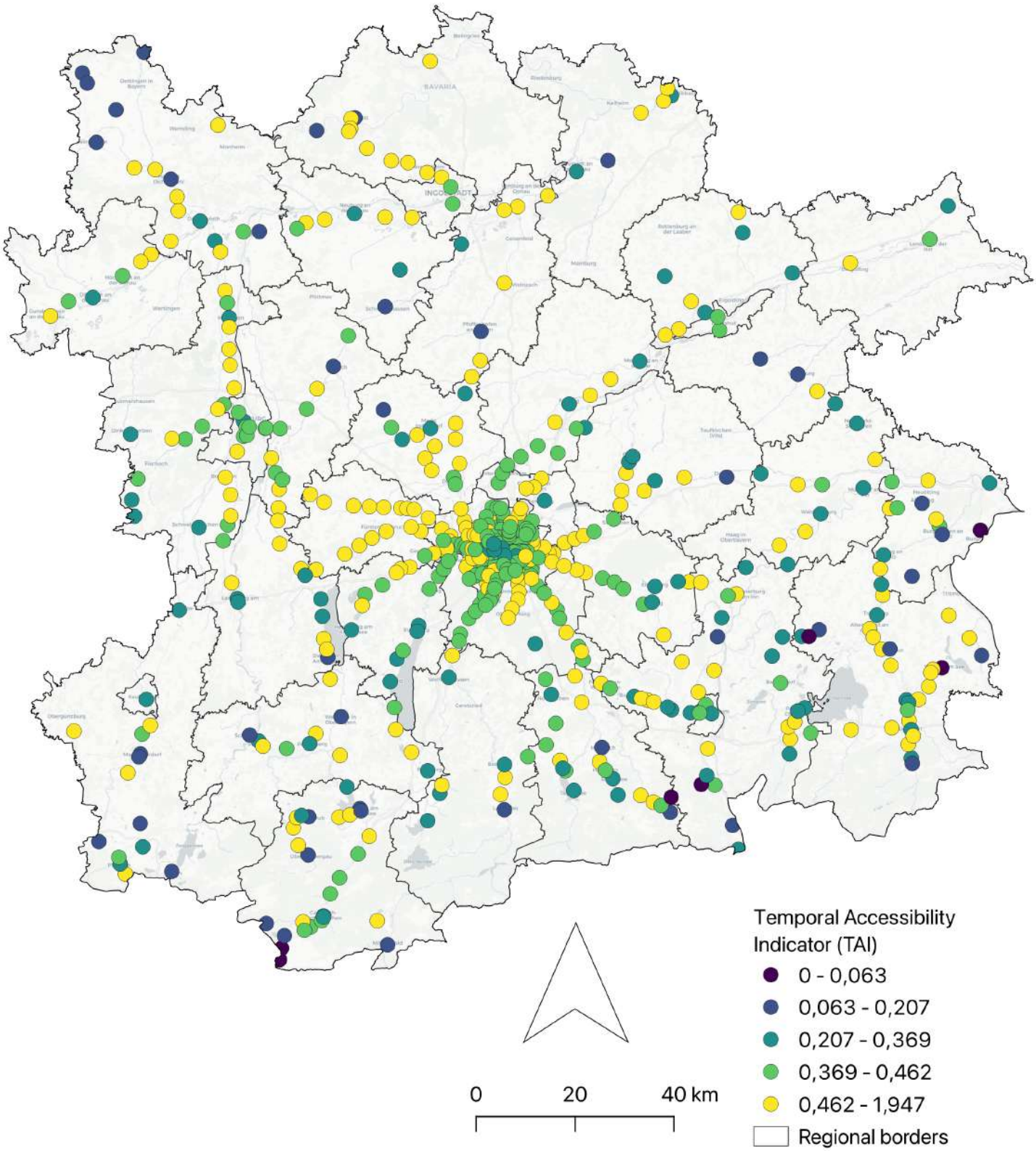


Figure 4.3: Temporal Accessibility to POIs in Munich's Metropolitan Region

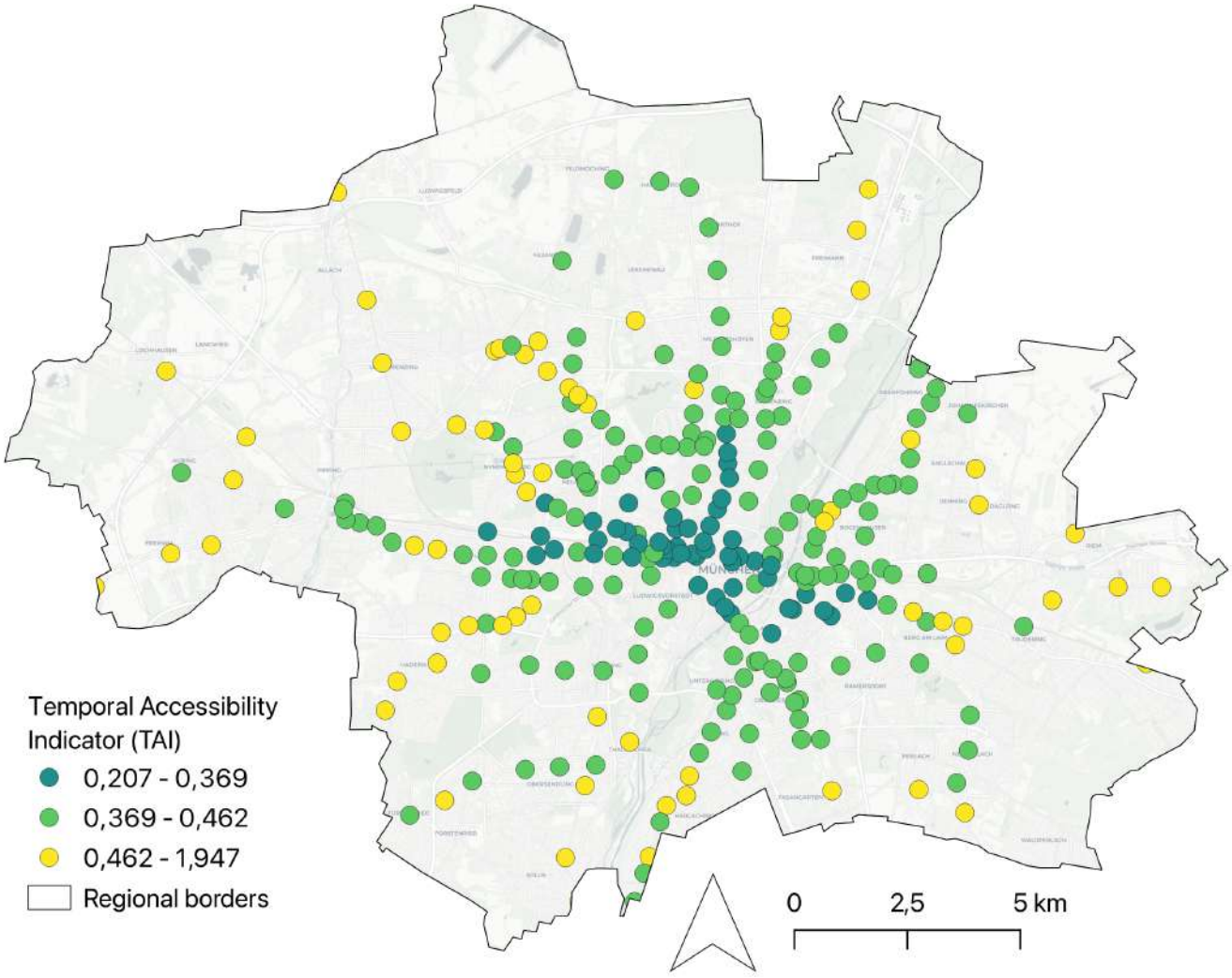
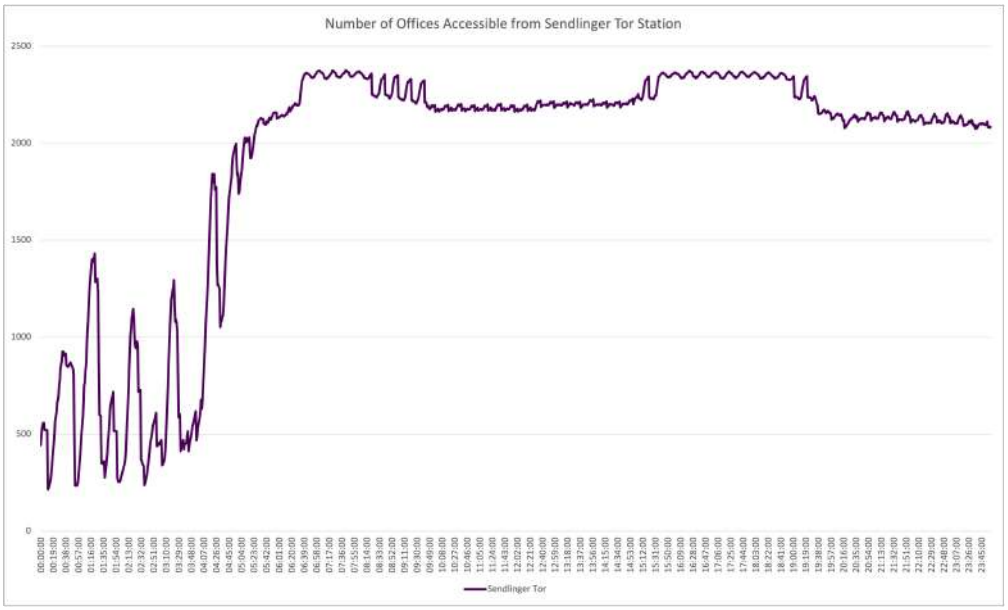
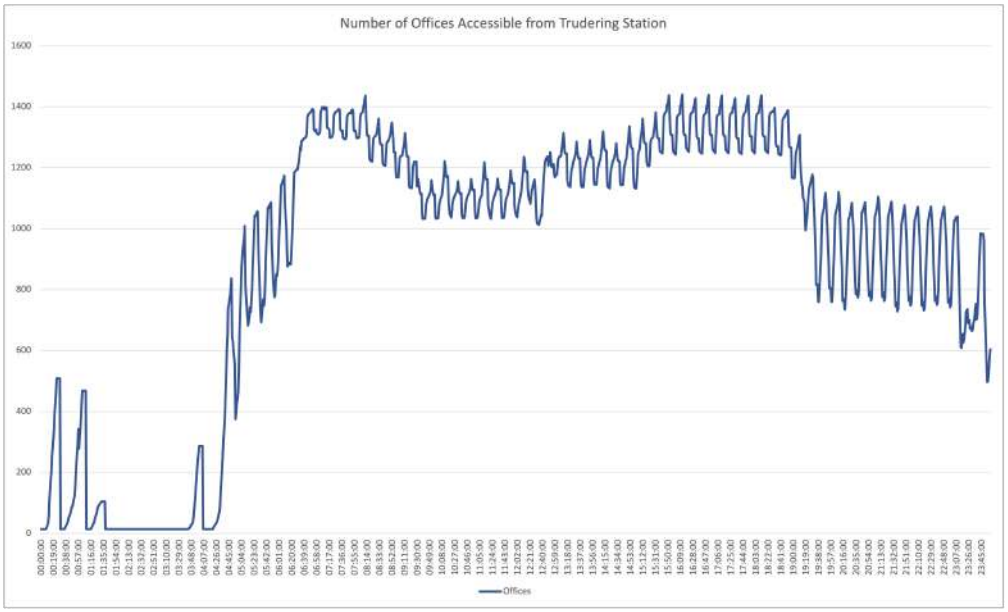


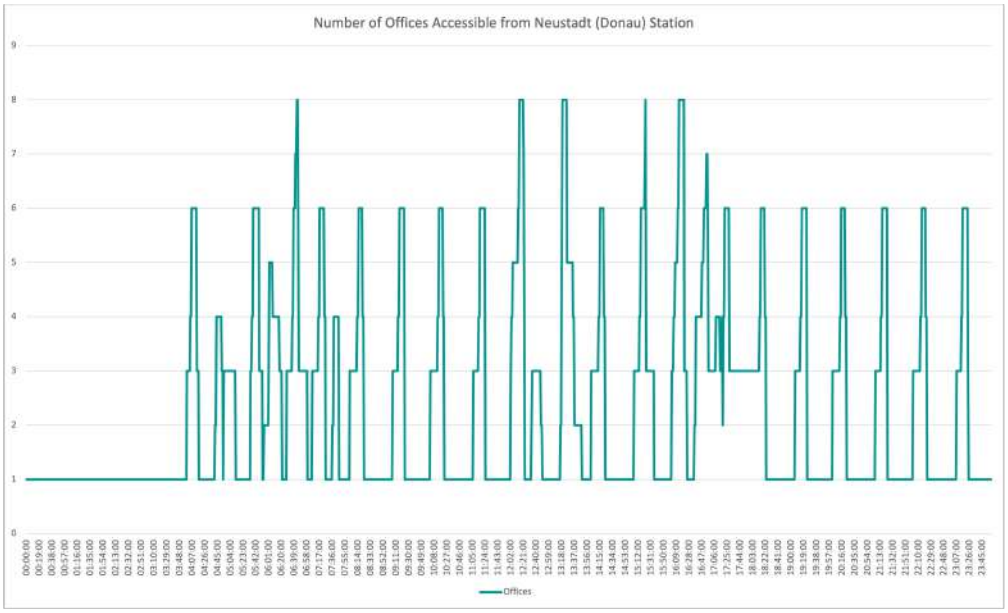
Figure 4.4: Temporal Accessibility to POIs in the City of Munich



(a) Sendlinger Tor

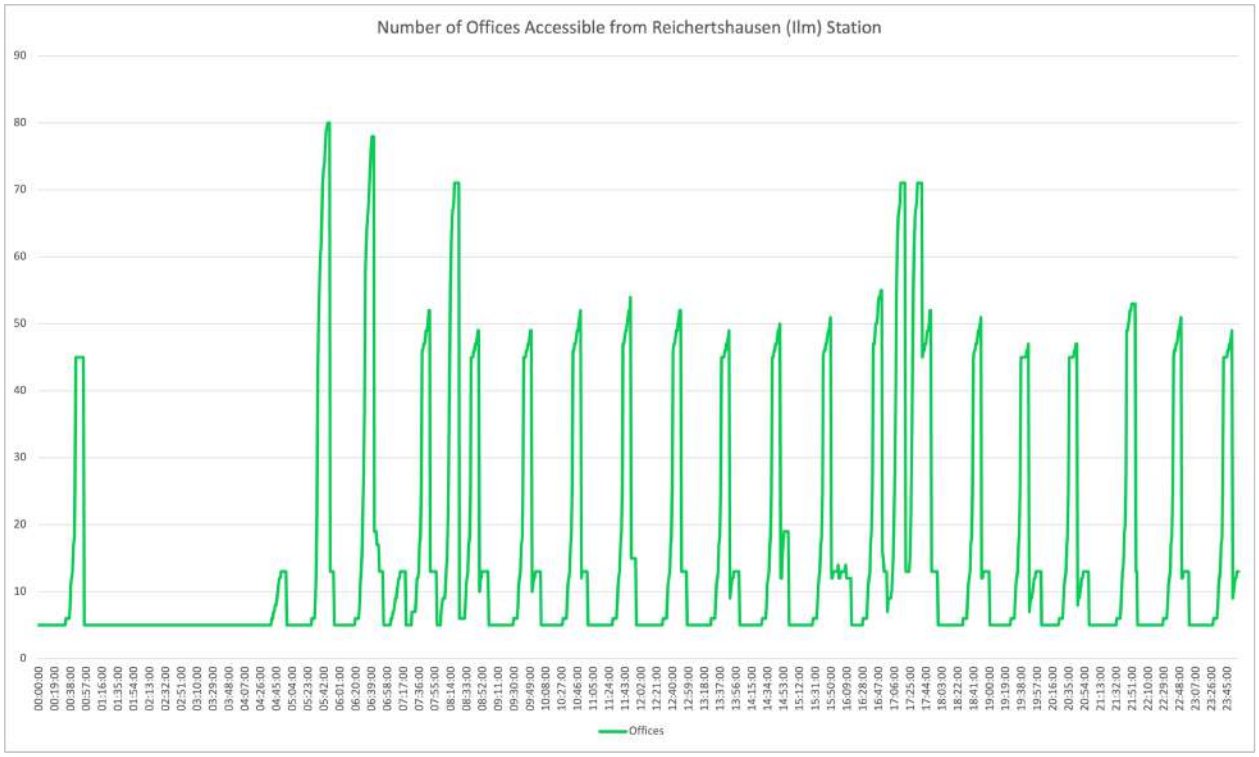


(b) Trudering

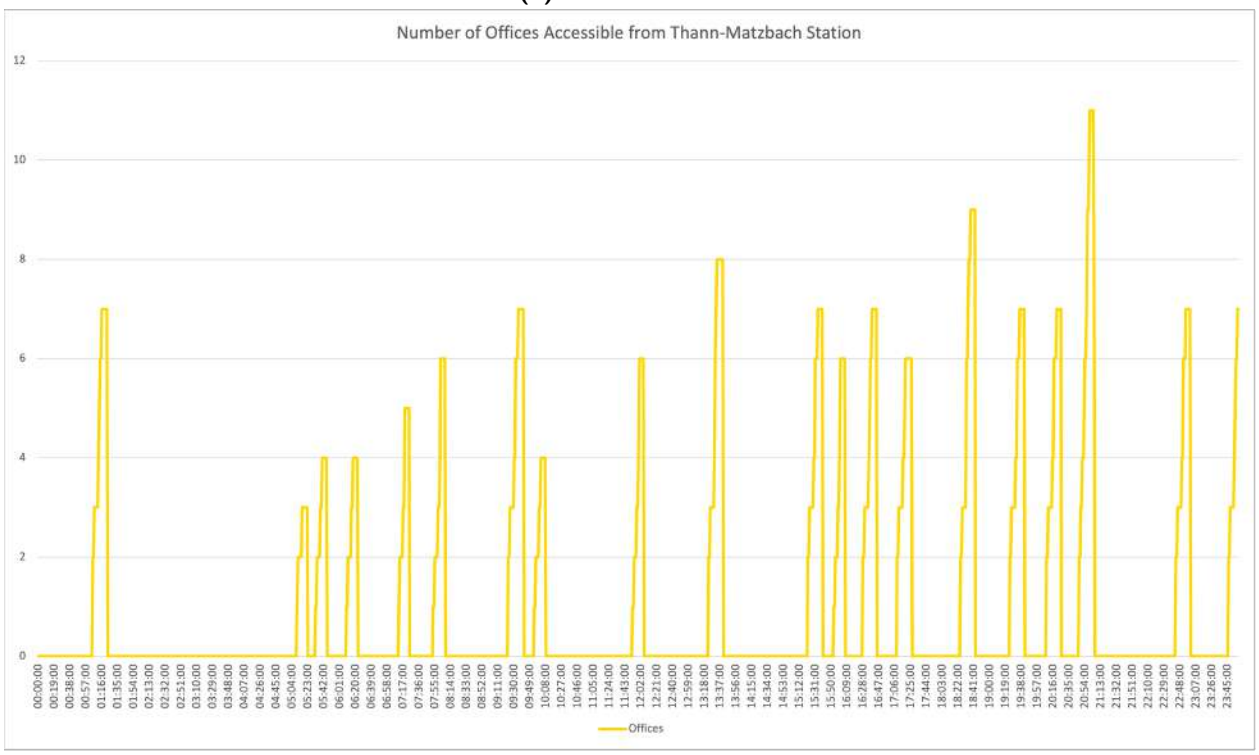


(c) Neustadt (Donau)

Figure 4.5: Accessible Offices over 24 Hours from Stations of Different Indicator Categories (Page 1)

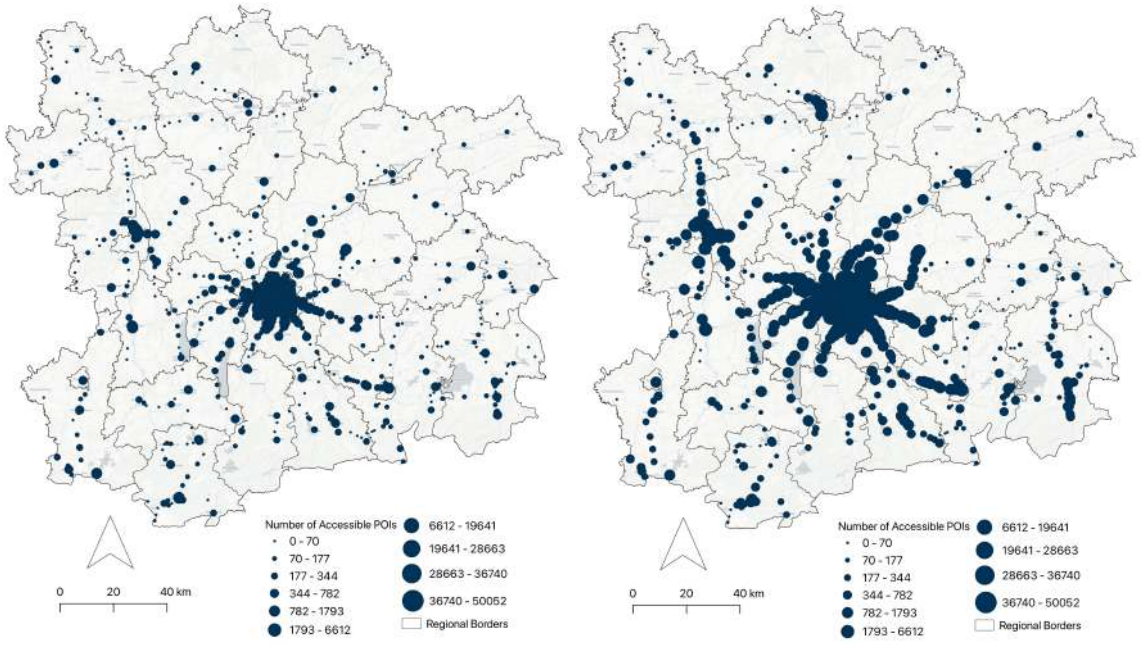


(a) Reichertshausen

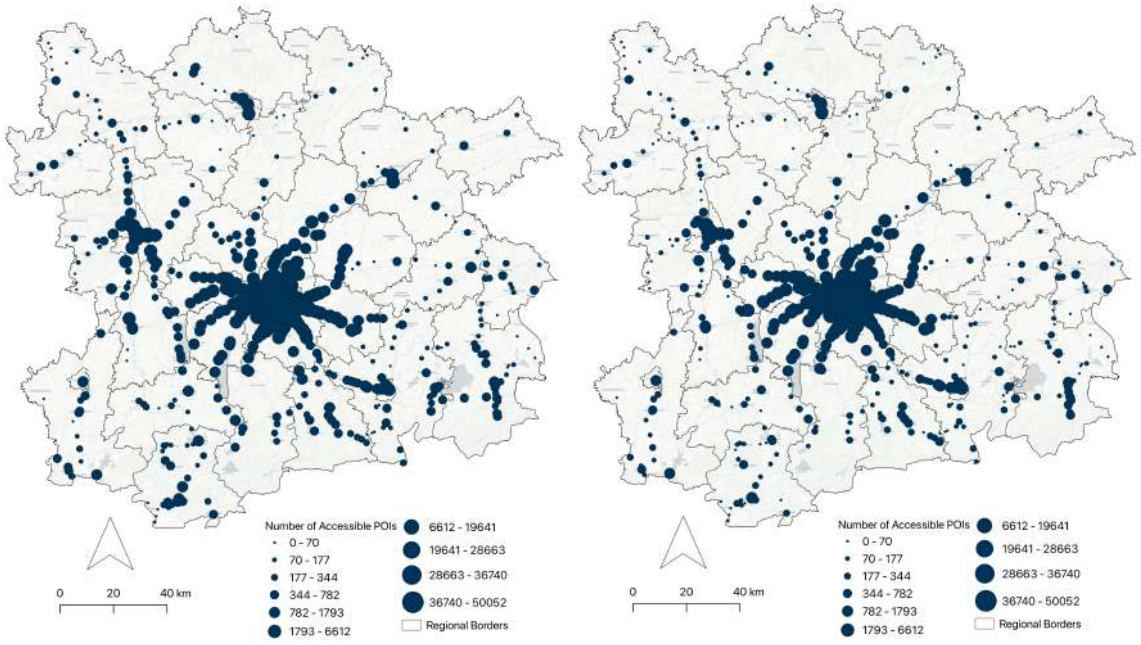


(b) Thann-Matzbach

Figure 4.6: Accessible Offices over 24 Hours from Stations of Different Indicator Categories (Page 2)



(a) 03:00 AM **(b)** 08:00 AM



(c) 13:00 PM **(d)** 22:00 PM

Figure 4.7: Map of the Metropolitan Region of Munich depicting the Accessibility to POIs at Different Times of the Aay

Temporal Accessibility Equity Analysis - Regression Analysis Results

After the elaboration of each station's temporal accessibility indicator, the results have been correlated and listed in table 4.1. Moreover, the results of all linear models can be found under Table 4.2, in which the models (1) and (2) represent the step-wise linear models using BIC, while (3) and (4) use the highest correlating coefficients per chosen category. The correlation coefficients and linear models of the office-based analysis disclose higher negative correlation with the temporal accessibility indicator for non-motorized households, residents around 30 years old holding a university degree and having a higher economical status (middle to very high). In addition to that, the step-wise linear model also included strongly positively correlating variables such as a car ownership, lower educational background, underage residents or those aged between 50 and 70. While results for the POI-based analysis differ, here, households with a higher economic status, and residents around 30 years old have a small and positive correlation. The correlation coefficients of the assessed variables do not rise over 0.1 or below -0.1. Yet, a more in-depth analysis of these results will be given in the following chapter.

Category	Variables (%)	Offices	POIs
Economical status	Very low	0,050	-0,032
	Low	0,081	-0,007
	Medium	-0,013	-0,086
	High	0,004	0,071
	Very high	-0,083	0,046
Age	0-17	0,011	0,040
	18-29	-0,043	0,027
	30-39	-0,134	0,051
	40-49	-0,014	0,018
	50-59	0,090	0,008
	60-69	0,095	-0,003
	70-79	-0,056	-0,062
	Over 80	-0,037	-0,035
Education	No degree (yet)	0,002	0,045
	Secondary school (Hauptschulabschluss) degree	0,170	-0,002
	Secondary school (Realschulabschluss) degree	0,112	-0,004
	High school degree (Abitur)	0,063	-0,018
	College / University degree	-0,072	-0,008
	Other type of degree	-0,014	-0,006
Activity	Employee	-0,021	0,057
	Student/Apprentice	0,004	0,036
	Housemaid	0,053	-0,017
	Pensioner	0,007	-0,065
	Other	-0,021	0,011
Car ownership	No	-0,252	-0,058
	Yes	0,252	0,058

Table 4.1: Pearson Correlation Coefficients of the Temporal Accessibility Indicators with socio-economic/-demographic variables

Table 4.2: Summary of the Linear Models

	Dependent variable:			
	$log(TAI_{Offices})$	$log(TAI_{POIs})$	$log(TAI_{Offices})$	$log(TAI_{POIs})$
	(1)	(2)	(3)	(4)
Economical Status - Medium (%)	−0.261***			−0.018***
	(0.042)			(0.004)
Occupation - Retired (%)				−0.005
				(0.006)
Car Ownership - No (%)			−0.134***	−0.031***
			(0.009)	(0.008)
Economical Status - Very High (%)	−0.394***	0.086***	−0.019***	
	(0.053)	(0.017)	(0.006)	
Economical Status - High (%)	−0.214***	0.072***		
	(0.043)	(0.011)		
Car Ownership - Yes (%)	1.168***			
	(0.055)			
Education - Realschule (%)	0.282***			
	(0.047)			
Education - Volks/Hauptschule (%)	0.379***			
	(0.048)			
Age 60-69 (%)	0.232***			
	(0.038)			
Age 50-59 (%)	0.228***			
	(0.042)			
Occupation - Worker (%)			0.004	
			(0.005)	
Age 70-79 (%)				−0.014*
				(0.007)
Education - Abitur (%)				−0.006
				(0.008)
Gender - Women (%)			−0.015**	0.003
			(0.007)	(0.007)
Age 30-39 (%)	−0.443***	0.083***	−0.062***	
	(0.066)	(0.027)	(0.010)	
Age 0-17 (%)	0.435***			
	(0.077)			
Education - University Degree (%)	−0.221***		−0.064***	
	(0.048)		(0.005)	
Constant	−3.157***	−0.927***	0.184***	0.435***
	(0.067)	(0.006)	(0.005)	(0.004)
Observations	4,639	4,639	4,639	4,639
R^2	0.224	0.014	0.113	0.013
Adjusted R^2	0.222	0.014	0.112	0.011
Residual Std. Error	0.527 (df = 4627)	0.230 (df = 4635)	0.084 (df = 4632)	0.083 (df = 4632)
F Statistic	121.089*** (df = 11; 4627)	22.705*** (df = 3; 4635)	98.224*** (df = 6; 4632)	9.806*** (df = 6; 4632)
Note:				*p<0.1; **p<0.05; ***p<0.01

4.1.2 Complementary Temporal Accessibility Cluster Analysis

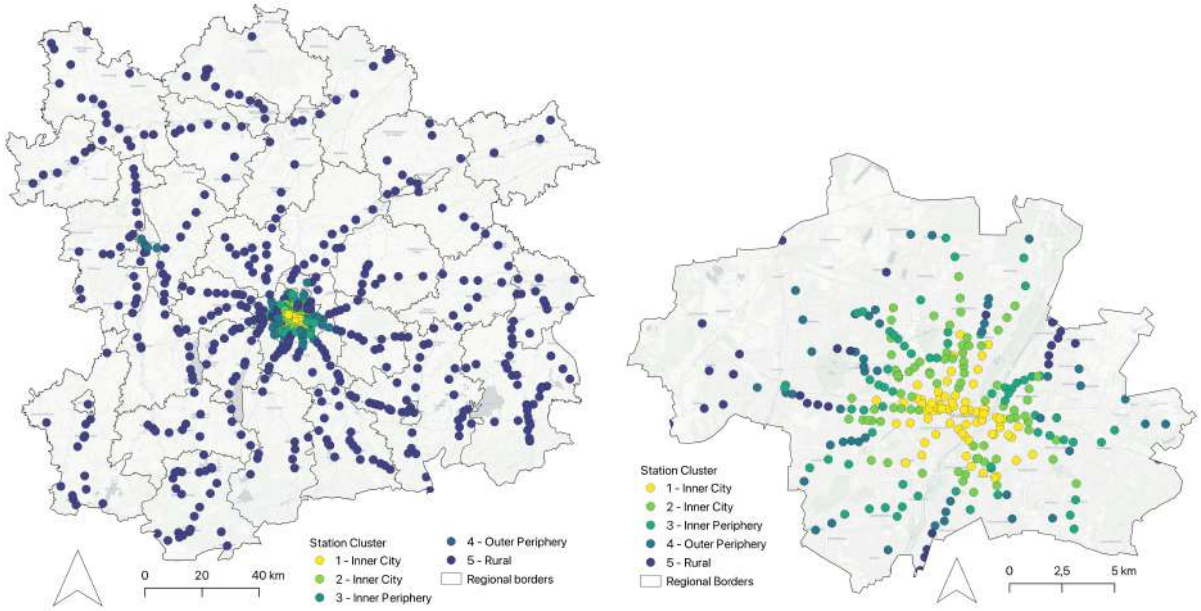
Cluster Locations and Categorization

The cluster analysis based on the generated heatmap for the office-based accessibility disclosed a total of 5 clusters, which have been subsequently described as follows:

Cluster No.	Title	Description
1	Inner City - Major Nodes	High and stable temporal accessibility.
2	Inner City - Moderate Nodes	Consistent temporal accessibility.
3	Inner Periphery - Local Access Stations	Moderate temporal accessibility.
4	Outer Periphery - Suburban-/Regional-/Long-Distance Stations	Peak-driven temporal accessibility.
5	Rural - Lower-Activity Stations	Lower and fluctuating temporal accessibility.

Table 4.3: Station Clusters based on their Temporal Accessibility to Offices

Moreover, the clusters have been depicted on a map which can be found in fig. 4.8 (a) and (b) for the metropolitan region as well as for the close-up on the city of Munich below.



(a) Metropolitan Region of Munich **(b)** City of Munich

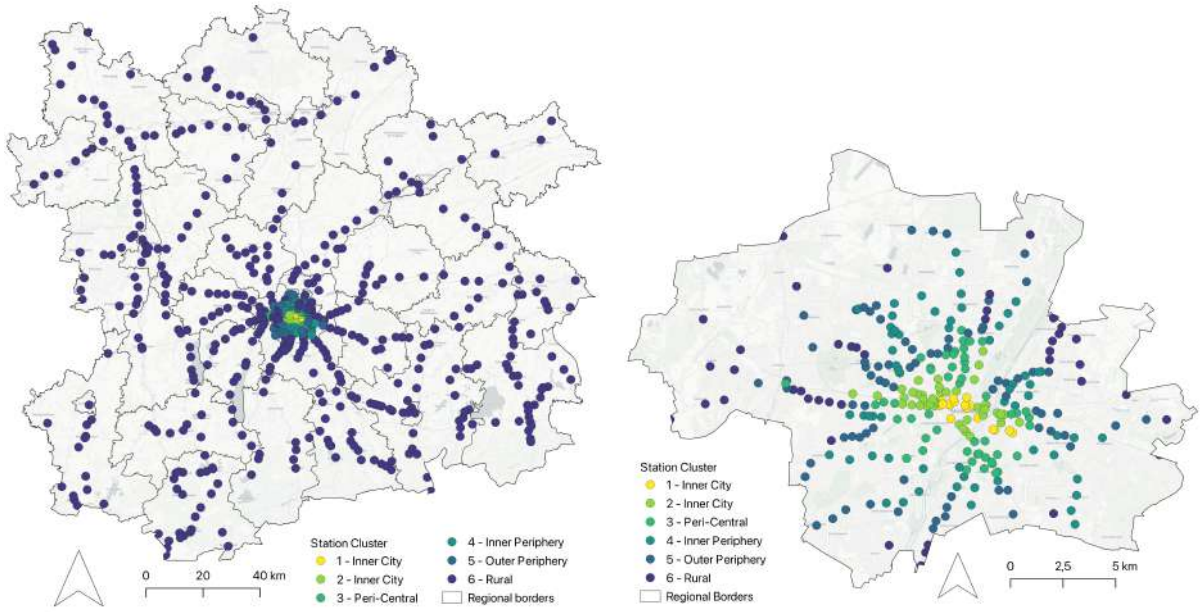
Figure 4.8: Clustered Stations in the Metropolitan Region of Munich by Temporal Accessibility to Offices

Similarly to the office-based analysis, 6 clusters have been identified for the POI-based analysis and described as follows:

Cluster No.	Title	Description
1	Inner City - Major Nodes	Highest number and frequency of service and stablest temporal accessibility.
2	Inner City - Secondary Nodes	High frequency of service and stable temporal accessibility.
3	Peri-Central - Moderate Nodes	Consistent temporal accessibility.
4	Inner Periphery - Local Access Stations	Moderate temporal accessibility.
5	Outer Periphery - Singular Line or Suburban Railway Stations	Peak-driven temporal accessibility.
6	Rural - Lower-Activity Stations	Lower and fluctuating temporal accessibility.

Table 4.4: Station Clusters based on their Temporal Accessibility to POIs

The clusters have been depicted as maps in fig. 4.9 (a) for the metropolitan region and (b) for the city of Munich below.

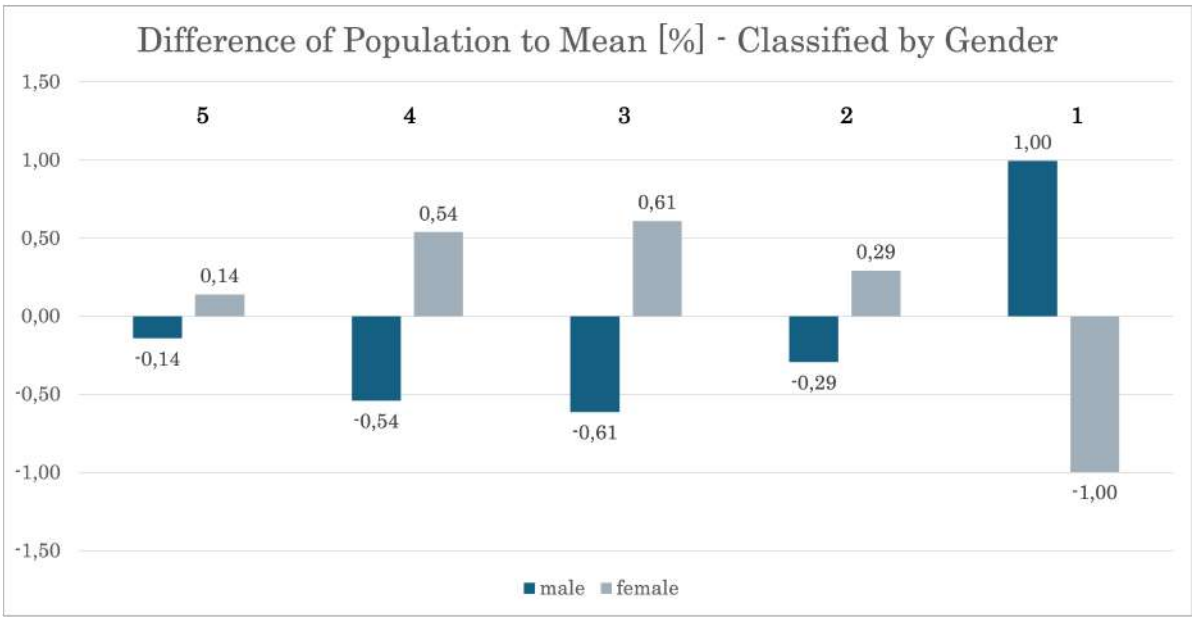


(a) Metropolitan Region of Munich **(b)** City of Munich

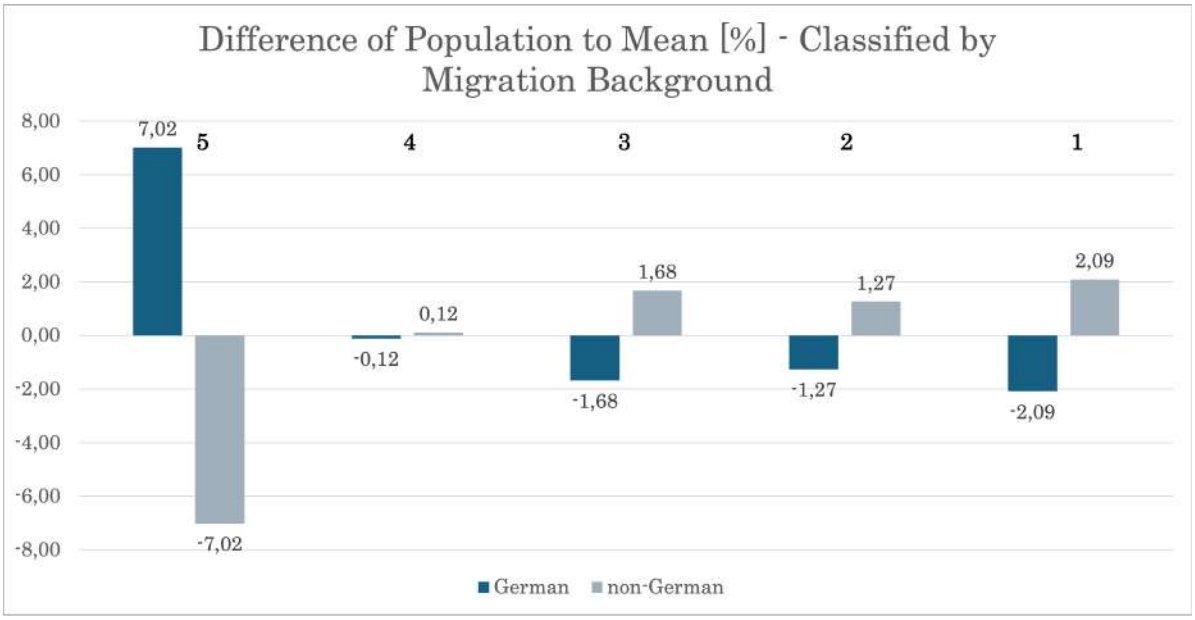
Figure 4.9: Clustered Stations in the Metropolitan Region of Munich by Temporal Accessibility to POIs

Socio-Economic and -Demographic Characteristics

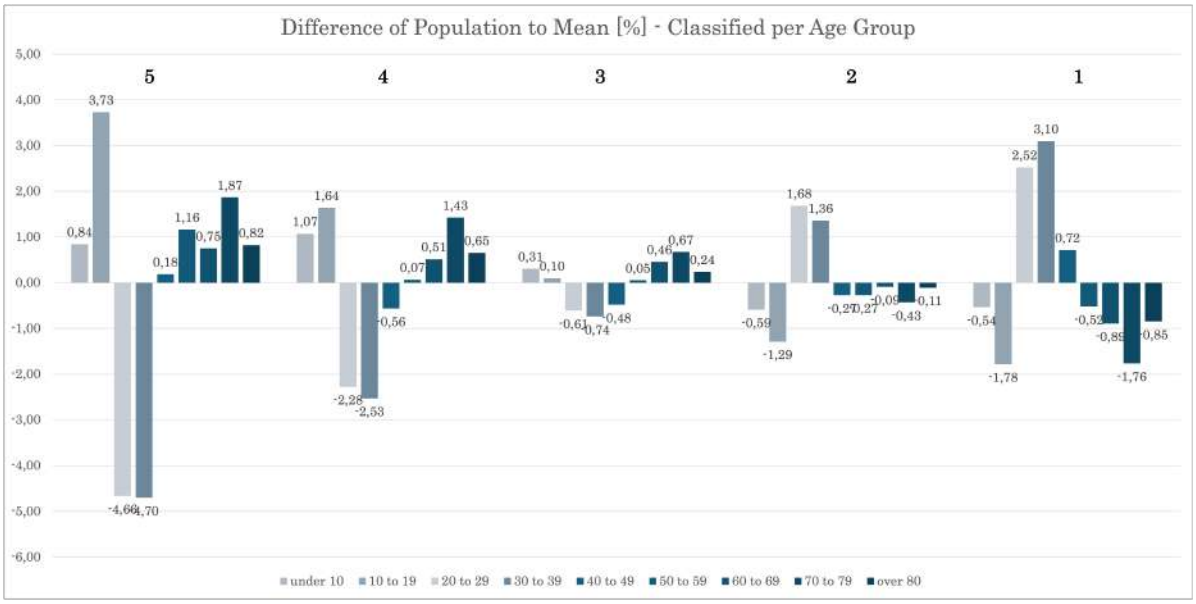
Bar charts of the deviation to the mean of both population-related and built environment-related data have been plotted and can be found in Fig. 4.10 (a-c) and 4.12-(a) for the office-based analysis, as well as in Fig. 4.11 (a-c) and 4.12-(b) for the POI-based analysis. As observed, a higher negative deviation can be found for residents between 20 and 40 as well as foreigners in more rural clusters (e.g. cluster 5 or 6), while a positive trend can be observed towards inner-city clusters (cluster 1). An opposite trend can be disclosed for residents under 20 and above 50, as well as German nationals. A non-linear trend can be observed for residents between 40 and 50 and male residents, with a negative deviation for most clusters (cluster 2-4 or -5), and a positive for the inner city ones (cluster 1), and very low negative deviation for rural clusters (cluster 5). Yet, the observed trends are almost identical for both age and migration related data. However, the POI related analysis result largely differs from the office-based in terms of gender differences. While the office-based analysis finds a non-linear trend can for female individuals, in which highest positive deviation is disclosed for cluster 3, while highest negative for cluster 1, the POI-based analysis does not depict a specific trend. Moreover, the POI-based analysis finds high differences to mean in terms of gender percentage differences - observations that cannot be made for the two remaining categories. The linear trend of deviation from mean is also observed within the built environment indicators for the Office-based analysis. While rural areas (cluster 5) are characterized by a higher negative deviation, inner city clusters (cluster 1) find a high positive deviation to mean. A similar observation can be made for the POI-based analysis as well, however with the difference that the cluster with the highest temporal accessibility finds the below average POI in its proximity.



(a) Gender

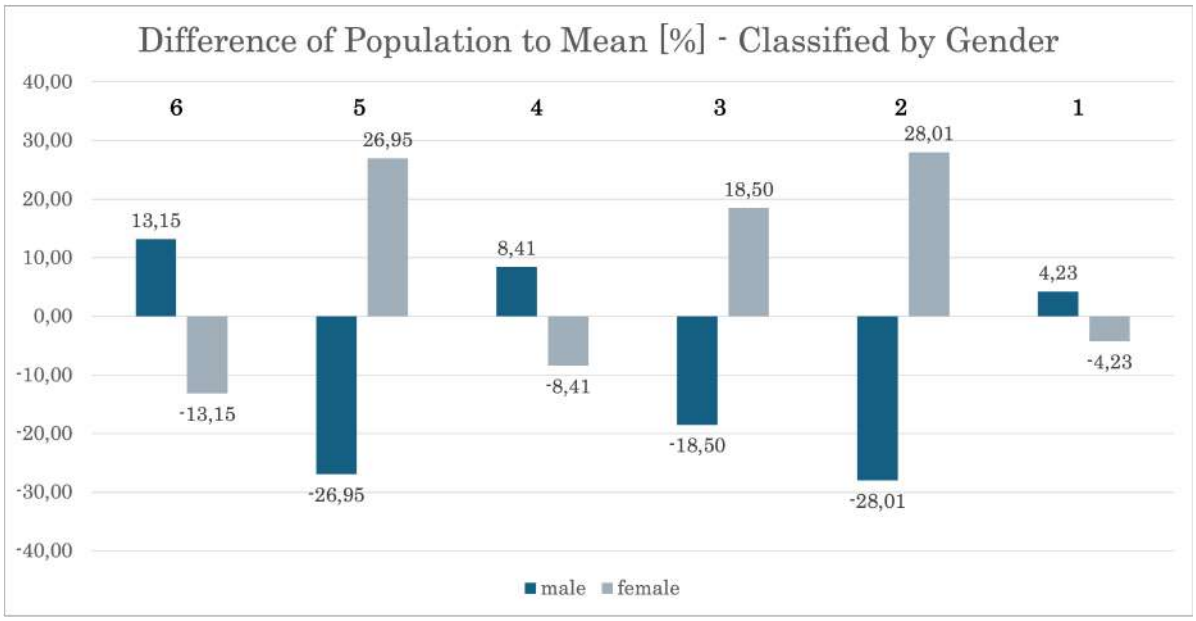


(b) Migration

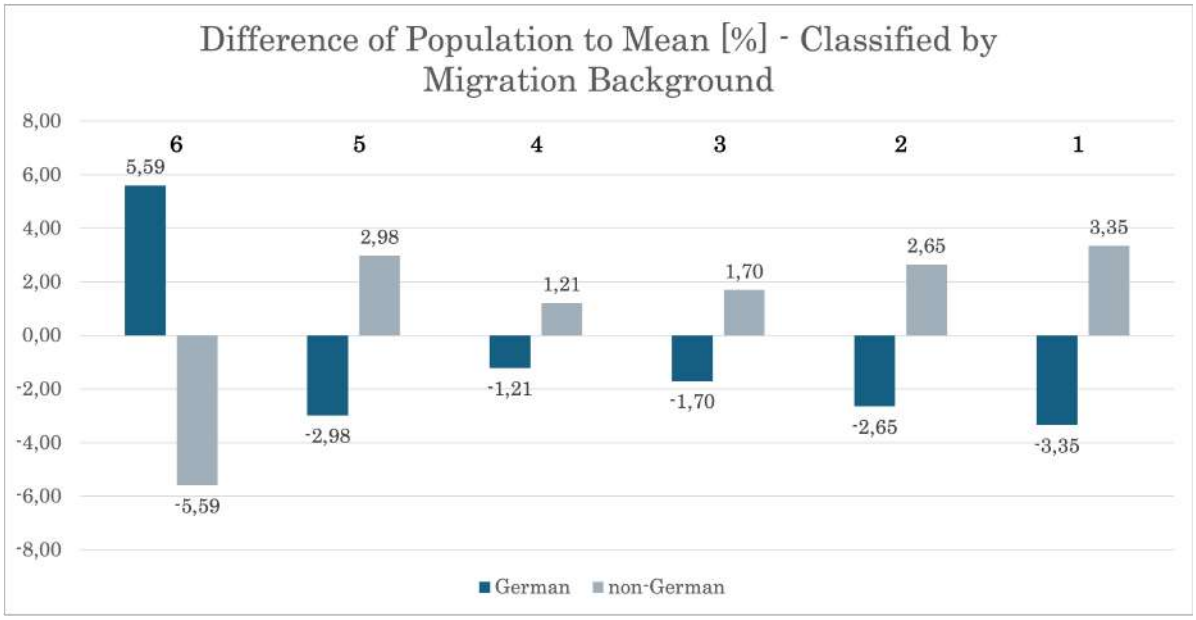


(c) Age

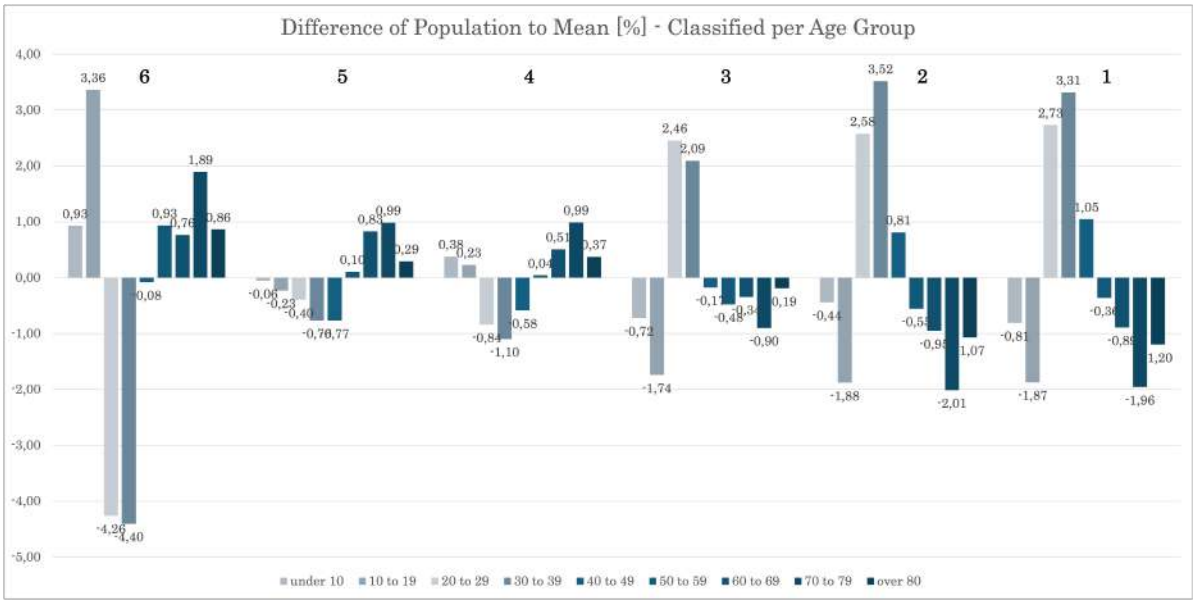
Figure 4.10: Difference of Population to Mean in % for the Office-based Analysis



(a) Gender

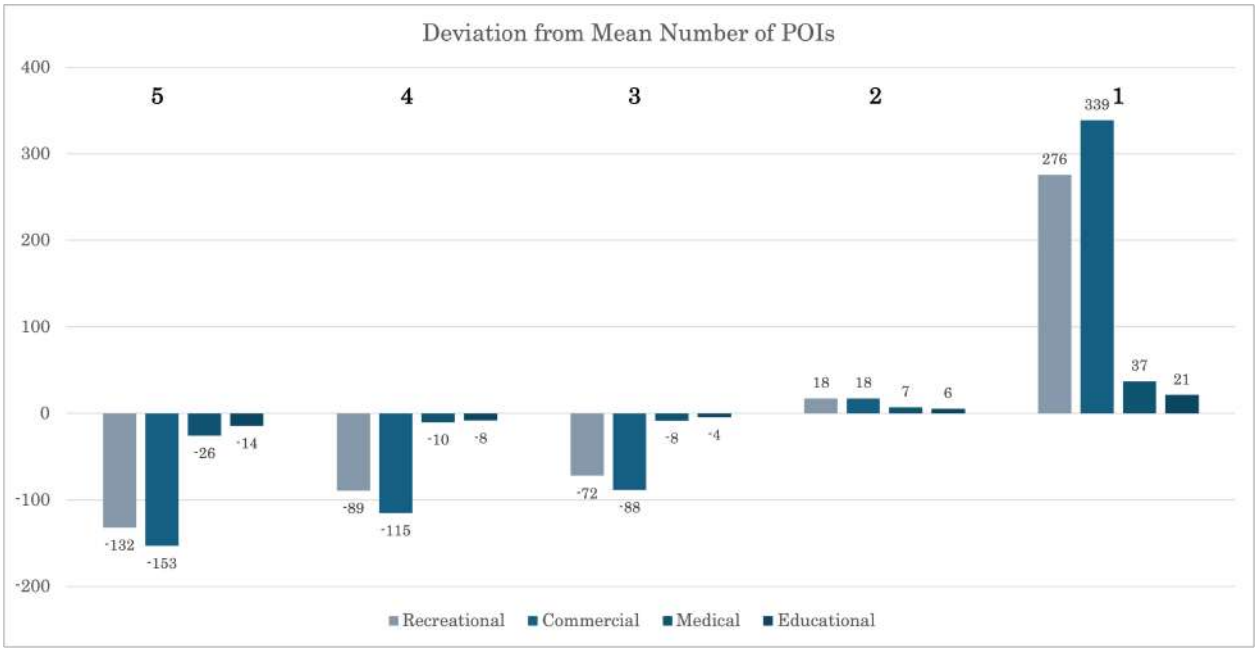


(b) Migration

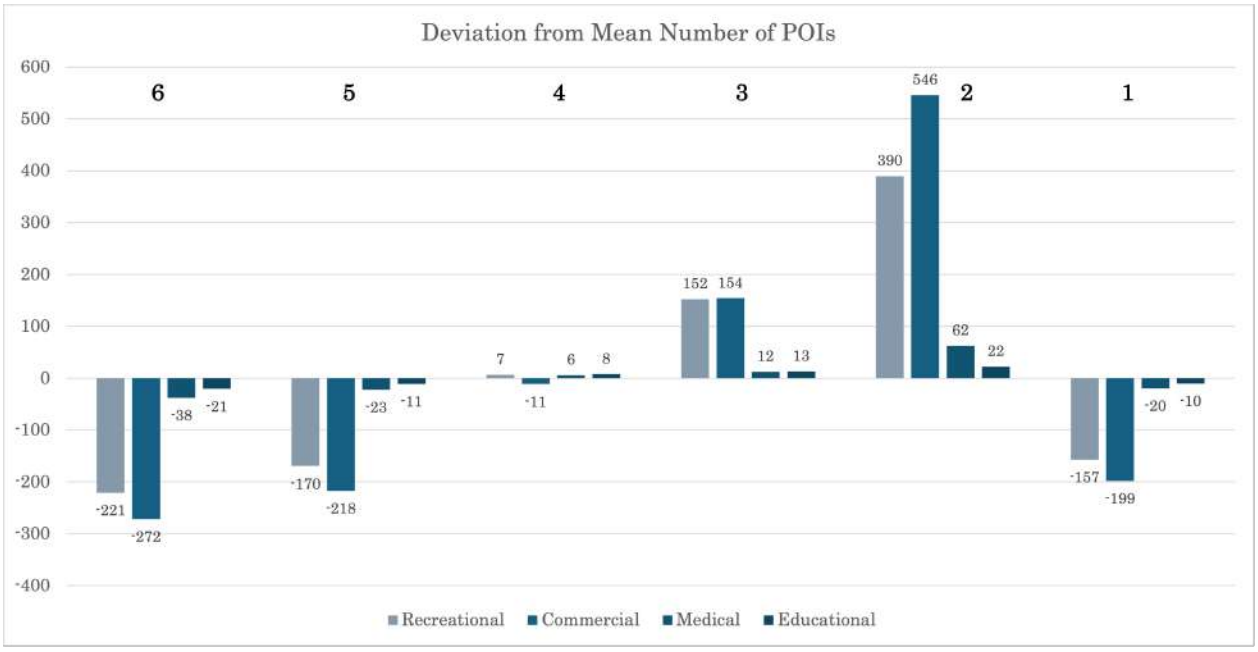


(c) Age

Figure 4.11: Difference of Population to Mean in % for the POI-based Analysis



(a) Office-based Analysis



(b) POI-based Analysis

Figure 4.12: Deviation from Mean Number of POIs per Cluster

4.2 Qualitative Temporal Accessibility Equity Assessment

In a third qualitative step of this methodology, a total of four interviews have been conducted and coded to allow a subsequent content analysis. While the complete transcripts can be found in the appendix, this section aims to highlight the key takeaways of the interviews, necessary for further discussions. Following the structure of the interview guide, this section will first provide an introduction of all interviewees as well as develop their own perceived challenges at different times of the day. After that, their opinion on the changes and impact on both own needs and different group of individuals will be showcased, followed by their reflection on fairness and equity in terms of temporal accessibility by RPT. Lastly, their critical confrontation with the quantitative results will be summarized.

4.2.1 Interviewee's backgrounds and travel patterns

Introduction of the respondents

The first interviewed respondent I1 is a 23 year old female student, living in the city center of Munich (Maxvorstadt) within a 2 minutes walking distance to the University she is attending. Her nearest subway station is also located within 5 minutes of walk, which allows her to reach her office in a total travel time of 20 minutes. In the past she used to live at Rosenheimer Platz, located on the main S-Bahn trunk line, in which she had a similar experience. She frequently travels to her research lab, located in Pasing, in which she has to rely on the S-Bahn services and use an additional bus, or her sports club located in the south of Munich, at the very end of a subway line. In cases in which she has a car at her disposal, she relies on it as travel times are heavily reduced.

The second respondent I2 is a 30 year old female young professional with an academic background, living in the closer suburban area of Munich. She mostly relies on the subway, which is located in a 10 min. walking distance from her home, and requires an additional 20 minutes to reach her workplace. Moreover, an additional tram line provides redundancy in case of disruptions. At night, night-tram services are being offered. She is not using the S-Bahn, prone of delays and cancellations.

Respondent I3 is a 60 year old female worker without an academic background, living on the outskirts of Munich. She commonly rides a bike in summer or drivers her car in winter to the nearest park and ride at the S-Bahn station. This station is served by a single line, running every 20 to 40 minutes depending on the times of the day. After reaching the central station, she relies on feeder bus services bringing her to her final destination. According to her, in the best cases it would take her about 1:15 to 1:30 hours from door to door. She only uses public transport to get to her work place and adapts her departure and arrival times in accordance to the fixed timetables of the train line. She does not use public transportation after 10 p.m., and every other non-work related activity is accessed by car or is located within the same residential area.

The last respondent I4 is a 65 year old male worker with an academic background, living in the rural area, about 50 km away from the city of Munich. To reach his workplace, he relies on his car to get to his nearest railway station that is about 15 km away from the village he resides in. From there, he uses either S-Bahn or regional train services to enter the city. While most of his trips are work-related commutes, he occasionally uses the buses that run through his village for recreational activities, but mainly follows the same travel patterns as his trips to work. His total commute time is about 1:30 hours. I4 enjoys

taking the train to enter the city, as he can avoid traffic jams in peak hours while being able to rest or read during his trip.

Respondent's experience and challenges at different times of the day

Despite respondent's rather positive experience in terms of temporal accessibility, challenges and gaps have been identified and summarized into 3 main times of the day, and 1 spatial aspect. First of all, all respondents identified peak-hours (both morning and evening peak) as challenging in terms of temporal accessibility, justified by the passenger crowdedness in the entire system. While I3 and I4 expressed their concerns in a reduced amount of comfort during those times on suburban railway lines...

> "Yes, so the rush hour in the morning is between 7 and 8 o'clock when a lot of people just drive into the city and all the students are on their way." (I3, Pos. 16)

> "Of course, in the morning the S-Bahn is pretty full. If you're unlucky, you have to stand." (I4, Pos. 16)

...younger respondents generally reflected on Munich's subway, in which crowdedness impacts temporal accessibility.

> "I think we are not equipped for the population" (I1, Pos. 15)

Another identified challenge by the two younger respondents were especially night times. Despite the fact that both respondents felt privileged in terms of temporal accessibility at night, the main issue raised was the accessibility of own homes after late night social activities.

> "Yes, at night for sure. It's very challenging. Again, I think I'm pretty lucky. I live by, the tram that I live close to is a night tram, so it goes through the night. But once you reach a certain hour, I think it only goes every 45 minutes or every hour [...]. And then the U-Bahn obviously also stops at some point. So that's starting at [...] 1:30-2:00 AM [...], so in the city center it's usually fine, but if you're somewhere that's not the center and you're not close to the tram, then it's very challenging." (I2, Pos. 16)

For the two older respondents, the temporal accessibility gaps at night were not of any significance:

> "I rarely travel at night time." (I4, Pos. 36)

Yet, not only the night time issue has been raised. Also the late start of services in the early mornings or poor late evening services have also been addressed, especially when one has to travel outside the main service hours:

> "...in the evening it's difficult again. Sometimes if you want to go home very late now, then the frequency is only every 40 minutes." (I3, Pos. 16)

The wish for more services in the late evenings and early mornings has also been expressed:

> "I would be glad that we have a metro at two or two 30 and then it stops and the first at four or five." (I1, Pos. 106)

Despite temporal accessibility gaps based on different times of the day, respondents pointed out also spatial factors, in which the temporal accessibility significantly drops. Most respondents highlighted, that once individuals live outside the S-Bahn service area or the metropolitan circular expressway, temporal accessibility gaps become more challenging:

> "So maybe that too, because I find it's, as soon as you leave the subway/tram network, I think it suddenly gets pretty difficult even though you're not that much further outside." (I2, Pos. 50)

> "I think every time you're outside of the ring it's kind of a mess to come back that for sure that for sure. As soon as you go out of the train station, you take a bus to go outside the ring to come back. If you don't have luck that the bus is just here, you have to wait 15, 20 minutes." (I1, Pos. 126)

> "Attenkirchen is still relatively well connected by bus to Freising. And as soon as you are 3-4 km from Attenkirchen, there are buses, but they only run twice a day. That's exactly the problem." (I4, Pos. 56)

Lastly, as all respondents are regular public transport users, reliability and punctuality issues have been raised, that are especially present for suburban railway services:

> "It was very annoying when we had Schienenersatzverkehr, because I somehow only had the S-Bahn." (I1, Pos. 19)

> " [...] there are also train failures. And the S7 is very vulnerable. (I3, Pos. 16)

> "Sometimes I come to Freising in the morning and then everything is standing still. Then you think about what to do. Do you drive with the car or do you drive back?" (I4, Pos. 24)

After showcasing commonly identified temporal accessibility challenges at different times of the day, perceptions on the impact on different types of residents will be presented in the following section.

4.2.2 Perceptions on Accessibility and Time-Variation

Experienced changes in the ease of reach of opportunities

All respondents did not experience significant changes in the ease of reach of opportunities. However, diverse reasons have been identified. While the younger residents live close to higher-frequency subway, bus lines or have other abundant modes,

> "Yeah, I mean I guess it all closes at some point, but otherwise, yeah, no, I think just based on the opening times." (I2, Pos. 28)

> "No, no, no. Because I take always the Bus 100 or 58 or 68." (I1, Pos. 23)

...older residents claimed that trips only happened during core service hours, in which the level of service is allegedly equally distributed throughout the day:

> "Actually, I'm usually travelling in the core time, so not after 10 p.m. I'm no longer using public transport at that time. And if that really happens, then I get into the private car. But otherwise I'm actually the whole core time equally well supplied with the public." (I3, Pos. 28)

> "No, I don't. The workplace has been over 20 years and always the same. Car, S-Bahn, train. The connection is optimal for me." (I4, Pos. 48)

Yet, younger residents still expressed their wish for higher temporal accessibility at night time.

> "[...] when we were in Studentenstadt, we wanted to go home. There's always a bus, like a night bus that comes every hour or something. [...] the public transports at night are there. They exist, but I think that we could improve more." (I1, Pos. 27)

Impact of Time Variations on daily activities and mobility needs

Respondents were also asked how potential time variations impact basic mobility needs. Yet, not all respondents were asked to reflect on this question, as most of them did not experience signification changes throughout the day. Despite already fixed opening times of most commercial destinations laying inside core service hours as I2 noted, the two respondents I3 and I4 living further outside of the city of Munich also highlighted the presence of a higher amount of basic opportunities in their respective commune. I4 also combines most activities by car on his way home from the station.

> *"But mainly I travel with the public transport to get to work. So my private appointments are actually more here in the environment." (I3, Pos. 44)*

> "In our environment there are bakeries, butchers, where you can walk by bike. Because I work in Freising I can always go to a supermarket by car. [...] If I do, I can do it as part of my commute." (I4, Pos. 48)

However, I4 also highlights the necessity of car ownership in certain areas due to gaps in temporal accessibility and the absence of basic necessities in the commune itself.

> "It's only 4 km from Attenkirchen. There's nothing there. 500 people live there. There are no shops, nothing, people always have to drive their car." (I4, Pos. 52)

Impact of Temporal Accessibility on different groups of Individuals

While respondents did not point out particular negative impacts in their daily activities and mobility needs as potential temporal accessibility gaps were either compensated by their place of residence or car ownership, they highlighted which group of individuals are impacted different types of temporal accessibility gaps.

In terms of potential temporal accessibility gaps at night, mainly young residents as well as female individuals or those who feel unsafe at night have been found to be impacted. As this age category is most likely to have late-night social activities, returning home can be challenging since temporal accessibility is low or absent in different parts of the metropolitan region, as respondents suggested.

"I guess the most affected probably would be younger people who are out." (I2, Pos. 44)

However, younger female respondents found general, especially women safety-related issues induced by a lack of temporal accessibility:

"[...] maybe also if you can't get home at night, maybe it's a bit more of a problem for women compared to men. It could also be a thing, I know now they have vouchers for taxis for women in case you can't get home." (I2, Pos. 50)

"[...] I think there are a lot of people who also take taxi or don't go out because [...] they're scared." (I1, Pos. 27)

Besides younger residents being affected at night time, respondents found that also older or physically disabled residents are impacted by a gap of temporal accessibility during peak hours. According to them, despite a high frequency of service during those times, the crowdedness poses additional barriers to those groups of individuals, which they try to avoid. Yet, their limited ability or inability to drive a private car make them rely on public transportation.

"[...] for older people maybe it's more difficult when everything's very full and everyone's stressed again at the rush hour times." (I2, Pos. 40)

"I think at rush hours, it's unfair for people with a disability or with a wheelchair. Because there's a lot going on. And because they're being pushed and pushed. And that's where it's difficult." (I3, Pos. 106)

The core service hour shoulders, in other words early mornings and late evenings, have also been identified as challenging in terms of temporal accessibility by RPT. Here, respondents mainly identified that lower-wage or shift-based jobs are affected by those temporal accessibility gaps:

"I think it's people with part-time jobs, for example, people who, because they have a part-time jobs or I don't know, don't really have a university degree." (I1, Pos. 183)

"[...] there are people who don't work in core hours from eight to five o'clock, but have shifts, have to start very early or very late. And they do have a problem." (I3, Pos. 56)

Above most identified and impacted groups of individuals at different times of the day, the level of income has been highlighted by all respondents. Here, all respondents pointed out that lower income households have less opportunities, as they either do not have the freedom of choice where to live,

"[...] it's probably more generally people who also maybe have a lower income and therefore can't afford to live in central Munich and maybe live a bit outside." (I2, Pos. 58)

...or the sufficient funds to afford a private car.

"People who actually can't switch to alternative methods like private car use or have co-driving opportunities are already disadvantaged." (I3, Pos. 64)

Therefore, lower-income households have been found to be impacted by temporal accessibility gaps, regardless of the time of the day.

"And this usually affects socially "weaker" more heavily." (I4, Pos. 128)

4.2.3 Perceptions on Fairness and Equity

All respondents found their needs to be satisfied and therefore equitably treated. However, their reflection on the social equity perspective in terms of temporal accessibility in the temporal region of Munich largely differs.

First of all, despite the fact that younger respondents pointed out a negative impact of temporal accessibility at night on younger individuals, they did not describe it as unfair.

> "I think when you are young you can live with that [...]. (I1, Pos. 27)"

I2 also clarified, that according to her, the situation in the city of Munich is fair and socially equitable, as she could not identify severe inequity situations. However, she is aware that different groups of individuals might have different answers to such a question.

> "I think it's pretty fair. I mean I can really only speak from my perspective. I mean I'm sure groups that would answer differently [...] (I2, Pos. 62)"

I1 followed a similar view, and pointed out that social equity in terms of temporal accessibility by RPT in Munich is not as problematic as in other major European cities.

> "[...] the gap is not as big in Munich than in other cities. (I1, Pos. 49)"

Yet, she pointed out that mainly lower-income and low-wage workers are impacted by it, and pinpointed the lack of equity by their own face expression:

> "And you see [...] that [...] their face does not express happiness." (I1, Pos. 49)

The unfairness and inequity towards lower economic status of households has been also highlighted by both I3 and I4, in which the inability to afford a car has been indicated. In general, I4 judged the situation generally as unfair for the socially "weaker" part of the population.

> "Because if you need a car and the income is weak, you have to pay the cost of the car when you want to access the closest bus or railway station in rural areas. Usually you want to access railways and not buses, but of course buses are possible too. But yeah, then you need a car. For me, that's the main problem – when someone is car dependent." (I4, Pos. 185)

However, both I3 and I4 also pointed out a rather fair spatial accessibility, which is why I3 found it difficult to describe the social equity situation. According to her, individuals live outside of Munich, in which temporal accessibility is worse than in the center, by choice. Moreover, lower economical households or lower-wage workers would commonly be employed in the commune in which they live in. Thus, a commute would not be necessary, as opportunities would be accessible within walkable or cyclable distance.

> "But if you live here, then you've actually already made the choice. [...] These are just families. The father works in Munich and the rest is somehow here too. And the children go to school here. And that's already a choice they've made." (I3, Pos. 76)

> "But what does fair mean? I have made the choice that I don't want to live in the city and take it for granted. And that's why I have a hard time with the term fair. Because that would be unfair. And it's not. Because it's a choice I made." (I3, Pos. 94)

I3 also pointed out, that in terms of income groups, the price of a trip plays a much more important role than the temporal accessibility itself:

> "And of course the 49 euro ticket is a great [...] achievement. And here you can talk about fair and unfair. Because it allows many, many people to be more mobile and to make bigger trips with the same budget." (I3, Pos. 102)

I3 focuses much more on physical disabilities and health, as for her, those are the main factors that make the overall situation in terms of temporal accessibility socially inequitable.

> "So I think at rush hours, it's unfair for people with a disability or with a wheelchair." (I3, Pos. 106)

The issue of social equity in terms of temporal accessibility by RPT has also been picked up by I1 again. I1 had a broader perspective of the issue, linking it to general social inequities. I1 judged an ideal socially equitable situation as "Utopian", and pointed out a potential vicious circle of equitable access to RPT.

> "I think the problem is [...] very utopic because [...] the reason why some place are expensive is because it has this accessibility." (I1, Pos. 61)

4.3 Mixed-Methods Assessment

The reactions of the respondents were mostly unsurprised after the results have been shown to them. All respondents gave their approval, as they could relate or imagine that the quantitative results described the general temporal accessibility situation in the metropolitan region of Munich. However, some respondents found parts of the result surprising. First of all, I1 found that the results in the second quantitative assessment, specifically the portion of individuals between 10 and 20 residing in proximity to rural RPT stations to be very high. Moreover, I2 found the difference between male and female individuals surprising, as the male proportion was found much higher in the inner-city cluster in comparison to all other clusters. I3 also noticed that a difference between German nationals and non-German nationals exists, which she did not expect.

After being confronted with the results, respondents acknowledged that the profile of a resident with a high temporal accessibility was most likely privileged. Linking all characteristics together, respondents agreed with the fact that all of them are also closely related, since a strong educational background also has a positive impact on the future economical status an individual may have.

> "[...] socially weaker group of individuals are not included in this profile. Yes, I can actually imagine that." (I4, Pos. 141)

> "Education opens many doors. And that's also a budget thing, of course. That's the point, I think. And health. And that's important. So health is also a quality of life. And if you are sick, that limits you." (I3, Pos. 178)

The perceptions on equity largely remained the same for all respondents, or got even reinforced.

> "Of course it's unfair. But there are so many things who are unfair." (I1, Pos. 187)

I2's stance changed a little, as she then compared the city center with the surrounding rural areas.

> "[...] at least in the Munich City Center, pretty good. And then I guess you showed on, I think the first map. I guess the further outside you go, the worse it gets or the more rural you go, the worse it gets. And I guess that's true probably during the day, but I guess even more so at night." (I2, Pos. 102)

I3 also added, that the problems probably persists, but weighed it with the number of projects that are currently being conducted to improve the overall mobility justice situation in the metropolitan region of Munich. Yet, I4 generally kept his stance, that spatially speaking, Munich is quite equitable in terms of accessibility, yet less in terms of the temporal aspect.

> "Spatially, definitely, because everyone has the same spatial accessibility. But yeah the socio-economic aspect, well that depends on the areas." (I4, Pos. 189)

Lastly, while I1's answer did not significantly change after the results have been shown, she pointed out the fact that, for her, the temporal accessibility by RPT is planned efficiently, as she understands why no investments in certain areas are being made.

> "[...] unfortunately the economic of the world are very, people want to do money, they don't want to help people. I think the only way to help the people is with public money [...]." (I1, Pos. 191)

In conclusion, respondents were rather satisfied in their own situation in terms of temporal accessibility by RPT. As respondents suggested, the situation worsens the further away from the city center. While the overall situation has not been qualified as highly affected by inequities in terms of temporal accessibility by RPT, respondents highly suggested that especially lower-income or non-motorized households would suffer from these gaps, making the system inequitable. According to them, this has also been reflected in the quantitative results, which they found unsurprising yet not unproblematic. This is why the following chapter will provide an in-depth discussion of all provided results in combination with state-of-the-art literature.

Chapter 5

Discussion

By making use of both qualitative and quantitative data through a mixed-methods approach, the level of equity in terms of temporal accessibility by RPT stations has been assessed for every socio-economic and socio-demographic group of individuals in the greater metropolitan region of Munich. After the results have been showcased in the previous chapter, the temporal accessibility to offices seems inequitable, while the temporal access to POIs seems fairer. In combination with the qualitative results, it seems that the situation inside the city of Munich is more equitable than on its outskirts, as respondents suggested. Hence, the proposed mixed-methods approach successfully achieved its goal, as it provided evidence on how equitable temporal accessibility by RPT in the greater metropolitan region of Munich is. The following section will first discuss the proposed mixed-methods approach, by understanding strength and weaknesses in order to formulate potential recommendations for future studies. In a second term, an in-depth analysis on the level of equity per socio-economic and socio-demographic group of individuals in different areas will be conducted, explaining the early conclusions drawn above and allow further policy implications and recommendations to strive towards socially sustainable solutions in both rural and urban areas.

5.1 Mixed-Methods Discussion

5.1.1 Significance of Temporality in Accessibility

In a first term, it is important to note that this research highlighted why temporal accessibility is more than relevant in state-of-the-art accessibility equity assessments. As suggested by multiple research articles, assessing spatial accessibility alone is insufficient, as individual needs, travel and public transport service patterns differ at different times of the day [Kamruzzaman and Hine, 2012, Farber et al., 2014, Robbennolt and Witmer, 2023]. In line with past research conducted on temporal accessibility, the proposed method has allowed similar observation. While a single station might allow to access a very high number of places during daytime such as noon, night-time accessibility might significantly change. This has also been observed in the figures 4.5 and 4.6 in the previous chapter, each depicting the variation of accessibility per Temporal Accessibility Indicator value. The fluctuation of accessibility is evident, and can also be observed on the maps in Fig. 4.7 in the previous chapter, as they describe the accessibility to POIs at different times of the day.

While a strong spatial correlation can be observed, including the temporal dimension of accessibility is

still inevitable, since specific areas might be benefiting from strong spatial and low temporal accessibility, or vice versa. Prominent examples can be found in rural areas, in which all basic necessities for local residents are covered - an observation also made by I3 and I4, both living further from Munich's city center. While local public transport is much more present during peak hours, thanks to the high demand of school children or workers working in core working times, workers with irregular work hours are disadvantaged by it, as those services are significantly reduced, or even absent at noon and on weekends.

On the other hand, examples of high temporal and low spatial accessibility can be given as well. Munich's airport benefits of a suburban railway service in a 40 min. frequency throughout the entire night, despite the ban of night-time flights in Germany. While this train certainly is highly beneficial for airport workers and neighboring villages, the strong temporal accessibility may also seem unfair to other areas and residents of the city. Therefore, this research has successfully highlighted the significance of temporal accessibility in social equity assessments, and advocates the incorporation of this dimension in further studies.

5.1.2 Limitations

Before highlighting potential strengths of the proposed mixed-methods approach, it is important to acknowledge its limitations. First, it is debatable whether Munich's metropolitan region is the most suitable place to conduct such an analysis. While some respondents highlighted the high living standard, a good distribution of wealth and an overall positive social equity situation, recent news articles brought structural issues, especially in terms of migration backgrounds to light [Landeshauptstadt München, 2022, Taube, 2020].

On another note, although high changes in the opinion of the interviewees would not be expected, the number of four interviewees could potentially be considered as too little, as it increases the volatility in the weight of each stated opinion. However, the aim of this research was also to showcase the principle and use of mixed-methods in temporal accessibility related social equity assessments, a goal it successfully fulfilled.

Lastly, this research mainly covered station areas, as a form of simplification for such kind of assessments, as the density of goods, services and opportunities is high [Benenson et al., 2011, Culver, 2017]. However, this research only gives insights about who is most likely or least-likely to live in proximity of such stations, leaving out more detailed assessments in areas with only bus, demand-responsive or absent public transit services.

5.1.3 Strengths

However, the proposed methodology successfully disclosed potential social equity gaps in terms of temporal accessibility by RPT, by combining both quantitative and qualitative methods. Both results complemented each other, cross-validated, but also critically questioned specific results. Moreover, the high acceptance of the quantitative results by the respondents highlighted the strength of the proposed method. Furthermore, the use and comparison of the respondent's statement before and after the results have been shown and explained to them, disclosed a lack of awareness on specific issues, hence reinforced again the need for both methods.

The newly developed Temporal Accessibility Indicator has proven itself to be successful, not only for further analysis and combination with socio-economic and -demographic data, but also by highlighting

the general distribution of temporal accessibility in a wider area. As observed on the different maps such as in Fig. 4.2, spatial patterns can also be recognized in the temporal accessibility indicator values. While central places in inner-cities find strong indicator values, rural areas are characterized by much lower values. What seems like a spatial distribution is temporal as well - higher service frequency is usually to be found in central places, as also literature suggests [Ryan et al., 2023].

Lastly, the proposed methods are highly flexible and simple to transfer and implement in other areas in the world. Since the quantitative methods are based on widely used and standardized GTFS and OpenStreetMap datasets, they have been designed independently of any spatial context. Moreover, a mixed-methods approach also has the power to capture local specificities much better than sole quantitative or qualitative approaches, which also strengthens the utility and transferability of such a methodology onto other areas in this world.

5.1.4 Recommendations

Based on the enumerated strengths and limitations of this research, recommendations for further research developments have been formulated. In a first term, it would be highly favorable to apply the proposed methodology onto other metropolitan regions or areas renowned for higher social disparities. This could strengthen and further highlight the method's versatility and transferability. However and above all, areas that are in much higher need to reduce socio-economic disparities would benefit much more, as it would allow them to disclose potential equity gaps and serve as an incentive to solve those.

Moreover, future mixed-methods assessments on equity in temporal accessibility by RPT could also involve more interviewees, especially with more disperse age gaps. Since all interviewees found their own needs satisfied, it would be interesting to gain further insights from potential respondents feeling actively disadvantaged in terms of temporal accessibility by RPT. However, finding such respondents may be difficult as disadvantage may be a sensible topic.

Lastly, the proposed method should be extended to other types of services, such as bus services, as those are particularly renowned to have very low temporal accessibility due to infrequent services as respondents suggested. However, to gain an even more detailed insight, the analysis could also be conducted on a building or census data scale. This would shift the analysis from specified origins and destinations to a more general approach. Temporal accessibility could then be measured from "everywhere to everywhere".

After methodological insights have been provided and recommendations for further research have been given, the results of the previous chapter will be interpreted. In a first step, every assessed socio-economic and -demographic characteristic's results will be assessed and linked to state-of-the-art research. In a second step, an overview of the equity situation in terms of temporal accessibility by RPT will be provided and policy recommendations will be given.

5.2 Equity Assessment

The proposed mixed-methods approach to assess equity in terms of temporal accessibility by RPT has brought significant results for multiple socio-economic and -demographic groups. In a first term, age-related equity will be assessed, which will be followed by disability, gender, migration background, occupation and education, as well as the economical status and car ownership of the households. Following this in-depth analysis, a precise image of the equity situation in terms of temporal accessibility by RPT in the metropolitan region of Munich will be given.

5.2.1 Age

In a first term, the level of temporal accessibility for different age groups has been assessed. Trip patterns and temporal accessibility differs throughout different age groups. While younger or middle-aged individuals have a higher share of mandatory trips, with - depending on their occupation - regulated schedules, older people find a much higher flexibility with a higher share of non-mandatory trips [Kamruzzaman and Hine, 2012, He et al., 2018]. This section will begin by exploring equity in temporal accessibility for younger residents and then address the equity gaps that older residents may experience.

As quantitative results suggested, a resident with high temporal accessibility is most likely a young adult. At first, this result seemed coherent, as younger residents aged between 20 to 40 years seem to choose a place to live in which they could potentially maximize their accessibility to opportunities over an entire day. However, qualitative results suggested that this group of individuals does not always benefit from sufficient temporal accessibility at all times. Younger residents, who are more likely to engage in social activities during late-night hours compared to other age groups, are potentially disadvantaged by the limited temporal accessibility of RPT during these times. What seems like a contradiction of qualitative and quantitative results is effectively a general lack of temporal accessibility in the city of Munich at night time. While the inner city benefits from a sparse number of services in a (half-)hourly headway, suburban or rural areas have a much lower or absent temporal accessibility at these times.

However, respondents also highlighted that young residents could easily cope with the identified night-time gaps. This has also been confirmed in a recent report of the International Transport Forum, in which the high flexibility and adaptability of younger people's mobility behavior has been highlighted [ITF, 2024]. In other words, younger individuals do not "suffer" from those gaps. In return, this reinforces the overall already positive quantitative results for younger residents, making nighttime gaps just a minor inconvenience, hence an overall equitable situation for them.

The situation has been found different for older individuals. Quantitative results suggested that older age groups (60 and above) have among the worst temporal accessibility. Moreover, the complementary cluster analysis backed up these findings: Older individuals commonly live in areas characterized by a below average number of goods, services and opportunities. Yet, this does not necessarily translate itself into a potential disadvantage, as two respondents stated that most needs (e.g. basic necessities) are locally covered, for which no long trips or public transport services are required. However, other respondents found the generally low spatial and temporal accessibility a normal pattern for this age group, as most residents in that age choose to live in "calmer" areas with a general lower infrastructure density. These results have been found particularly intriguing, as older individuals are an age group prone of suffering from social exclusion [Juma and Fernández-Sainz, 2024]. Moreover, their poor both temporal and spatial

accessibility has been highlighted by a multitude of research articles [Guida et al., 2022, Fatima et al., 2021]. By confronting the quantitative findings in addition of results from other researches articles with respondent's point of views, a general lack of awareness on the topic of mobility-induced social exclusion for older individuals can be highlighted. The poor temporal accessibility seems well-acknowledged, the process of social exclusion widely accepted.

Another identified issue was the temporally induced physical accessibility barrier during peak hours, which heavily restricts older residents from using public transport services due to a much higher crowdedness and commuting pace. Surprisingly, this issue has been highlighted by most respondents, while the quantitative results were unable to identify them, yet strongly reinforces the already limited temporal accessibility this age group has. Fatima et al. [2021] found similar results, as they highlighted that older resident's trips occur mostly around noon, avoiding peak hours.

Older individual's trip patterns may depend on multiple factors and differ around the globe [Kamruzzaman and Hine, 2012]. Their patterns are often explained by a lower number of mandatory trips during a day and a general absence of trips at night-time. However, recent researches suggest a higher activity space of older residents, often due to more time for other non-labour activities and a resulting higher share of non-mandatory trips, thus contradicting the commonly expected travel patterns [Kamruzzaman and Hine, 2012, He et al., 2018]. Therefore, the combination of recent literature and the general identified gap catalyzes social exclusion and advocates the need for better temporal accessibility for these age groups.

5.2.2 Disability

After the age-related equity situation in terms of temporal accessibility has been discussed, part of the identified gaps also affect individuals with disabilities. While these results have only been identified qualitatively due to a lack of such variables in the available socio-demographic datasets, they have been found significant and will be discussed in the following paragraph.

Disabled individuals have been found to be strongly affected during peak hours. These results are also in line with observations of past research and reports such as Fu et al. [2020] or Field et al. [2007], who pointed out that a high share of people with disability find travelling during peak hours especially challenging. Yet, individuals with disabilities might have a higher share of mandatory trips than older individuals, which pushes this group towards car-dependency and worsen the social equity situation [Field et al., 2007]. However, the mentioning of this temporally induced accessibility gap highlights the strong awareness of physical accessibility issues for disabled residents, yet the absence of general spatial and especially temporal accessibility gaps. Generally, no disability-related temporal accessibility equity assessments have been found in the proposed systematic literature review.

Hence, it is yet to be debated whether temporally induced physical barriers should be considered in this research, as the temporal aspect does not directly impact spatial accessibility, but is mediated by its physical dimension. However, the temporally induced physical accessibility gap poses great additional challenges for individuals with physical disabilities and is therefore not to be neglected.

5.2.3 Gender

In addition to the identified gaps for disabled individuals, also gender-related differences have also been identified. Gender-related equity assessment, specifically in terms of temporal accessibility is highly rele-

vant, as both genders encounter very different challenges while using (R)PT. This section will demonstrate which differences have been identified and how potential gaps translate into inequities, by showcasing potential challenges different genders might face.

Both quantitative results suggested very small yet visible gender differences. The POI-based analysis disclosed very high and random differences per cluster. As those results are considered as highly unlikely, they won't be utilized in further assessment steps as the gathered data seems faulty. On another note, the office-based analysis disclosed a small advantage for women in comparison to men or others. Yet, in the cluster with the highest temporal accessibility of the office-based analysis, male individuals were clearly advantaged. This result came as a surprise, as well as to the respondents of the qualitative assessment.

However, the overall equal allocation of temporal accessibility amongst men and women, as well as the higher share of men living in proximity to stations with very high temporal accessibility can be seen as problematic. As respondent I2 also pointed out, women public transport travellers are much more exposed to safety issues in public transport services, especially at night time. Moreover, the scarce amount or lack of services amplify this issue, as waiting areas are particularly considered as unsafe for women at night time. These observations are also in line with gender-equity related accessibility assessments by Stark and Meschik [2018], pointing out that women encounter much more barriers while using public transport than men, such as safety-related issues [Stark and Meschik, 2018].

Yet, the allocation of temporal accessibility to this date seems more equal, hence not equitable as men do not face the same challenges in public transport as women do. State-of-the-art research also suggested that women are more likely to engage in part-time or shift-based work, thus travelling both outside and within core service hours, hence highlighting the need for better temporal accessibility for this gender at all times of the day [Ryan et al., 2023, Neutens et al., 2010]. Gender based equity in accessibility is a recent topic as state of the art research suggests, which reinforces the importance of this research's result, being one of the first research tackling gender-based inequity in temporal accessibility by rpt to the best of our knowledge.

5.2.4 Migration Background

Besides the gender-based equity assessment, migration-based equity has also been assessed both quantitatively and qualitatively. Potential disparities in terms of temporal accessibility are not to be neglected, as residents with migration background are easily disadvantaged [Taube, 2020, Landeshauptstadt München, 2022]. This section will investigate if potential gaps exist, by confronting own results with state-of-the-art literature and highlighting issues of potential equity gaps.

The results of the quantitative assessment suggested that non-German nationals have been found to be more advantaged by living in proximity to stations with high temporal accessibility. Yet, these results contradict partly with the respondent's point of views, as some highlighted the difficulty of choice where to live due to a prevalent disadvantage in the real-estate market, pushing them outside in the far-suburbs [Kinkartz, 2023, Taube, 2020]. Also past research by Vitrano and Mellquist [2023] suggested that residents with migration background endure a small disadvantage in terms of temporal accessibility in the city of Malmö, highlighting the transferability of this issue onto any area [Vitrano and Mellquist, 2023]. A recent study conducted by the city of Munich also disclosed that individuals with migration background are most prone to suffer from poverty, another disadvantage that will be discussed in a later section [Landeshauptstadt München, 2022]. Moreover, as stated by I4, this is then amplified by language-

barrier induced difficulties such as the obtention or translation of a driver's license, highlighting the higher need for non-German nationals for strong temporal accessibility by RPT to participate in activities. Yet, not all research articles find significant migration background or ethnicity-based evidence of a potential disadvantage when it comes to temporal accessibility [Farber et al., 2016].

The mixed reviews of past literature disclose that inequity situations based on individual's migration background is difficult to disclose, as evidence might be sparse. This may also be transferable onto Munich's case: the overall positive situation of the quantitative results suggest that scattered situations of inequity for non-German nationals in the metropolitan region of Munich exists, in which especially refugees are suffering as they have commonly been relocated to rural areas with poor temporal accessibility and the absence of a car.

5.2.5 Occupation and Education

Both Occupation and Education can also be indicators of potential disadvantage as past research suggested. These socio-economic characteristics are commonly directly related with the number of opportunities an individual can reach, which is why employment-based equity assessment can be commonly found [Neutens et al., 2010]. As occupation and education is often closely linked, the following section has considered both characteristics combined. The quantitative results of this mixed-methods approach emphasized that a resident with very high temporal accessibility usually has the highest possible educational background in Germany, which is a university degree, and is an employee. In return, residents with the lowest educational background, which are school diplomas after the 9th or 10th high-school grade, commonly follow apprenticeships and do not live in proximity to stations with high temporal accessibility. Yet, these results have to be interpreted in different ways and also be considered within the German context and its educational system.

On one hand, one could say that a higher education grants better future career opportunities, opens more doors and higher-wage jobs. This has also been highlighted by I3, which, if considered in that context, the temporal accessibility seems inequitable. However, this theory only applies if a lower educational background actively excludes individuals from their choice on where to live. Most sole equity in spatial accessibility assessment highlight this common interrelation, describing access to education and employment as an enhanced access to (socio-economic) opportunities [He et al., 2018, Ma et al., 2018]. This has also been highlighted in a recent article by Tagesschau [2024], in which temporal accessibility gaps in the early mornings or late evenings for lower wage workers and apprentices due to the absence of services has been pointed out [Tagesschau, 2024]. Moreover, state-of-the-art temporal accessibility assessments noted that employed individuals have a much lower activity space and also lower temporal accessibility to destinations due to business closing times or lower frequency of services, while the opposite has been observed for unemployed individuals or those with other types of occupation [Neutens et al., 2010, Kamruzzaman and Hine, 2012]. Yet, these observations partly contradict with the results of this research. Moreover, due to the missing social equity implications in the cited articles addressing temporal accessibility depending on the employment status, it is difficult to conclude whether or not the higher temporal accessibility for working individuals is equitable [Neutens et al., 2010, Kamruzzaman and Hine, 2012].

The German educational system also allows individuals without the highest-ranked diplomas such as the German "Abitur" or a university degree to access solid career opportunities and higher-wage jobs

[1] [BPB, 2018]. At the same time, a lower educational background can also translate itself into less environmental awareness [Roos et al., 2020]. These observations have also been made by [Roos et al., 2020], stating that a higher car usage is often linked to a lower educational background - results that are also observable within the linear models of the office-based accessibility analysis. Thus, it seems that residents with lower temporal accessibility could be much more car-addicted than car-dependent, explaining their high inverse correlation with temporal accessibility by RPT. This result is also in line with [Kühne et al., 2018]'s research, stating that educated households are less likely to use or own cars in Germany. In addition to that, the higher temporal accessibility for residents with higher educational background can also be understood as students that are lower-income households, unable to afford a car, hence living in proximity to RPT stations with higher temporal accessibility as I3 suggested. The high freedom of the place of living in and around the city of Munich has been highlighted multiple time by I3 and I4, which is why, in combination with quantitative data and literature, the second explanation seems plausible as well.

Therefore, two main ways of interpretation exist. First the situation could be qualified as inequitable, as a clearly privileged characteristic (employed) having a university degree has the strongest temporal access by RPT. An effect that is the result of residential self-selection or spatial sorting. Secondly, it can also be seen as equitable, as for instance individuals with lower educational background actively prefer using private motorized vehicles. Disclosing a disadvantaged individual is difficult, which is why this topic will be further discussed at a later stage of this discussion. However, the next section will give further insights on the economical status related equity, which can also give further insights on occupation and education related equity, as those are closely linked.

5.2.6 Economical Status

Income is a common limiting factor on the choice on where to live as the respondents also confirmed. Especially in cities in which housing is very competitive such as Munich, lower-income households suffer more severely and are systematically pushed out in the far suburbs of the city - an effect observed by both quantitative and qualitative results [Kinkartz, 2023]. Moreover, lower-income households have been found to have a higher dispersion of commuting patterns, less flexibility to work at different times of the day and rely often on off-peak hours such as early mornings or late nights characterized by a lower level of service [Ryan et al., 2023, Robbennolt and Witmer, 2023]. Thus, the economical status of households is a commonly used indicator in equity-related research, as it is an undeniable factor limiting or getting limited by temporal accessibility [Ryan et al., 2023, Robbennolt and Witmer, 2023, Vitrano and Mellquist, 2023].

As observed in the quantitative results, mainly middle to very high income residents have a high temporal accessibility to offices by RPT. This phenomenon is unsurprising, neither to the respondents nor in literature - as evidence from the U.S. by Tribby and Zandbergen [2012] or Yan et al. [2022] as well as from Stockholm by Ryan et al. [2023] suggests. Moreover, Ryan et al. [2023] found that mostly middle to high income classes have high temporal accessibility, as they are often concentrated in the center of the city - a case that seems transferable onto the city of Munich. For instance, Yan et al. [2022] and Robbennolt and Witmer [2023] argue that their needs are mainly unfulfilled during off-peak hours, an observation also made by I1 and I3 [Yan et al., 2022, Robbennolt and Witmer, 2023]. However, mixed

[1] In practice, however, this simplified statement is subject to numerous debates in Germany

results can be found. Research led by Robbennolt and Witmer [2023] or Farber et al. [2014] disclosed an equal temporal accessibility or almost higher general accessibility for lower-income households, probably induced by the fact that higher income residents choose to live further outside and prefer cars of public transit [Ryan et al., 2023]. A similar observation has also been made by respondents I3 and I4, as well as the POI-based analysis, both stating that most amenities can be accessed within their own commune or place of residency. This would allegedly make lower-income households independent from temporal accessibility by RPT.

Therefore, the social equity situation in terms of temporal accessibility for lower-income households seems to differ by city and depends on the type of destinations that needs to be reached. While the case in the metropolitan region of Munich disclosed a mostly equal temporal accessibility to goods and services - here defined by POIs - the temporal accessibility to offices is undeniably inequitable, as lower-income households are in much higher needs of strong temporal accessibility at any time of the day than higher income households [Robbennolt and Witmer, 2023, Yan et al., 2022].

5.2.7 Car Ownership

As Yan et al. [2022] also suggested, a lower economical status has a direct impact on the affordability, especially when it comes to modal choices [Yan et al., 2022]. Owning a car in Germany comes with much higher costs than using public transportation, as I4 stated, making it even more difficult for individuals with low economical status to afford a private motorized vehicle, a statement that has been confirmed by [van Dülmen et al., 2022]. However, non-motorized households that do not have the choice are prone of being socially excluded, as public transport remains the only mode available to cover distance that cannot be cycled or walked.

Quantitative results for the POI-based temporal accessibility analysis did not include car ownership in the step-wise linear model, yet the variable seems highly significant in the model based on the highest correlating variables. This mixed-response discloses that car ownership is probably irrelevant when it comes to accessibility to basic necessities (in this case POIs). However, quantitative results disclosed that mostly non-motorized households benefit of high temporal accessibility to offices. This has also been backed-up by qualitative results, which strongly suggested that a car ownership is the highest limiting factor, especially in rural areas. These results have also been found by own past previous research, in which non-motorized households are more likely to live in proximity to RPT stations [Juhasz-Aba, 2022]. The interpretation of such results can be difficult and explained in multiple ways. As past research also suggested, "car-addicted" car owners or those who can afford multiple modal choices also deliberately live in areas in which both spatial and temporal accessibility by RPT is poorer Ryan et al. [2023]. This case has been confirmed in Stockholm and is likely to be extended to other cities such as Munich as well Ryan et al. [2023]. Therefore, to interpret the results two different aspects need to be taken into consideration: car-dependency and car-addiction.

However, interpreting only single socio-economic characteristics is difficult and likely incomplete, which is why in a last section, a general interpretation and comparison with possible sinus milieus will be given to identify a typical type resident profile that has strong temporal accessibility.

5.2.8 Synthesis

As observed throughout previous sections, drawing conclusions based on the analysis per specific socio-economic and -demographic characteristic is difficult, as interpretation differs with different combinations of characteristics. By looking at the combined results of the quantitative and qualitative results, both suggest that a large part of the population living in proximity to stations with high temporal accessibility to offices have higher flexibility in their choice of place of living due to an overall socio-economically privileged background. While the temporal access to POIs has been found equally distributed due to the insignificance of the variables and respondent's satisfied needs, the temporal accessibility to offices is advantageous for the so-called "Liberal Intellectuals" Sinus Milieu - a part of the society characterized by mostly young professionals who have a high educational background, environmental awareness and an active lifestyle [SINUS, 2021].

Despite the difficulty to identify whether individuals are disadvantaged or decide to live in areas with lower temporal accessibility by RPT by choice, the advantaged type of resident is evident and undeniable. This socio-economic gap in terms of temporal accessibility to offices has been found inequitable throughout this research - an issue that has largely not been addressed in the city of Munich until now. Finally, the next chapter will conclude this research and provide policy recommendations to solve potential equity gaps in terms of temporal accessibility by RPT.

Chapter 6

Conclusion

This research set out to explore how equitable the temporal accessibility by RPT stations within the greater metropolitan region of Munich was, by identifying potential equity gaps and proposing solutions to overcome those. As one of the first mixed-methods approaches to assess equity in temporal accessibility by RPT to the best of our knowledge, the proposed methodology has proven itself to be successful. While the combination of both methods disclosed more equal accessibility to basic amenities or POIs, the accessibility to offices remains inequitable, as it favors Liberal Intellectuals - a highly privileged milieu of the society [SINUS, 2021]. Especially in suburban and rural areas, the situation has found to be more critical than within the city of Munich despite the presence of infrastructure - gaps that are affecting specific socio-economic groups and emphasizing the importance of addressing the temporal dimensions in accessibility planning practices. Based on the disclosed results, potential policy recommendations have been formulated, in order to solve equity gaps in terms of temporal accessibility by RPT.

Recommendations for more social housing, specifically for lower-income households exists, yet are not implemented rigorously enough. While the demand for more social housing is rising every year, the local government does not respond to it as recent newspapers suggested [Mölter, 2024]. In fact, a decrease in the number of new social housing entities has been observed in the city of Munich [Mölter, 2024]. Moreover, it seems that most social housing can be found in suburban areas, characterized by low both spatial and temporal accessibility [Münchner Wohnen, 2024]. This is partly due to the challenging and highly competitive real estate market in Munich [Mölter, 2024]. However, this does not justify overlooking the inclusion of such housing near RPT stations with high temporal accessibility, as doing so could exacerbate socio-economic disparities. The city and metropolitan region of Munich may, with the help of this research, identify stations with high temporal accessibility and further promote social-housing in proximity of such RPT stations.

Another recommendation is the adoption of Demand Responsive Transit, a mode of transport that can be implemented in various forms. Until recent years, Germany found two main types of demand responsive transit, both of which had certain limitations. While private ride-sharing/-pooling companies were always associated with higher trip costs than adjacent public transport services, so-called "Anruf-Sammel-Taxis" (so-called demand responsive bus lines) were highly inflexible and often needed to be reserved at least 45 mins. in advance [MVV, 2024b]. In recent years, there has been an increase in ride-sharing services owned by public transport companies, which aimed to address both challenges [MVV, 2024a]. These services featured ride-pooling with short waiting times available at all times of the day and are integrated into the standard public transport fare system. [MVV, 2024a]. According to the stated information, these

type of "semi-public" services could efficiently provide equitable temporal accessibility, as they would be highly beneficial to non-motorized, lower-income households as well as to younger residents living in the outskirts of the city. Therefore, such type of demand responsive transit in further suburban or rural areas is highly recommended to resolve social equity issues in temporal accessibility by RPT.

The proposed recommendation would in theory also be favorable to improve women safety at night. Local public transport companies and authorities tried to improve women's safety by offering taxi vouchers or allowing night bus services to stop in between pre-defined bus stops [Landeshauptstadt München, 2024]. Despite the efforts, they are still insufficient, since taxis are undoubtedly associated with higher trip costs, while concurring night bus services provide a below average level of temporal accessibility. While more ride-pooling or on-demand services could be a solution to bridge these issues, some private services have also been neglecting women safety issues as some of their own drivers sexually harassed female passengers in the past [Kachwala, 2024]. Today, private ride-hailing/-pooling companies tackled this issue and tried to improve women safety in their own services [Kachwala, 2024]. However, this should also serve as an incentive to think whether and why such issues are being resolved by their effect and not by their cause.

Moreover, to improve temporal accessibility for older and disabled individuals a more flexible interior in vehicles should allow small exclusive spaces for them. While most vehicles own reserved spaces for disabled individuals, they are still inconvenient to use during peak hours as vehicles tend to be too crowded. However, leaving those spaces permanently empty and exclusive to these groups of individuals could help them overcome temporally induced physical barriers. Moreover, these modular spaces could also be used as general safe spaces for vulnerable individuals at night time, such as women or children. Furthermore, to promote the use of on-demand services for older residents, better use instructions should be provided. Nowadays, such services are exclusively accessible over mobile apps, which older individuals have more difficulty to use since digital barriers are highly persistent.

In conclusion, this mixed-methods approach demonstrated that while Munich's metropolitan region has a solid foundation in terms of public transport infrastructure, the current temporal accessibility situation remains inequitable and leaves significant room for improvement. Therefore, the proposed policy recommendations, such as expanding demand-responsive transit and increasing social housing near high-accessibility RPT stations, aim to address these observed disparities and offer first steps toward a more equitable and sustainable future of transportation. By integrating both quantitative and qualitative assessment methods, this research not only establishes a new standard for equity assessments in temporal accessibility, but also serves as an incentive to solve identified gaps, as it aspires to support policy makers and planning practices to strive towards a sustainable future of urban, suburban and rural areas.

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Appendix A

Appendix

A.1 Systematic Literature Review

Authors	Article Title	Source Title	Author Keywords	Publication Year	Research Areas	(A) Type of Measurement (Indicator)	(B) Time Variation Representation; Period; Resolution	(C) Equity / Socio-Demographic; Types
Farber, S; Morang, MZ; Widener, MJ	Temporal variability in transit-based accessibility to supermarkets	APPLIED GEOGRAPHY	Public transit; Dynamic accessibility; Food deserts	2014	Geography	Travel time from all census centroids to nearest supermarket	Variation of travel time; 24h; 1 min.	YES; disparities; race, income, age
Lei, TL; Church, RL	Mapping transit-based access: integrating GIS, routes and schedules	INTERNATIONAL JOURNAL OF GEOGRAPHICAL INFORMATION SCIENCE	Public transit; accessibility; schedule and route information; geographic information systems; urban applications	2010	Computer Science; Geography; Physical Geography; Information Science & Library Science	Travel time from any origin to university	Variation of travel time; 1 day, 3 times	NO
Dubé, J; Thériault, M; Des Rosiers, F	Commuter rail accessibility and house values: The case of the Montreal South Shore, Canada, 1992-2009	TRANSPORTATION RESEARCH PART A-POLICY AND PRACTICE	Commuter train; Public transportation; Hedonic price model; Difference-in-differences estimator; Spatio-temporal analysis; Policy evaluation	2013	Business & Economics; Transportation	Travel (Walking and Driving) to nearest station	Variation of property value; 18 years; yearly	NO
Järv, O; Tenkanen, H; Salonen, M; Ahas, R; Toivonen, T	Dynamic cities: Location-based accessibility modelling as a function of time	APPLIED GEOGRAPHY	Dynamic accessibility; Space-time modelling; Big data; Travel time; Public transport; Spatial equity	2018	Geography	Travel time to nearest food stores	Variation of travel time; 24h; hourly	YES; GINI + Lorenz
Farber, S; Fu, LW	Dynamic public transit accessibility using travel time cubes: Comparing the effects of infrastructure (dis)investments over time	COMPUTERS ENVIRONMENT AND URBAN SYSTEMS	Public transit; Accessibility; GTFS; Temporal dynamics	2017	Computer Science; Engineering; Environmental Sciences & Ecology; Geography; Operations Research & Management Science; Public Administration	Average travel time between population weighted centroid (OD) and job (using employment count)	Variation of travel time; 24h; 1 min	NO
Kamruzzaman, M; Hine, J	Analysis of rural activity spaces and transport disadvantage using a multi-method approach	TRANSPORT POLICY	Activity spaces; Transport disadvantage; Rural Northern Ireland; Activity-travel diary; Focus groups	2012	Business & Economics; Transportation	Accessibility to basic needs and transport provision (survey based)	Temporal Distribution of Trips; 1day; 5 times	YES; Gender, Age, Occupation, Car-Ownership, Home-Ownership, Income
Lee, J; Miller, HJ	Measuring the impacts of new public transit services on space-time accessibility: An analysis of transit system redesign and new bus rapid transit in Columbus, Ohio, USA	APPLIED GEOGRAPHY	Transportation; Space-time accessibility; Public transit; Bus rapid transit; Jobs; Healthcare	2018	Geography	Number of accessible jobs and healthcare facilities	Variation of number of reachable opportunities; 1 day; 4 times	NO
Tribby, CP; Zandbergen, PA	High-resolution spatio-temporal modeling of public transit accessibility	APPLIED GEOGRAPHY	Accessibility modeling; Public transit; Transportation equity; GIS-T	2012	Geography	Travel time from all origins / destinations (probably centroids)	Variation of travel time; 1 day; 3 times	YES; low-income, age, no car

Polzin, SE; Pendyala, RM; Navari, S	Development of time-of-day-based transit accessibility analysis tool	TRANSIT: PLANNING AND DEVELOPMENT, MANAGEMENT AND PERFORMANCE, MARKETING FARE POLICY: PUBLIC TRANSIT		2002	Engineering; Transportation	Number of trips to work, school, shopping, social and other. (Calculation of service availability wighted by temporal distribution of travel demand)	Variation of service availability; 1 day; hourly	Partly; Socio-Economic
Kamruzzaman, M; Yigitcanlar, T; Yang, J; Mohamed, MA	Measures of Transport-Related Social Exclusion: A Critical Review of the Literature	SUSTAINABILITY	transport-related social exclusion; transport disadvantage; social exclusion; activity participation; accessibility; mobility; activity spaces	2016	Science & Technology - Other Topics; Environmental Sciences & Ecology	Review paper	Review paper	YES; all
Stepniak, M; Pritchard, JP; Geurs, KT; Goliszek, S	The impact of temporal resolution on public transport accessibility measurement: Review and case study in Poland	JOURNAL OF TRANSPORT GEOGRAPHY	Accessibility; Travel time; Temporal resolution; Public transport; GTFS	2019	Business & Economics; Geography; Transportation	Accessibility from centroids to adress points	Diverse, comparison of resolution types; 4 times*1 hour in 1 day	NO
Xu, WT; Ding, YJ; Zhou, JP; Li, Y	Transit accessibility measures incorporating the temporal dimension	CITIES	Accessibility; Two-step floating catchment area (2SFCA) method; Gravity method; Urban transit system; Traffic analysis zone (TAZ); Xiamen City	2015	Urban Studies	Transit Accessibility Index Value based on TAZ centroids	Variation of TAIV; 2 days; 2*3 times	NO
Delafontaine, M; Neutens, T; Schwanen, T; Van de Weghe, N	The impact of opening hours on the equity of individual space-time accessibility	COMPUTERS ENVIRONMENT AND URBAN SYSTEMS	Accessibility; Equity; Opening hours; Time geography	2011	Computer Science; Engineering; Environmental Sciences & Ecology; Geography; Operations Research & Management Science; Public Administration	Temporal accessibility / availability of libraries (no transportation)	Variation of opening hours; 1 week; hourly	YES; occupation
Liao, Y; Gil, J; Pereira, RHM; Yeh, S; Verendel, V	Disparities in travel times between car and transit: Spatiotemporal patterns in cities	SCIENTIFIC REPORTS		2020	Science & Technology - Other Topics	Citywide average travel times	Variation of travel time; 1 day; hourly?	Partly; Population Density
Kujala, R; Weckström, C; Mladenovic, MN; Saramäki, J	Travel times and transfers in public transport: Comprehensive accessibility analysis based on Pareto-optimal journeys	COMPUTERS ENVIRONMENT AND URBAN SYSTEMS	Transit; Routing; Temporal distance profile; Temporal network; GTFS; OpenStreetMap	2018	Computer Science; Engineering; Environmental Sciences & Ecology; Geography; Operations Research & Management Science; Public Administration	Travel time from specified district to university	Variation of travel time; 6-9pm; 1 min.	NO
Tenkanen, H; Saarsalmi, P; Järv, O; Salonen, M; Toivonen, T	Health research needs more comprehensive accessibility measures: integrating time and transport modes from open data	INTERNATIONAL JOURNAL OF HEALTH GEOGRAPHICS	Accessibility; Health; Door-to-door approach; Spatio-temporal; Multimodal; Public transport; Private car; Open data; Travel time; Food	2016	Public, Environmental & Occupational Health	Number of accessible "healthy food" stores	Variation of number of reachable opportunities; 1 day; 3 times	Partly; Population Density

Fayyaz, SK; Liu, XC; Porter, RJ	Dynamic transit accessibility and transit gap causality analysis	JOURNAL OF TRANSPORT GEOGRAPHY	Public transit; Accessibility; Transit gap; Spatiotemporal analysis; Transit travel time	2017	Business & Economics; Geography; Transportation	Travel Time (weighted & averaged) between all stop pairs	Variation of travel time; 4am-10pm; 10 mins	NO
He, SY; Cheung, YNHY; Tao, S	Travel mobility and social participation among older people in a transit metropolis: A socio-spatial-temporal perspective	TRANSPORTATION RESEARCH PART A-POLICY AND PRACTICE	Economic activity; Employment; Mobility; Older people; Travel behaviour; Transit-oriented cities	2018	Business & Economics; Transportation	Number of undertaken trips	Variation of number of trips; 1 day; 5 times	YES; occupation, age
Neutens, T; Schwanen, T; Witlox, F; de Maeyer, P	EVALUATING THE TEMPORAL ORGANIZATION OF PUBLIC SERVICE PROVISION USING SPACE-TIME ACCESSIBILITY ANALYSIS	URBAN GEOGRAPHY	space-time accessibility analysis; locational benefits; time constraints; operating hours; Ghent	2010	Geography; Urban Studies	Accessiblity to government offices	Variation of timing utility; 7am-9pm; 10-20 mins. (estimated)	YES; Household structure, employment, gender, mobility
Benenson, I; Ben-Elia, E; Rofé, Y; Geyzersky, D	The benefits of a high-resolution analysis of transit accessibility	INTERNATIONAL JOURNAL OF GEOGRAPHICAL INFORMATION SCIENCE	Accessibility; transit; equity; high-resolution spatial analysis	2017	Computer Science; Geography; Physical Geography; Information Science & Library Science	Number of accessibile Jobs	None; 7.15-7.30am; cumulated	NO
Aman, JJC; Smith-Colin, J	Transit Deserts: Equity analysis of public transit accessibility	JOURNAL OF TRANSPORT GEOGRAPHY	Equity; Transit Desert; Accessibility; CPTA; Public transportation	2020	Business & Economics; Geography; Transportation	Network and destination connectivity, service frequency, flexibility, time efficiency	Variation of frequency; 1 day; 3 times	YES; transit dependency and employment
Farber, S; Ritter, B; Fu, LW	Space-time mismatch between transit service and observed travel patterns in the Wasatch Front, Utah: A social equity perspective	TRAVEL BEHAVIOUR AND SOCIETY	Public transit; Social equity; Travel time cubes; Transit mismatch; Temporal mismatch	2016	Transportation	Results based on method Farber (2014), Census to Census centroid?	Moving average; 1 day, 1 min.	YES; Age, Gender; Education; Employment; Race; Income; HH/Res Type
Wang, YF; Chen, BY; Yuan, H; Wang, DG; Lam, WHK; Li, QQ	Measuring temporal variation of location-based accessibility using space-time utility perspective	JOURNAL OF TRANSPORT GEOGRAPHY	Accessibility; Temporal variation; Space-time utility; Rich facility information; Time geography	2018	Business & Economics; Geography; Transportation	Activity Intensity, Consumer Welfare Aggregation, Random Utility Maximization	Variation of activity intensity; 1 day; hourly	NO
Moyano, A; Moya-Gómez, B; Gutiérrez, J	Access and egress times to high-speed rail stations: a spatiotemporal accessibility analysis	JOURNAL OF TRANSPORT GEOGRAPHY	Access to stations; High-speed rail; Spatiotemporal accessibility; Big data	2018	Business & Economics; Geography; Transportation	Accessibility from/to HSR stations	Variation of access time to HSR; 1 day; N/A	NO
Stepniak, M; Goliszek, S	Spatio-Temporal Variation of Accessibility by Public Transport-The Equity Perspective	RISE OF BIG SPATIAL DATA	Accessibility; Public transport; Open data; GTFS; Spatial and temporal analysis; Szczecin	2017	Geography; Remote Sensing	Weighted Number of Trips and Gini Coefficient	Variation of GINI; 1 day; 15 min.	YES; GINI
Guan, JP; Zhang, K; Shen, Q; He, Y	Dynamic Modal Accessibility Gap: Measurement and Application Using Travel Routes Data	TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	Dynamic accessibility; Public and private travel modes; Points of Interest (POIs); Temporal variations; Modal accessibility gap (MAG)	2020	Environmental Sciences & Ecology; Transportation	Number of Accessible POIs (general)	Variation of accessible POIs and DMAG; 6-24h; 1h	NO; only gap identification

Chen, GP; Wang, CC; Jin, PB; Xia, BY; Xiao, L; Chen, SY; Luo, J	Evaluation of healthcare inequity for older adults: A spatio-temporal perspective	JOURNAL OF TRANSPORT & HEALTH	Healthcare inequity; Accessibility; Older adults; Gaussian 2SFCA method; Real-time speed data	2020	Public, Environmental & Occupational Health; Transportation	Older individual's medical service accessibility, calculated with gaussian distance decay fnctn.	Variation of EMSA; 1 day; 1 min	YES; Older Individuals
Lee, SG; Hickman, M; Tong, DQ	Development of a temporal and spatial linkage between transit demand and land-use patterns	JOURNAL OF TRANSPORT AND LAND USE	Transit stop aggregation; smart card data; transit service areas; transit and land use	2013	Transportation	Land-Use measurement	Variation of Transit Demand; 1 day; unknown	NO
Niedzielski, MA; Hu, YJ; Stepniak, M	Temporal dynamics of the impact of land use on modal disparity in commuting efficiency	COMPUTERS ENVIRONMENT AND URBAN SYSTEMS	Excess commuting; Temporal dynamics; Modal disparity; Big data; Warsaw	2020	Computer Science; Engineering; Environmental Sciences & Ecology; Geography; Operations Research & Management Science; Public Administration	Commuting Efficiency (using excess commute time etc.)	Variation of commuting efficiency; 5-11AM; 1h	NO
Xiong, QQ; Liu, YL; Xing, LJ; Wang, LY; Ding, YM; Liu, YF	Measuring spatio-temporal disparity of location-based accessibility to emergency medical services	HEALTH & PLACE	Emergency medical services; Spatio-temporal disparity; Location-based accessibility; Competitive effects	2022	Public, Environmental & Occupational Health	EMS performance (spatial location within response time treshhod)	Variation of EMS events and travel speed; 24h; 5x1h	NO
Tomasiello, DB; Giannotti, M; Arbex, R; Davis, C	Multi-temporal transport network models for accessibility studies	TRANSACTIONS IN GIS		2019	Geography	Number of low-wage jobs and service area calculation	Variation of cumulative indicators; 1 day; different times of the day	NO
Tasic, I; Zhou, XS; Zlatkovic, M	Use of Spatiotemporal Constraints to Quantify Transit Accessibility Case Study of Potential Transit-Oriented Development in West Valley City, Utah	TRANSPORTATION RESEARCH RECORD		2014	Engineering; Transportation	Number of Accessibile transit stops	Variation of the number of accessible transit stops; 6am-8pm; 15min	NO
Cheng, SW; Xie, B; Bie, YM; Zhang, YP; Zhang, S	Measure dynamic individual spatial-temporal accessibility by public transit: Integrating time-table and passenger departure time	JOURNAL OF TRANSPORT GEOGRAPHY	Public transit operation; Public transit planning; Trip planning; Sustainable transport; Land use	2018	Business & Economics; Geography; Transportation	Timetable connectivity / Time-dependent weighted directed graph	Change in network graph/paths; 1 day; different times of the day (first/last services)	NO
Yan, X; Bejleri, I; Zhai, L	A spatiotemporal analysis of transit accessibility to low-wage jobs in Miami-Dade County	JOURNAL OF TRANSPORT GEOGRAPHY	Accessibility; Public transit; Transportation equity; Modal disparity; Spatiotemporal analysis; Miami Dade	2022	Business & Economics; Geography; Transportation	Number of accessible low-wage jobs	Variation of the number of accessibile low-wage jobs; 1 day; 4 times	YES; density, income, ethnicity
Dong, LQ; Lv, Y; Sun, HJ; Zhi, DY; Chen, TT	GPS Trajectory-Based Spatio-Temporal Variations of Traffic Accessibility under Public Health Emergency Consideration	JOURNAL OF ADVANCED TRANSPORTATION		2021	Engineering; Transportation	Healthcare opportunity, cumulative healthcare grid calculation	Variation of medical opportunities; 1 day; 2h	NO
Murphy, B; Owen, A	Temporal sampling and service frequency harmonics in transit accessibility evaluation	JOURNAL OF TRANSPORT AND LAND USE		2019	Transportation	Number of accessibile Jobs	Variation of number of jobs that can be accessed; 7-9AM; 1 min	NO

Ryan, J; Pereira, RHM; Andersson, M	Accessibility and space-time differences in when and how different groups (choose to) travel	JOURNAL OF TRANSPORT GEOGRAPHY	Accessibility; Time geography; Public transport; Stockholm; Spatio-temporal; Differences; Transport justice	2023	Business & Economics; Geography; Transportation	Number of work-related trips	Comparison of work-related trips; 1 day; 3 times (pre-/post-/peak)	YES; income, employment, modal choices, age, gender
Fatima, K; Moridpour, S; Saghapour, T	Spatial and Temporal Distribution of Elderly Public Transport Mode Preference	SUSTAINABILITY	elderly travel behaviour; spatial-temporal analysis; elderly trip characteristics; hotspot analysis; travel decision; public transport mode	2021	Science & Technology - Other Topics; Environmental Sciences & Ecology	Travel Time to POIs (shopping, recreation, education)	Variation of travel time; Weekday/-end 24h; 1h	YES; Older Individuals
Langford, M; Price, A; Higgs, G	Combining Temporal and Multi-Modal Approaches to Better Measure Accessibility to Banking Services	ISPRS INTERNATIONAL JOURNAL OF GEO-INFORMATION	reconfiguration of banking services; multi-modal accessibility; floating catchment area models; impacts of closures; spatial patterns of access	2022	Computer Science; Physical Geography; Remote Sensing	Number of Banking services	Variation of the Floating Catchment Area; 3 days; 3 times	NO
Henriksson, M; Berg, J; Lindkvist, C; Lucas, K	Questioning mobility ideals - the value of proximity for residents in socially deprived urban areas in Sweden	MOBILITIES	Mobility types; motility; time-geography; transport poverty; social inclusion	2021	Geography; Transportation		Qualitative Mixed-Methods approach	
Robbennolt, D; Witmer, AP	GIS-Based Approach to Dynamic Accessibility: Incorporating a User Perspective to Recognize Social Equity Implications	TRANSPORTATION RESEARCH RECORD	accessibility; GIS; planning and development; public transportation; contextual engineering	2023	Engineering; Transportation	Accessible Area (sq ft)	Variation of accessible area; 1 day; 7 times	YES; income, poverty, NMH, population density
Vitrano, C; Mellquist, L	Spatiotemporal accessibility by public transport and time wealth: Insights from two peripheral neighbourhoods in Malmo, Sweden	TIME & SOCIETY	spatiotemporal accessibility; accessibility inequalities; time wealth; public transport; Malmo	2023	Social Sciences - Other Topics	Accessible Area (m2), Mixed-Methods	Variation of accessible area; 2 days; 2x5 times	YES; migration background; degrees; income; car ownership
Pinelli, F; Hou, AY; Calabrese, F; Nanni, M; Zegras, C; Ratti, C	Space and time-dependant bus accessibility: a case study in Rome	2009 12TH INTERNATIONAL IEEE CONFERENCE ON INTELLIGENT TRANSPORTATION SYSTEMS (ITSC 2009)		2009	Computer Science; Engineering; Transportation	Number of reachable bus stops	Variation of number bus stops; 1 week; 7*6 times	NO
Gan, ZX; Liang, T; Yang, RX	Identifying temporal variations in accessibility inequity to healthcare services across different travel strategies	JOURNAL OF TRANSPORT & HEALTH	Accessibility inequity; Healthcare services; Travel time; Spatiotemporal analysis; Public transit	2024	Public, Environmental & Occupational Health; Transportation	Accessibility to Healthcare services	Variation of the FCA; 1 day; 3 times	NO
Price, A; Higgs, G; Langford, M	Spatial and temporal access to warm spaces during the winter of 2022/2023	ENVIRONMENT AND PLANNING B-URBAN ANALYTICS AND CITY SCIENCE	warm spaces; public transport/walking; geographical accessibility	2023	Environmental Sciences & Ecology; Geography; Public Administration; Urban Studies	Number of accessible warm spaces	Variation of the number of warm rooms; 2 days; 2*3 times	NO

A.2 Quantitative Assessment

A.2.1 Bounding Boxes

Used bounding boxes for the extraction of the GTFS dataset:

- 9.756370725427816, 49.143217247297621
- 14.078199817050127, 49.128566309608473
- 14.048342621253084, 47.186964831775221
- 9.748906426478557, 47.141290006786775
- 9.756370725427816, 49.143217247297621

A.2.2 Modified r5r Code

Listing A.1: Modified r5r Code

```
options(java.parameters = "-Xmx6G")

library(r5r)
library(lubridate)

path <- ""
r5r_core <- setup_r5(data_path = path, verbose = FALSE)

o_points <- read.csv("")
d_points <- read.csv("")
mode <- c("WALK", "TRANSIT")
max_walk_time <- 15    # minutes
walk_speed <- 5        # kph
max_trip_duration <- 30 # minutes
start_datetime <- ymd_hms("2023-11-13 00:00:00")
directory <- ""

for (i in 0:1439) {
  current_datetime <- start_datetime + minutes(i)

  ttm <- travel_time_matrix(
    r5r_core = r5r_core,
    origins = o_points,
    destinations = d_points,
    mode = mode,
    walk_speed = walk_speed,
    departure_datetime = current_datetime,
    max_walk_time = max_walk_time,
    max_trip_duration = max_trip_duration
  )

  write.csv(ttm,
            file = paste0(directory, "ttm_", format(current_datetime, "%Y%m%d_%H%M"
            row.names = FALSE)
}
```

A.3 Qualitative Assessment

A.3.1 Interview Guide

Semi-Structured Interview

Basic required information

- Age
- Migration Background
- Gender
- Education
- Job

General aim of semi-guided interviews in this mixed-methods approach

➔ Understand if the needs of the interviewee in terms of temporal accessibility by RPT have been satisfied and whether he/she/they feels equitably treated.
➔ Understand the perception on fairness of temporal accessibility across the city/area the interviewee is aware of.
➔ Deeper understanding and critical validation of quantitative method results.
➔ Explore potential improvements in temporal accessibility or planning policies to ameliorate equity in temporal accessibility by RPT.

I. Interviewee's Background

Aim: Understanding travel and RPT-use circumstances of the interviewee. This general first step helps to draw an image of his/her overall satisfaction of mobility needs and serves as an introduction to the following questions.

Question	Aim
Please describe your mobility / travel behavior when you use public transportation. Include for example average travel times, frequency of use, ease of reach etc.	*Establish the interviewee's familiarity with the (R)PT system, furnishing deeper insights about their baseline knowledge. Identify the interviewee's travel patterns, hence connect their experience to potential gaps in temporal accessibility.*
Could you tell me about your general experience with public transport in the city/ the area you live in?	*Understand the frequency of interaction with the (R)PT system, as the perception might be based on regular or occasional use.*
Do you experience or notice challenges at specific times of the day?	*Identify the interviewee's travel patterns, hence connect their experience to potential gaps in temporal accessibility.*

II. Accessibility and Time-Variation

Aim: This section helps to highlight whether the interviewee has a general awareness of the impact of temporal variation in accessibility. If not, this section serves as an incentive and raises awareness if the interviewee has not yet put a thought to it.

Question	Aim
Did you experience changes in accessibility / ease of reach of different opportunities (e.g. basic amenities, workplaces, recreational areas) or PT use at different times of the day? If yes, can you describe these changes?	*Giving a direct insight in the perceived temporal variation in accessibility by the interviewee.*
How do these variations / changes impact your daily activities and/or mobility needs?	*Understanding the interviewee's needs, and to what extent temporal accessibility (gaps) impact the interviewee's life. Provides a link towards potential equity issues.*
Do you think that variations of accessibility in a day affect different groups of individuals in different ways?	*Understanding the interviewee's perception of general social equity…*
Which group of individuals (in your opinion) are more affected?	*.. and how different group of (potentially disadvantaged) individuals are affected by temporal accessibility changes.*

III. Equity

Aim: In a next step, the interviewee will have to reflect on general social equity, and bridge it to accessibility. It will also disclose how equitable the system is perceived by the interviewee.

Question	Aim
What does equity in temporal accessibility by public transport mean to you?	*Aligns the definition of equity in temporal accessibility by RPT of the interviewee with the one used in this research.*
Potential question if the definition has not been given properly: - Do you think everyone has an equitable access to public transport during the day?	*This critical reflection on reality of temporal accessibility pushes the interviewee to highlight potential disparities he has not been aware of until now.*
How fair do you think the accessibility to/by RPT is in and outside of Munich at different times of the day? (Help: Compare Peak, Off-Peak and nighttime)	*Understanding the interviewee's perception on fairness (equity) in the assessed area/region.*
Are there specific times in which the accessibility by/to RPT seems more/less fair?	*Exploring the interviewee's perception on the relationship between temporal variation in accessibility and equity.*

IV. Mixed-Methods

Aim: This section aims to validate or critically question quantitative results of the equity assessment. This section is core to this mixed-methods approach, as it also aims to highlight to what extent both methods may or may not complement each other.

Question	Aim
Please describe whether those results are surprising or come as expected to you.	*Understand whether the interviewee is potentially affected, and highlights potential gaps between quantitative and qualitative results.*
If you are able to identify your socio-economic group, would you (from your own perception) validate those results?	*Understand which socio-economic group the interviewee belongs to, and whether quantitative and qualitative data aligns.*
Are there group of individuals that are potentially disadvantaged or advantaged in terms of temporal accessibility?	*Qualitative analysis of quantitative results. Disclosing potentially (dis)advantaged group of individuals.*
How equitable would you judge the overall situation (in terms of temporal accessibility by RPT) is?	*Open-end question to let the interviewee reflect on the overall fairness of the system.*

➔ Is there anything you would like to add?

A.3.2 Interview 1 (I1)

1 Speaker 1 (00:01):

2 Okay, it's running. So my first question would be just briefly describe your mobility behavior or travel behavior when you use public transportation. For example, you can talk about your average travel times frequency of use and also ease of reach. So how you use public transport on a daily basis.

3 Speaker 2 (00:24):

Perception on (Under-)Pr
Mobility Behavior, Travel
Perception on (Under-)Pr
Mobility Behavior, Travel

4 I think I am very privileged because I live just nearby the university, so I don't need to take the public transport to go to my daily work or university. I go by foot. If I go to work, I can reach the U2 by five minutes and I am at the office 20 minutes later. I have to change at Sendlinger Tor because I work at Marienplatz. So I think that I am part of the 10% or bit less, I don't know the statistics, that are very privileged and don't have to travel much or change that often. I used to live at Rosenheimerplatz there, as well, I was on the Stammstrecke. I didn't really notice when the Stammstrecke had problems or when one specific suburban train had difficulties. I just took the next one that came two minutes later. So that made it also very nice.

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Temporal Accessibility N

5 When I used to work at Pasing in the Zentrum für Geotechnik of the University of Munich, I somehow sometimes had difficulties to walk from the place in the Franz-Langinger-Straße or Baumerstraße previously called to come to the S-Bahn station because there was this bus 161 that came every 10 to 20 minutes and then there was this other train eh bus that came only on peak hours at the morning, maybe at lunch, I don't remember. We should check on that. And at night of course. So worst thing that could happen to me is that I didn't see the bus, so I had to walk 15 minutes, which is fine, but, it's the things that I had to live with. “Je suis pas à plaindre”, that's what I want to say.

6 Speaker 2 (02:39):

Mobility Behavior, Travel Pa
Mobility Behavior, Travel Pa

7 So Rosenheimer Platz was nice, Luisenstraße is perfect. I think as soon as you live in the center like Schwabing / Maxvorstadt, since it's the heart of the city, you can reach everything by foot. Also nearly half an hour, 45 minutes if you like to walk, it's perfect. I do sports in a club in Großhadern. There I really noticed the difficulty to go there. By bike it's 45 minutes, by train it's 45 minutes. I have to go to the end of the U6 at Klinikum Großhadern and then I should go I think 10 minutes. It's bad. It's very bad and I think I could not live there because of that. Since my dad is sponsoring me for my studies, I can allow myself to live in the center of the city. I saw how it is to live with a car in Munich for one month in September 24. It was one of the best months I had in Munich because everything was more comfortable. I must admit I didn't have a lot of difficulties to park the car inside TU Viertel, which is the place where we had the Parklets, in the Steinheil- and Enhuberstraße. This is

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where I could park my car also. So I didn't have a lot of difficulties to park there. And I could come to the sports club where I am a member in 20 minutes instead of 45. For me, I think when I will come back to Germany, it sounds very bad, but I think I want to come back with the car of my dad because then I get very fast to the Sports Club. It would not contribute to the environmental wellbeing of the city. But you see when you compare Mainz to Munich or Freiburg to Munich, that Munich is a very car friendly city and I work on the Stammstrecke and I still don't understand why they did the same route, the first Stammstrecke for the second Stammstrecke and not like a circle, like we do in Paris, like we have in Barcelona, like we have in Berlin and Munich is growing more and more and I don't understand why we are not thinking in advance because the plans we have from the nineties and we are 2024, I don't know when the plans of the Ringbahn will be planned. I don't think there will be planned before the end of the 2. Stammstrecke, which is in 2030. So I don't think we will have a ring band before 2050-60. So this is very sad and this is something that is also due to politics, but now we are going off the theme. But yeah, this is my behavior and in Munich.

Speaker 1 (05:50):

So you would say your average experience is since, okay, since you live close to university, you don't have to use it every day. And also that it's a bit more difficult when it comes to reach places that are little bit further out. Right?

Speaker 2:

Exactly!

Speaker 1:

I see. Okay. Interesting. But so then about the times you use public transport, do you experience or notice challenges at specific times of the day?

Speaker 2 (06:16):

Temporal Accessibility Chal

Mobility Behavior, Travel

Yes, yes. When I lived at Rosenheimerplatz and I came to the university, the U2 was always full because there were a lot of students who took it. I feel like you cannot have every two minutes a train. It's every five I think, or seven, or 10 in Munich. So sometimes I also used to walk or take the bus. I think that we are not equipped for the population. This is why a lot of people take the car and this is why we cannot improve in the mobility because we are in between car and train. And because it's like this circle of Verkehrsplanung, you have the demand and the supply and it works together. And if you have the car in between, it kind of kills the ÖPNV. So the transport mobility. So I don't want to be in a dictatorship where we forbid the car, but I think we have to

work with push and pull factors. I think paying 30 euros for a car on the street is way too little. I was surprised while seeing that, but I didn't really notice big problems in Munich. Also with the ICE to Frankfurt, I think we have a very nice line. I think people who travel more or also further have way bigger problems with the Deutsche Bahn or with the MVG.

16 Speaker 1 (07:56):

17 So your main challenges then you would say at specific times of the days, especially the crowdedness, like on peak hours.

18 Speaker 2 (08:03):

Temporal Accessibility Chal

19 Yeah, the crowdedness and when I, I lived in Rosenheimer Platz on the weekend. It was very annoying when we had Schienenersatzverkehr, because I somehow only had the S-Bahn. I had some trams and buses, but they went to places outside like Rotkreuzplatz or, it was not where I wanted to go or I would have to change with the Tram 25 to take the U2. So it was not a clean line that put me through the city. I had to do some detours. So this was annoying, but nevertheless I had the Schienenersatzverkehr. I could go to another place and take the bus, but it was also crowded. So I am not the biggest fan of the S-Bahn in Munich, but I think I'm not the only person.

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20 Speaker 1 (08:56):

21 Understandable. I mean, okay, so I see what your main issues were on that point. Yeah, I guess there's also construction works late nights very often, but so in your own perception when you wanted to access different types of opportunities, for example basic amenities, commercial things like shopping related things or workplaces or recreational areas with public transport, did you experience changes in that kind of accessibility at different times of today?

22 Speaker 2 (09:34):

Temporal Accessibility, Acc

23 No. No, no, no. Because I take always the Bus 100 or 58 or 68. I don't remember which one goes where. And when I go to the Leopoldstraße, I took this one or I took the metro. No, no. I am thinking out loud maybe to go to Danny at Wilhelm-Hertz-Straße. Maybe this is one bus after the 161, but it's not to go to a shop or to a store. No, no. I always had..

24 Speaker 1 (10:09):

Temporal Accessibility, Acc

25 You never had issues in terms of temporal accessibility. I see. So would you say that your mobility needs, especially your temporal mobility needs, so mobility needs over the span of an entire day or 24 hours are satisfied, right?

26 Speaker 2 (10:44):

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Temporal Accessibility Chal

Impact per Socio-Econon

27 Eh, yeah maybe I have high expectations, but when we were in Studentenstadt, we wanted to go home. There's always a bus, like a night bus that comes every hour or something. I think when you are young you can live with that or you stay in a McDonald's and then you go out or you just walk home if you're in the inner city, the public transports at night are there. They exist, but I think that we could improve more. I think there are a lot of people who also take taxi or don't go out because of that because they're scared or I don't know what. But, I think it's more a problem for people who live outside the Ring, than for people who live inside the Ring. Inside the Ring it's fine, but if you live outside the ring, it's a bit more difficult.

28 Speaker 1 (11:31):

29 Yeah, that would be my next question. So you think that there are areas or people living in those areas that are more affected by these temporal changes, right?

30 Speaker 2 (11:41):

31 Of course, of course. And I don't know how the lines or the stations have been planned. I don't know on what statistics everything is based or on what arguments. So I don't know if it's politic or else, but I believe and I see people who live in Neuperlach Süd or in Grünwald. I took one time the car to go to a friend in Grünwald. I had to walk 10 minutes or 15 minutes, which is okay, but then I had to take the Tram at the terminus and go inside the city and the Tram takes 20 minutes to go inside of the city and by car, I was there in 20 minutes from Luisenstraße, and you have to change two times or three times. And the public transport in Munich can definitely improve when you have a city where you pretend it's the best city in Germany, that everything looks better than in other Bundesländer and you have this kind of public transport, it's a bit of a shame.

32 Speaker 1 (12:54):

33 But then, ok that are interesting views. So especially for you also about spatial aspects, but do you think that the variations in terms of accessibility in a span of 24 hours in a day, do they affect different groups of individuals in different ways?

34 Speaker 2 (13:13):

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Impact per Socio-Ecor

35 Yes. Yes. I think people who have lower incomes are more likely to live in suburbs or in places where the rent prices lower, which is already difficult to find in Munich. And so they are living outside the center and then the temporal accessibility is lower. Of course. I'm thinking of what's in the center of the U2, Feldmoching or over there. And also this is a bit of a bad neighborhood. What's his name? It's a U2 station where Kim lived.

36 Speaker 1 (14:06):

37 Hasenbergl?

38 Speaker 2 (14:12):

39 Yeah, Hasenbergl. Exactly.

40 Speaker 2 (14:14):

41 I don't know if it's a bad neighborhood. I mean I live in Tucuman right now. I think this is way worse. I think it's logical and it's proved also this point is proved. When you see people who come to exchange in Germany and are foreigners and have less incomes or don't know about how it works here, they always live outside of the city and then you see how difficult it is to come inside of a city by their experience.

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42 Speaker 1 (14:49):

43 Yeah, yeah, that's quite interesting. So do you think, or in your opinion, because you already talked about lower income people, which group of individuals in your opinion, are more affected? Are there other groups of individuals that are more affected, other, for example, than lower income?

44 Speaker 2 (15:08):

45 I think it's like, how do you say, cleaning ladies, construction workers, because when I took the train to go to the construction site at Marienhof, at the construction site, at marine roof, I saw a lot of people... I had to be there at six so, or six or seven, I don't remember. So you see people who are with PSA, like these construction site shoes, or Engelbert Strauß pants, you see also people who come from Homeless residences (Obdachlosenheime) who have to leave the place very early. So you see that people who have, I mean in Paris, it's the same in Paris. You see the same people who have lower incomes have to start a day earlier also. And you meet them in the public transport early at six or so and cleaning ladies who go and work in a company that is for cleaning, cleaning bureau and buildings. So it's a lot of that. Security, people who work in security. Kitchen I don't know, in restaurants I couldn't tell really because they also started early. I don't think they have a high salary. It's more if you're the manager. But yes. And you see also, it's maybe a bit off topic, but alcoholics, you see people started there with a beer in their hand..

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46 Speaker 1 (16:35):

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47 So more marginalized groups then..

48 Speaker 2 (16:38):

Fairness and Equity Perc

49 Yeah, of course. And you see in their face that they, they're

Fairness and Equity Perc
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Fairness and Equity Percept

not very... their face does not express happiness. See it, it's not the same vibe when you are in this train at 6:00 AM than where you're in this train at eight or seven. But I think it's less... the gap is not as big in Munich than in other cities.

Speaker 1 (17:06):
Yeah, okay. So you mean the gap is way bigger if you go for example, like in Paris, suburbs. Suburbs of much bigger cities.

Speaker 2 (17:13):

Yeah.

Speaker 1 (17:14):

I mean, okay, that's very good. Thank you very much. So I'm going to switch to topics of equity. So I'm going to start with a question that might be a little bit complicated to answer, so don't worry too much, but what does equity in temporal accessibility by public transport mean to you?

Speaker 2 (17:38):

You mean the link to that?

Speaker 1 (17:41):

Yeah, yeah, exactly. What does, to you what does the equity implication, if we're talking about equity and temporal accessibility by public transport, what does it mean to you or what comes to your mind when you hear that.

Speaker 2 (17:58):

Fairness and Equity Percept
Fairness and Equity Percept
Fairness and Equity Percept

That everyone regarding the fact how much they gain should have the same, the same, how do you say, the same offers of train transport or bus transport have. But I think it's the problem of that it would be perfect. The world will be perfect if everyone would've enough money to live or to take the train or the bus to go to somewhere. I think the problem is it's very utopic because then I mean the reason why some place is expensive is because it has this accessibility. Everyone has that. I think, I don't know if it would work out. I think it'd be perfect, but I don't think that the society would, I forgot what I wanted to say, but I don't know if it's something that would work out or do cities where it's perfect like that?

Speaker 1 (19:05):

Probably not. That's why we're doing research about, but of course it's this whole equity implication. So basically just to come back, just to what you described, you described a more equality behavior. If we talk about equity, it means to give more to the ones who... exactly. And I think we don't

have real world examples because our world is just not equitable. I think it's my personal opinion and that's why we can only try to strive to it but not... But that... off grids of my own perception. So in your opinion, and now maybe you can also take a greater scope also outside of Munich, because basically the area that I am assessing is also the greater metropolitan region of Munich, which spans basically, and I can show you a map after, it spans almost like Ingolstadt, Augsburg, München and Rosenheim, they're all part of it. It's a more broader upper Bavarian, little bit outside of upper Bavaria, but it's mainly upper Bavarian region. So this is the metropolitan, so-called metropolitan region of Munich. So how fair, in your opinion, do you think the accessibility, the temporal accessibility by rail, public transport is in and outside of Munich at different times of today? So you can for example, compare peak of peak time and nighttime and with fairness, I mean how equitable it is in your opinion.

Speaker 2 (20:37):

Okay, you have to explain the question again. Can I compare, for example, Rosenheim with where you lived in Berg am Laim?

Speaker 1 (20:46):

Yeah, exactly. You can compare any, but also you don't have to dig into places you don't know. Just purely feel free to talk about the areas that you are aware of, but exactly, and what I mean how equitable it is, I'm still speaking about who has that kind of temporal accessibility, right? We're talking about socioeconomic group of residents. So how fair is it, the temporal accessibility basically?

Speaker 2 (21:17):

I dunno if it answers the question, but I know someone that lives in Rosenheim because he cannot pay the rent in Munich and it takes about 45 minutes from Rosenheim to come here. He lived just next to the Hauptbahnhof of Rosenheim. And I think that - how long did you take sometimes to come from Steinhauser Str. to the university?

Speaker 1 (21:38):

I guess from half an hour, 40 minutes max.

Speaker 2 (21:43):

So he takes 45 minutes to come from his place, which is way further from your place and your place is not very badly connected. I think there are people who live inside the city in Munich, but almost very bad connected, and they come inside the city for the same amount of time that he in Rosenheim comes inside the city.

It doesn't really answer the question.

75 Speaker 1 (22:13):

76 No, no, no. It's already a first step. But then if we really put a focus on the temporal accessibility aspect, so how it varies over the day, how fair do you think that is?

77 Speaker 2 (22:23):

Temporal Accessibility Chal

78 I don’t know how many trains you have to come from Rosenheim to there. I think enough because otherwise he wouldn't take the apartment. But it's difficult to come home at night and I don't know much about English that I know that in Augsburg and Ingolstadt that you have the ICE, in Rosenheim there is this rail jet that comes from Hungary or Austria. I think Augsburg is nice because I know of lot, or 3 people who live in Augsburg and work in Pasing at the Zentrum für Geotechnik and they come with the ICE and it's very fast and the living in quality in Augsburg is very nice. Ingolstadt that is way further, the Audi industry. But I don't know people who live in Munich and would work in Ingolstadt that what other cities do we have?

79 Speaker 1 (23:17):

80 No, but I mean you're focusing on cities which is already quite interesting. So you're saying mainly if you live in one of these sub-centers of this metropolitan region, your temporal accessibility is good. So you mean that you have a lot service provision over the entire day and so...

81 Speaker 2 (23:36):

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Fairness and Equity Perc

82 I think the major point would be that people who live outside Munich have a better accessibility than some that live in Munich and work in Munich. I think this is the more interesting point is to say that people who live outside the center can reach it more easily and then it shows more the lack of equity inside Munich. I think if you live in Munich and you work in Munich, you should be privileged to have a good transportation system and people who live outside Munich should or should be able to go inside Munich. But the preference should be for people in Munich, it would be my opinion,

83 Speaker 1 (24:25):

84 Okay, I see yeah. But yeah, so if we really take also our different social economic groups for example into consideration and if we look at for example, also different areas like rural areas also between the cities and because there's plenty. So the area stretches really I think even the part where Karl lives is also part of that metropolitan region. So there's many, many, many areas, right? Because the span is like Inglstadt for example in the north, Rosenheim south, etc., so the region is quite big. So there's a lot of rural areas in between. But yeah. So how fair is it for example, for

different socioeconomic groups at different times of the day in that area? How fair is the allocation of temporal accessibility to them? How fair is it for different groups to access different places over different times of the day?

Speaker 2 (25:23):

For people who live further out?

Speaker 1 (25:25):

For example, I don't know, anywhere actually in the area, I can actually show you really quick.

Speaker 2 (25:30):

Yeah, I don't know about the schedule of the regional trains. I don't know if at 11 there is a hole until four. I heard a lot that people who live in Countryside like Karl often take a car until the park and ride station, which is often free.

Mobility Behavior, Travel Pa

Speaker 1 (26:02):

So you would say in that way in terms of equity, accessibility is not a huge problem to them because they rely on car.

Speaker 2 (26:11):

Yes. I think for now it's like a 50/50 thing. People are fed up to be in a traffic jam in the Ring, so they come with the car from their small villages, they go in Ingolstadt, park the car, or in Freising, in Landshut like how Karl does it or how a lot of people do it and then they take the regional train and go inside the city. In Germany we are very privileged because we have the Deutschlandticket. It is I think one of the big revolutions of the public transport and ÖPNV Network. It's a great political move of the current coalition in my opinion. And it's, as we discussed also some days ago, very, very sad. And it's a big shame that it's gotten increased. It's sad because a lot of people rely on that and I believe that the Deutschlandticket ticket will make the use of the traffic network improve, because it's always a thing of habit, if people are used to use the traffic network, then they will use it and teach it to the children, say we do that, and if people are used to take the car then they get used to it. That has to be, you have to break that point to say, no, if we're doing 15 kilometers, we don't take the car, we use this.

Speaker 1 (27:58):

That makes sense. But then interestingly, so why do you think, for example, in the area of where our friend Karl lives, why do you think people are relying on their car: because of a lack of just general public transportation or because there is not enough services?

97 Speaker 2 (28:13):

98 I think both, but also because the car is a comfortable way. When we went with Danny to see Karl, we did groceries with the car, we went to Freising there, Michelle took us, then we went to the supermarket, we bought some things. You cannot do that with the public transport. You should have to take a bus from the train station to go to the supermarket. From the supermarket to take another bus with your groceries that are maybe heavy and then go to the bus station of your village and from there on walk. And if you count the time that you take to do that and you compare with the car, the ÖPNV is clearly the loser. It's clearly the loser. So if you just go home because you work in Munich and you live in Attenkirchen, so then of course people would do the park and ride. But I mean I took the bus in Attenkirchen, I took the bus and it was okay, it was okay, but it was not running every 20 or 10 minutes. There are not a lot of people in Attenkirchen, so it's not lucrative for the MVV or I don't know how it's called. I think if more people would take it, there would be more people, then they would of course increase it. It is the reason why we don't have a lot of night buses, it is because the city says that we don't use them and there is no one inside. But then people who really want to take it think that it's badly. It's like a vicious circle. Then people are more likely to take the taxi because people say no, we don't have that much night buses or night trains.

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99 Speaker 1 (30:02):

100 Yeah, of course.

101 Speaker 2 (30:05):

102 I think, if we want to change the behavior of the people, the city would have to do a move. To say, hey, now we have night trains. And even though there is no one inside, people would start to take it then when you say we put security if people feel unsafe and, you have to pay in advance to change the behavior of the people. But I don't think Munich would be the best spot to start it because people are very conservative in that place and it's difficult to implement this because politics wouldn't support it. It would probably work better in Berlin, or in Frankfurt and Colone. But I do not believe that Munich would be the most suitable city for such implementations.

Reflection on potential Impr

103 Speaker 1 (30:57):

104 That's interesting point. So because you talked about there are still some people who would use that kind of public transport even at night. So are there specific times in which the accessibility by public transport, by rail public transport especially seems more or less fair to some socioeconomic group of residents? And you can talk about also the entire area if you feel like it. This is by the way, the metropolitan

region of Munich. So yeah, I guess you can see, right?

105 Speaker 2 (31:32):

106 I think people who live outside of Munich, like in Dachau, Starnberg, Miesbach, Mühldorf who go in a nightclub and want to come home for example because it's difficult to say yes, I work until 2:00 AM because in Germany or in Munich, everything close so early. So you are more likely to come home late or after your work hours in Berlin than in Munich. I think for that Munich would be an exception regarding the behavior of public transport in Germany. So because people work less or not less, but not as long as in other places, the public transport is according to that behavior of the rhythm of work of the people. So I think it's more people who would go out at night or people who go very early. But the first metro I think is at four or 5-ish something and the last metro is at 1:30. So I would be glad that we have a metro at two or two 30 and then it stops and the first at four or five when you come out of the club, I think it stops too early. They have to do it at least until 2:30. And this would be a start to say we do it until 2:30, then people will take it until 2:30 and then we see people who take it at 2:30 and we continue. But I somehow feel that the politics of Munich, of the state of Bavaria don't want people to the city to be like that. They want a calm city, in which they go pray on Sundays, and stop working at 8pm, that no one works on Sundays. It is very much due to religion, it only exists in Munich or in Bavaria.

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107 Speaker 1 (33:44):

108 So you would say especially we are talking about nighttime issues mainly, right?

109 Speaker 2 (33:49):

110 For me. For me and also for a lot of young people who live in Munich.

Impact per Socio-Economic

111 Speaker 1 (33:56):

112 So young people. Yeah. Do you think there are other socioeconomic groups that have problems at other times of the day in that way that there are unfairly treated at other times of the day or not?

113 Speaker 2 (34:16):

114 What are you thinking about? Do you think I missed the point or..?

115 Speaker 1 (34:20):

116 No, no, no, no. I'm just digging.

117 Speaker 2 (34:22):

118 Yeah, I want to dig but I'm kind of in a dead-end

119 Speaker 1 (34:27):

120 No, but then it's fine. If you're in a dead-end, that means that there's no point to make.

121 Speaker 2 (34:31):

122 But do you have an example?

123 Speaker 1 (34:35):

124 I don't know. I don't know. I cannot guide you through this so I have to let you speak for your own, but it's okay, don't worry about it.

125 Speaker 2 (34:44):

Temporal Accessibility Cl

Impact per Socio-Econon

126 I think every time you're outside of the ring it's kind of a mess to come back that for sure that for sure. As soon as you go out of the train station, you take a bus to go outside the ring to come back. If you don't have luck that the bus is just here, you have to wait 15, 20 minutes.

127 Speaker 1 (35:03):

128 Yeah. So it's always like...

129 Speaker 2 (35:06):

Mobility Behavior, Travel Pa

130 So people don't go outside of the ring if they don't have to. I have my bike reparation outside of the ring, like 20 minutes walk from Danny's old place and it's kind of a shit to come back. I don't like to let my bike there. I want to go back by bike. And Munich is a very nice city because it's not that big. So you can do everything by bike. So if the transport network is shit, but it's a good day, you can everything by bike, which makes it very nice. I love that. You cannot pretend that of every city. You know in Munich, no one would steal your bike if you have a good locker, in Berlin it's different. And Berlin is also way bigger.

131 ---- Explanation Start

132 Speaker 1 (35:49):

133 Okay then that's good for this section. So I would thank you very much for your answers. In the last part I will show you some of my quantitative research results and I would ask you to reflect on it. I'll guide you also to some questions.

134 Okay. So how can I explain this? I developed a temporal accessibility indicator for the whole metropolitan region, so to kind of have some quality indicator to see how good or bad the temporal accessibility is over the entire day. So of course, not of course, but basically the darker the spot, the

better it is, the brighter the spot is. So if we go more towards the value, if the value is higher, it means that the temporal accessibility gets worse. But if the spot is dark, it means that it's good temporal accessibility basically, or better than the white spots. So before showing you the entire map, I can show you how Munich looks like. So as you can see, Munich is mainly full of dark spots or maybe darker spots. So it's not zoomed in right now, but this is like the whole region. You see a bunch of different colors. So this was for example, one of my first analysis to have a quantification, to see what kind of stations exist. So you see in the eastern part we have more brighter spots. That means they have very low temporal accessibility. They have more difficulty in reaching places over the entire day. What I did then was correlate this kind of variables with socioeconomic variables and what came out was that most people that have very good temporal accessibility, people that can reach places over a good time span of the day are middle to very high economical status households, mostly young, around 30 own no car and have a university degree.

That's the entire region actually, these are average values for the entire region, they are correlation coefficients. So all the different areas and zones have been all calculated and this is a linear regression analysis that has been conducted and this kind of profile of a resident came out of that linear regression analysis. I'll come back to this in a second.

Speaker 2 (39:00):

Yes, of course.

Speaker 1 (39:00):

I'll continue still showing you. I did another analysis clustering the stations in terms of their temporal accessibility. So as you can see, this is cluster number one and basically it includes almost all stations except the centers. So as you see, Munich is quite empty, Augsburg is empty Ingolstadt is empty, but all the rural areas are all blue dots. Second cluster. Etc..

Speaker 2 (39:24):

What blue dots is that? It's not well connected right ?

Speaker 1 (39:25):

Yeah, basically it's clusters. But I will explain to you the clusters in a second. They're all, I will show you all the clusters basically. Second cluster is for example Munich and Augsburg, but more some I would say outskirt stations still. So still not the city center. There's another cluster it seems from your own knowledge maybe you can also confirm that it's more probably Tram services, but especially not completely on the outskirts but not fully in the inner city.

And then comes another part, it's more closer stations. And last one is I would guess the core stations that we have in the city where all the big interchanges are. So as you can see, basically I have five different clusters of stations, kind of understand it as different categories of stations. I don't have names for them yet. I'll develop names. And what I did is to analyze, okay, what kind of people live in there?

144 So right now you see the number of clusters and basically to help you, I already ordered them by the order of this. So from basically outer to more inner one and maybe the male female one is not that important for now. But for example, this is the difference of clusters to the mean. So that means that for example, we are taking the average population in the entire area. We're assessing and see okay, how much over or undershoot of a percentage of population we have. So for example in the cluster two, so in the very rural cluster we see that we have way more Germans than the average and way less foreigners than the average in the cluster number 1, 3, 4, 5. We see that it goes a little bit up and down, but basically we see that there's way less Germans than the average population.

145 Speaker 2 (41:20):

146 Two is Munich?

147 Speaker 1 (41:22):

148 Two is the most outside one. This is cluster two.

149 Speaker 2 (41:26):

150 This is cluster one.

151 Speaker 1 (41:26):

152 Yeah, basically. But they're ordered basically from left to right is here from top to bottom.

153 Speaker 2 (41:35):

154 Okay. What you're saying is outside of Munich, or what this bar chart is saying, is that for number two, the ratio of Germans is higher outside of or like in the suburbs and in the metropolitan region than in Munich?

155 Speaker 1 (41:57):

156 Basically? Yeah, it's a difference to me. So basically how you can understand it is that Germans outside of the city center are way more privileged in terms of, no, they're not more privileged, but they have a better accessibility to that kind of stations and basically foreigners have a better accessibility to actually these more city center stations. Another thing you can observe. So basically it just means that if it's in positive, the difference to the mean, it's that these people

have a better accessibility to that kind of infrastructure or some kind of not privilege, but they have a better accessibility to that kind of type of station to the type of cluster. So that means that for example, they are foreigners are more likely to have good accessibility to cluster 3, 4, 5, which are more like 3, 4, 5, the inner city clusters. To give you another example, we also have the ages. So here again, they're sorted from more outskirts station to more inner city station. And for example, the two blue bars are residents between 20 and 40-year-old. And as you can see there are way less people between 20 and 40 on the outskirts stations and way more people that have access to the very inner city stations. And we see the exact opposite trend for elderly people actually, especially here, residents 70, 80. So old people are more likely basically if you want to make a profile, there's more old people living on the outskirts, especially the rural areas and more Germans living in the rural areas and in the inner city would have for example, more foreigner and more young people and less older people and less Germans in that way that live in proximity to these kind of stations. Because still remember that this what it depicts are stations with high temporal accessibility. It's not spatially meant but more temporally so that they have a very high number over the entire day of places that you can access. And if you go more outside they have way worse temporal accessibility. So I don't know if I made that clear to a little bit of a lot of results, but I was wondering, yeah. So can you describe whether those results are surprising or they come as expected to you? For example?

157 --- End of results description

158 Speaker 2 (44:27):

Approval

159 They come as expected. I did, no. The only one that doesn't come as we expected is the one of the when you can come back down. No, the other, yes, this one. This one between 10 and 20 who live under the second. It is very high. This one is surprising. The other one that young people are in the city and old people outside the city. Of course it makes sense of course because there is more working opportunities inside the city and people who are older wants to live a bit outside to be more calm. And when they have their retirement, maybe they want to have their house next to their family from before. And I think that it depicts this very well.

Socio-Economic/-D

Critical Reflection

Approval

Socio-Economic/-D

160 Speaker 1 (45:26):

161 So interesting points. So if you are able to identify your own socioeconomic group in this also talking about this year, so you can validate those results from your own perspective?

162 Speaker 2 (45:45):

163 What you mean? What do you mean?

164 Speaker 1 (45:47):

165 If you agree with the results. If you can identify your own..?

166 Speaker 2 (45:52):

Approval

167 Yeah. Of course. I don't know why there is a woman with a stick and "young around 30" next.

168 Speaker 1 (45:58):

169 I know it's just a pictogram I'm sorry.

170 Speaker 2 (46:01):

Mobility Behavior, Travel Pa

171 No car, because today people also think it's useless to have a car. They can do leasing or I don't know, car sharing, which is way cheaper. And I think this kind of model or car sharing is a big step for mobility in the city and it's helping also people to use more. I mean the behavior of the young people will contribute a lot to the improvement of the public transport. In the world. The world. In the world. It's not the politics, it's not the amount of money, it's the behavior of the people. It's the behavior of the people.

172 Speaker 1 (46:50):

173 That's a good point,...

174 Speaker 2 (46:52):

175 And I think it's in our favor or in yours especially.

176 Speaker 1 (46:57):

177 Yeah, probably. So do you think looking at, for example, these results of that, for example, typical profile of a residence with very high temporal accessibility, are there a group of individuals that are potentially disadvantaged or advantaged in terms of temporal accessibility? So of course advantage, you see it in front of your eyes, but actually about, for example, potentially disadvantaged group of residents in terms of temporal accessibility. What do you think they are for example, from those results?

178 Speaker 2 (47:35):

179 I think you mean to say if they are not...

180 Speaker 1 (47:40):

181 If they have bad temporal accessibility basically.

182 Speaker 2 (48:09):

Fairness and Equity Perc

Impact per Socio-Econon

183 I think it's people with part-time jobs, for example, people who, because they have a part-time jobs or I don't know, don't really have a university degree. It's like people...

Fairness and Equity Perc
Impact per Socio-Econon

because in Germany you can have different jobs. You can bundle two part-time jobs. So it's also people with not very high economical statuses. It can be children because they end up earlier with school and then they have to take the bus, which was the case in Pasing for me, I saw a lot of children. So it's more that.

184 Speaker 1 (48:47):

185 So reflecting on what you just said, this is actually the very last question. How equitable would you judge the overall situation in terms of temporal accessibility by rail, public transport? Do you think that the fact that this profile of a residence that you see now in front of your eyes, do you think that this is fair that this kind of profile of a residence has the highest temporal accessibility to a public or viral public transport?

186 Speaker 2 (49:17):

Fairness and Equity Percept
Temporal Accessibility Cl
Fairness and Equity Perc
Temporal Accessibility
Critical Reflection
Fairness and Equity Pe
Critical Reflection
Fairness and Equity Perc

187 Of course it's unfair. Of course it's unfair. But there are so many things who are unfair. I couldn't tell you how to improve it. I couldn't tell you. I think that in Munich you see it at a line's last station or at places who close to these last stations, because it has to be badly connected to say that it's not equitable. Yes. And it's the same in Frankfurt, in Höchst or in Unterliederbach. It's a bad place, you, am Kapellenberg for example. Also, and I don't know, if I were a private person who has to invest, I would never invest in that of course because I know there would be no money to bring up that. You have to. Yeah, I understand the point. I think the solution for that would be to invest more and more public money from the taxes. But I don't know if someone privately would want to invest that in order to improve the equity. So of course there are, how do you say, obviously this is an unfair situation. You cannot deny that.

188 Speaker 1 (50:50):

189 Then. Thank you very much. Is there anything else you would like to add?

190 Speaker 2 (50:56):

Fairness and Equity Perc
Critical Reflection

191 If you have a solution to that, please share it with me. I would love to share the points of view of the professors you work with, of the people who study that and in order to wanting to improve it. I think it's a very interesting topic and unfortunately the economic of the world are very, people want to do money, they don't want to help people. I think the only way to help the people is with public money or with ONGs or with other things. And I don't know how much disadvantage the people are. Is it like they take half an hour more a day to come to work? Or is it like I couldn't take this job because I could not reach it because I live where I live. You have to scale that to see how disadvantaged you are.

Taking 20 minutes more to go to work is a comfort problem I think. Okay. I would hate it if I would have to do it. I would be the first person to complain about that. And because I have the money, I can afford to live in the center. But I think the real very important and difficult issue would be if people are disadvantaged in the society about, people judge them because they live in this place. Or if they cannot get a job because it's so far away. This would be the major issue in my opinion. Because then you cannot live if you don't gain money or you have to move to another place moving out of a place, it's, it's a mess. But yes.

Speaker 1 (52:59):

Thank you very much. That's great insights.

A.3.3 Interview 2 (I2)

1 Speaker 1 (00:02):

2 Okay. So my first question would be to just ask you to describe your mobility and travel behavior. So when you use public transportation, especially rail public transportation, but also in general, so you can for example, include what your average travel times or your frequency of use of public transport, and in general also your ease of reach.

3 Speaker 2 (00:29):

4 Okay. So I use the U-Bahn mostly, subway mostly. And I use public transport every day, I would say. So I use it to get to work and back. So during the week, usually twice at least. And for me, it's pretty well accessible. So I have maybe a 10 minute walk to the next U-Bahn stop and then I use it, I think it takes me 20 minutes to get to work and then 20 minutes back. But yeah, I use it for everything. So mostly subway and the tram. Yeah, and mostly I would say, I think for me, everything is pretty well accessible just because I'm close to the U-Bahn and close to the tram as well.

Mobility Behavior, Travel Pa

5 Speaker 1 (01:23):

6 What is your overall general experience with public transport then in the city and the area?

7 Speaker 2 (01:31):

8 Yeah, it's generally pretty good, I would say. I think again, because I'm not using the S-Bahn, the experience would be a lot worse if I were to use it. But for the U-Bahn mostly it works fine. Sometimes there's some accident or some, how to say, emergency situations?

Mobility Behavior, Travel

Temporal Accessibility Ne

9 Speaker 3 (01:55):

10 Yeah, I know what you mean.

11 Speaker 2 (01:57):

12 And then the trains are not going, or they're delayed or something. And then it's a bit difficult because I think I am pretty dependent on the U-Bahn. If that doesn't work, then there's not super many alternatives, but mostly it's positive.

Temporal Accessibility Chal

Temporal Accessibility Ne

13 Speaker 1 (02:14):

14 And so do you experience or notice challenges at specific times of the day?

15 Speaker 2 (02:21):

16 Yes, at night for sure. It's very challenging. Again, I think I'm pretty lucky. I live by, the tram that I live close to is a night tram, so it goes through the night. But once you reach a certain hour, I think it only goes every 45 minutes or every hour maybe. I'm not super sure. And then the U-Bahn

Temporal Accessibility Ne

Temporal Accessibility Cl

Temporal Accessibility Chal

obviously also stops at some point. So that's starting at, I don't know, 1:30-2:00 AM maybe, It's very limited and especially if you're somewhere where the tram isn't close to, then it's very, so in the city center it's usually fine, but if you're somewhere that's not the center and you're not close to the tram, then it's very challenging.

Speaker 1 (03:14):

I see.

Speaker 2 (03:15):

Yeah.

Speaker 1 (03:16):

So built on that, do you experience changes in accessibility or ease of reach of different types of opportunities? So for example, basic amenities or workplaces or recreational areas in the rail public transport at different times of the day. And if so, if you can describe the changes.

Speaker 2 (03:41):

Like amenities? Do you mean shop?

Speaker 1 (03:44):

For example? Yeah, exactly. Shopping can be very basic amenities or post offices or I don't know, bank or for example, these kind of things or...

Speaker 2 (03:54):

Temporal Accessibility, A
Temporal Accessibility Ne

Yeah, I mean I guess it all closes at some point, but otherwise, yeah, no, I think just based on the opening times.

Speaker 1 (04:06):

Based on opening times. Okay.

Speaker 2 (04:07):

Temporal Accessibility, Acc

Yeah, not so much otherwise.

Speaker 1 (04:10):

Okay, so, do you think that other people might be impacted by these temporal changes of rail public transport, for example?

Speaker 2 (04:33):

Temporal Accessibility Need
Temporal Accessibility Cl

Probably. I mean, I think especially for, because I still live in the central Munich transport system, so I think for me it's a bit annoying when things come irregularly, but I can always get home. But I think as soon as you live outside of that

Temporal Accessibility Chal

network, so if you, for example, need the S-Bahn, then I think it would be probably very difficult to get home or you'd need a taxi or something. So that I could imagine people are pretty impacted. I'm trying to think if there's any other way. Well, I guess also maybe at the rush hours it gets pretty full, or if there's big events, it gets super full that might impact people also, I guess. I find it's always, especially from if you're at Olympia Park and there's an event, then it's always like the subways come so... well even then they come at 10 minute intervals where you're like, well, maybe it would make sense that if there's a huge concert, that they come every few minutes maybe. Yeah.

Temporal Accessibility Chal

37 Speaker 1 (05:46):

38 Oh, that's interesting. So impact of temporal accessibility by crowdedness of the trains actually. Well, do you think that, for example, variation of accessibility over an entire day affect different group of individuals in different ways?

39 Speaker 2 (06:08):

Impact per Socio-Economic,

Impact per Socio-Econon

40 That's a good question. I don't know actually. I mean, I guess maybe for older people maybe it's more difficult when everything's very full and everyone's stressed again at the rush hour times. But at night, I guess, yeah, I mean it just mainly probably would affect people who are interested in going out at night. So probably the younger age range. Yeah. I'm trying to remember now how much of the public transport is in English, but I guess that's not temporal then.

41 Speaker 1 (06:59):

42 Yeah, that's not temporal, but that's true. It's also some kind of accessibility issue in its own way. That's very true.

43 Speaker 2 (07:05):

Impact per Socio-Economic,

44 But I guess probably the most temporally, I guess the most affected probably would be younger people who are out.

45 Speaker 1 (07:13):

46 People that are out. Yeah, would've been my follow up question, but I guess you answered that also.

47 Speaker 1 (07:19):

48 Yeah. But that's great. So apart from younger people, okay, these are the main people. Okay. Okay. Well, I'm going to ask a question which might be a bit difficult to answer, because it's quite broad, but for you, what does equity in temporal accessibility by public transport mean to you?

49 Speaker 2 (07:46):

Fairness and Equity Percept

50 I mean, I guess it would mean that anybody can access the

Fairness and Equity Percept
Impact per Socio-Economic
Fairness and Equity Perc
Temporal Accessibility Chal

transport they need and that they feel safe with. I guess I'm also just now thinking, I didn't say that before, but maybe also if you can't get home at night, maybe it's a bit more of a problem for women compared to men. It could also be a thing, I know now they have vouchers for taxis for women in case you can't get home. I mean, I think in general it would also just mean that kind of regardless of your location within whatever region you're in, you can get there. So not that someone who lives two or three S-Bahn stops outside of Munich can't get there anymore. So maybe that too, because I find it's, as soon as you leave the subway/tram network, I think it suddenly gets pretty difficult even though you're not that much further outside.

51 Speaker 1 (08:52):

52 So yeah, we're still talking a lot about night, and makes sense. Yeah, but it's a fair point. Well, I'm going to follow up on that, but maybe it might already answer a few other questions, so don't worry about it. Yeah. So do you think everyone has an equitable access to public transport during an entire time span of 24 hours?

53 Speaker 2 (09:27):

Fairness and Equity Perc
Temporal Accessibility Cl

54 I mean, probably not. I would guess. I mean, I think there's areas that are better connected than others. Maybe also where the transport goes more regularly than others. So I know for me, for example, on the weekends the U-Bahn only goes every 10 minutes and during the week it's every five I think. So I guess there's places maybe where the frequency is lower at certain times, especially if you are S-Bahn dependent, I guess maybe it's every 20 minutes in some places. So I would guess in general, the more central you are, the better access you have all the time. I don't know.

55 Speaker 1 (10:09):

56 And in your opinion, what kind of individuals like individual group would be more or less affected than by these kind of would be potentially disadvantaged for example, by such kind of lower frequency of service?

57 Speaker 2 (10:30):

Perception on (Under-)Pr
Impact per Socio-Econon

58 I mean, I would assume it's based on no knowledge, but I would assume it's probably more generally people who also maybe have a lower income and therefore can't afford to live in central Munich and maybe live a bit outside. I don't know, maybe it's also more families. I don't know if families maybe tend to move out also outside of the center of Munich and then have a harder time coming in. Yeah.

59 Speaker 1 (11:03):

60 Yeah. But I think, yeah, thank you for your answers. So in

general, maybe it's going to sound a little bit repetitive, but how fair do you think the access to temporal accessibility two by rail public transport is in or outside of Munich? Also, you can also expand on the whole metropolitan region, for example. You can also compare peak off peak times, early mornings, late evenings for example. I don't know, what is your fairness impression of it?

61 Speaker 2 (11:42):

62 I mean I think it's pretty good. I think it's pretty fair. I mean I can really only speak from my perspective. I mean I'm sure groups that would answer differently, but I think at least for me, the public transport that I need comes frequently enough. I mean obviously there's things you could improve, but I think it's a pretty comprehensive network of public transport. I mean at least compared to more rural areas, I think, I mean I don't know for sure within the greater region, but I know where I'm from Baden Württemberg, the more rural areas, the transport is much, much worse. There's only an S-Bahn that goes every hour or something. So compared to that, I think it's pretty fair. Obviously it would be nice if there was more transport during the night to get people to places. And it would be nice if when there's big events, the trams go or whatever the modes, transportation goes more frequently. But for me, I think it's pretty, I think everyone can access it when they need to. It's also price wise. Okay. I mean it could be cheaper, but yeah, I think it's pretty fair. I would say I think everyone gets where they need to go.

Fairness and Equity Perc
Temporal Accessibility N
Fairness and Equity Percept
Fairness and Equity Perc
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Temporal Accessibility N

63 Speaker 1 (13:13):

64 Okay, thank you very much. So you also expanded a bit about rural areas. I guess the area you live in is maybe not metropolitan you used to live in is not the metropolitan region, but probably very similar characteristics. So why do you think people there are relying more on their cars? You think it's more lack of spatial or temporal accessibility?

65 Speaker 2 (13:35):

66 Good question. I feel like depending, it could be both, but I would feel at least from my experience of living in a more rural area, I would be more temporal I think because, so I think a lot of small villages or places do have at least one train stop in them or they have bus stops, but they come so infrequently that there's really no point waiting for it. If there is a bus stop, it doesn't really matter if there is one or not. If the bus comes once an hour, then you're not going to plan your day around that kind of. So I would assume more temporal. But yeah, haven't lived, I haven't experienced it myself yet, but yeah.

Mobility Behavior, Travel
Temporal Accessibility Cl

67 Speaker 1 (14:24):

68 And from your perception, who or which group of individuals

would be potentially disadvantaged in more rural areas from this lack of temporal accessibility then?

69 Speaker 2 (14:36):

Impact per Socio-Economic,

70 I mean, I guess anyone who doesn't have a car who can't afford a car or doesn't know how to drive a car, I guess that would be mainly younger people who maybe don't have a driver's license yet, but also maybe older people who can't drive anymore, or people with disabilities who don't drive just in principle. Yeah.

71 Speaker 1 (15:06):

72 Thank you. And do you think there are specific times of the day in which the accessibility to or by public transport, rail public transport seems more or less fair in general?

73 Speaker 2 (15:21):

Fairness and Equity Percept

74 Yeah, I mean I guess I think I'm just always repeating the same point. I don't know if there's other ones that I'm not thinking about. No, just nighttime versus daytime, I think.

75 Speaker 1 (15:29):

76 Nighttime, Daytime, yeah. Okay. So in the last step, actually, I'm going to show you some of my quantitative results. Perfect. I'm going to explain to you a little bit this map. So this is the metropolitan region, right? You can also quite obviously see that this is Munich here in the middle.

77 (16:03):

78 And what it means, these are all rail public transport stations and basically the darker the spot... So this is a temporal accessibility indicator I developed and the darker just spot the better actually the temporal accessibility is, so the brighter the spot, the worse it gets. It's basically just the indicator value that gets higher. It means that the temporal accessibility is worse. And so this is for the metropolitan region. I can also show you how it looks for Munich. So as you already said, it's all quite dark spots. It also means that they have quite high temporal accessibility of the entire day also at nighttime. And I think these are points already raised. Maybe on the outskirts it gets a little bit less, but for example, in the metropolitan region looks like this. So for example, in the eastern part, quite brighter spots for some reason.

79 (17:00):

80 I don't know, I will ask maybe if you have also an opinion on that in a second. But yeah, and obviously like Munich and also other centers like Ingolstadt, Augsburg or things like that also stay quite dark. And so what I basically did based on that, I correlated this indicator with social economic or social demographic variables based on a study in Germany.

And what came out was a certain profile of a resident did the linear regression analysis. And this is a profile of a resident with very high temporal accessibility. So has middle to very high economical status is mostly young around 30, so not young, under 20, but yeah, around 30 has no car and has usually a university degree.

81 (17:55):

82 I will show this to you again in a second. Also, show another example. There's a second analysis I conducted. What I did was basically to cluster stations based on their temporal accessibility. So a separate, it's a separated analysis I did. And basically I found out five clusters. The first one is this blue point cluster you can see here. And it concerns mainly rural areas. As you can see, most stations on Munich are not included, same as inner city Augsburg stations are not included. It's mostly all rural or even S-Bahn areas as you can see here on the sides. And basically this cluster breaks it down spatially also can be interpreted maybe quite easily. So as you can see now, second cluster or stations that are in closer suburbs of Munich, for example, also some stations in Augsburg. Then comes another cluster, which might be probably some more tram stations or..., even closer to the city center. And actually it goes on this, we're getting even closer. This is and the highest level of temporal accessibility stations that we all know about, like the hubs in Munich.

83 (19:09):

84 Various scattered stations. So we have kind of this breaking down of stations. And so what I did is to assess, so I counted the population in there. So this is sorted now from most rural to most centered place. It's actually not meant to be spatially, but there are spatial patterns also behind for logical reasons. And this is actually the difference of population of clusters to the mean in the whole area. So as you can see, for example, in the rural area, the center is much higher for Germans than it is for foreigners. But for example, it goes much in the highest cluster. So the most city center one, the one also with the best temporal accessibility, there's a lot more foreigners living there. For example, this is for example, for German to foreigner. I also have one for male female. So for male female, one might look quite surprising results. But actually for all the clusters, the male ones have more lower ones, but actually only for the, I would say highest temporal activity cluster, the male female one is quite more distinct. And another result I can also show you is actually the ages. So again, we're going from cluster 2, 1, 3, 4, 5, but it's ordered like this. But it's again from lows temporal to highest temporal accessibility. And we can see that age groups from 20 to 40 have the worst technically in the most rural ones and best in the most centered places. And we see the other trend for elderly people actually opposite trend basically more elderly people actually having access to those more rural stations, more surprisingly might be these 10 to 20 results. But yeah. So I would like to ask in general, if these

results that I've shown you are surprising or come as expected to you or maybe not. And also based on this for example.

85 Speaker 2 (21:36):

86 No, I wouldn't say that's super surprising because I think that's the profile of people who live in the city center. So probably employed yet educated, pretty well wealthy, but making enough money to live in the city center. And I guess, yeah, it makes sense that you wouldn't have a car if you live right in the center. Yeah, no. So I think that makes a lot of sense. Yeah, the male female I find surprising. That's a bit interesting. Yeah.

Approval

Critical Reflection

87 Speaker 1 (22:16):

88 And so if you are also able to identify your own socioeconomic group in that from your own perspective, would you validate those results?

89 Speaker 2 (22:24):

90 Yeah, I would say so. I mean, I think, I don't know what my socioeconomic level is compared to Munich specifically, but I would guess it's pretty middle. So yeah, I think I fit that profile also.

Approval

91 Speaker 1 (22:45):

92 So if you now look at these results, for example, are there group of individuals in your opinion that are potentially disadvantaged in terms of temporal accessibility?

93 Speaker 2 (22:58):

94 Yeah, I mean I guess because you showed that one graph that showed older people having less access in the super central places. Yeah, I think that's interesting. I didn't think their accessibility fluctuated with time. I would've thought it's more accessibility related to maybe you can't go down the stairs or more with physical accessibility rather than temporal. So that would be interesting if you find out why that is.

Perception on (Under-)Privi

95 Speaker 1 (23:34):

96 It could be probably linked, I mean, it's not disclosed, right.

97 Speaker 2 (23:40):

98 Yeah. So I guess older people probably also and people with a lower socioeconomic status who live further outside. And I guess like you said, also, maybe there's also language barriers, especially in rural areas, I guess there's no English translation happening there, but I guess there's also not many people, not as many international people living in the

Impact per Socio-Econon

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rural areas.

99 Speaker 1 (24:13):

100 Yeah. Thank you very much for that insight. So in general, if you see all these results, it's kind of maybe a tough question for the end, but I don't know how equitable would you judge the overall situation in terms of temporal accessibility by RPT?

101 Speaker 2 (24:32):

Fairness and Equity Percept

102 Yeah, I think again, at least in the Munich City Center, pretty good. And then I guess you showed on, I think the first map. I guess the further outside you go, the worse it gets or the more rural you go, the worse it gets. And I guess that's true probably during the day, but I guess even more so at night. I guess if you're living rurally, I imagine there aren't that many public transport ways to get around. Yeah.

103 Speaker 1 (25:03):

104 Okay. Thank you very much. Is there anything else you would potentially like to add?

105 Speaker 2 (25:11):

106 No, I don't think so.

107 Speaker 1 (25:13):

108 Perfect, then thank you very much.

A.3.4 Interview 3 (I3)

Speaker 1 (0:02 - 0:27)
I would like to start with the first question. Could you describe your general mobility and travel behavior? For example, how long you... especially in the ÖPNV (Public Transportation), if you use the ÖPNV, what are your general driving times, how often you use the ÖPNV, how easy it is to reach places, for example.

Speaker 2 (0:28 - 1:54)
Well, I have been living in Wolfrathausen for a year. That is about 25 to 30 kilometers south of Munich. And there is only one possibility to get to the city center, that is the S7. And I don't live directly at the train station, but about three and a half kilometers away. So that's really just houses. But we are also very well connected by bus. We even have a city bus. But in summer I take the bike from my home to the Wolfrathausen train station. And then I get on the S-Bahn, which, if you're lucky, runs every 20 minutes. Then I go to the main train station and then I take the bus, the 100 or the 58, and then I'm at the TUM (Technical University of Munich). In the best case, that takes about a quarter to an hour and a half from the front door to the desk. But there are also often delays, construction work, train failures, and so on. And in winter I don't take the bike, but I take the car to the train station and park there. So park and ride.

Mobility Behavior, Travel Pa

Speaker 1 (1:55 - 2:10)
Yes, that seems to be the case in Bavaria. I've heard a lot of park and ride. How would you rate your general experience with the ÖPNV?

Speaker 2 (2:13 - 2:58)
An incredible amount of time and a lot of precious time and quality of life that I lose. And because it's on the S-Bahn, I can't work at all. I used to live in Starnberg until last year, and then I had the opportunity to take the S-Bahn or to take the Regio. So if one source failed, I could take the other. And in the Regional train (Regio) you can work well because there are tables and there are a lot of commuters. And it's quiet there. There are also rest areas. And now in the S-Bahn there are all the students and it's just very loud. And I can't use the time to work.

Temporal Accessibility Cl

Temporal Accessibility N

Impact per Socio-Economic

Speaker 1 (2:59 - 3:07)
So we're talking about reliability problems here. Reliability problems, right.

Temporal Accessibility Chal

Speaker 2 (3:07 - 3:08)
Yes.

Speaker 1 (3:08 - 3:25)
Okay, I understand. In general, are there times of the day where you find it particularly difficult to use the ÖPNV?

Speaker 2 (3:28 - 4:18)
Temporal Accessibility Ne

Temporal Accessibility Cl

Yes, so the rush hour in the morning is between 7 and 8 o'clock when a lot of people just drive into the city and all the students are on their way. And on the way back in the afternoon it's good, but in the evening it's difficult again. Sometimes if you want to go home very late now, then the frequency is only every 40 minutes. And there are also train failures. And the S7 is very vulnerable. And what is also interesting is that from the timetable change in December it no longer runs on the main line, but goes to the main station and ends there. And the Hackerbrücke stop also disappears. So that's completely new now.

Speaker 1 (4:18 - 4:23)
So not so bad for you, but probably a big problem for many commuters.

Speaker 2 (4:23 - 5:15)
Temporal Accessibility Chal

Temporal Accessibility Cl

Mobility Behavior, Travel Pa

Yes, who then have to continue, because the main station is enough for me. But many who then have to continue, they have to change trains and that's another expensive time loss. And what is also the case with us, this S7 is sometimes in several places, in two or three places, it is one-way. And then you always have to wait until the opposite passes. And I really only take all of it into account because I really like to work at the TUM, because it's a super interesting workplace and because I like to do two days a week at home. If I had to drive for five days, I wouldn't want to drive by car, because I have a 49 euro ticket. Why should I drive by car then? That's just a matter of cost and it's actually not sustainable. So I enjoy my two days of home office and drive to the office three days a week.

Speaker 1 (5:16 - 6:05)
Yes, okay. Thank you very much for this insight. Is there then ... If we look at your own accessibility situation, for example, accessibility to completely basic shopping opportunities or workplace or everything that is a bit, how do you say, recreational, for excursion... Exactly, is

there any change in the availability to these infrastructures, let's say, over a day?

Speaker 2 (6:06 - 6:14)
So if I look at my own situation, so now here, in my neighborhood where I live?

Speaker 1 (6:14 - 6:26)
For example, exactly, what you have to achieve, how your availability, general availability situation changes over the whole day. Are there any changes that you have noticed or not?

Speaker 2 (6:27 - 7:05)
Actually, I'm usually travelling in the core time, so not after 10 p.m. I'm no longer using public transport at that time. And if that really happens, then I get into the private car. But otherwise I'm actually the whole core time equally well supplied with the public. And this study is about rails. So it's not a bus now, but it's about suburban trains, trains and trams. Is that right?

Mobility Behavior, Travel Pa

Temporal Accessibility N

Speaker 1 (7:05 - 7:24)
Exactly, mostly, yes. You can also talk about buses. I have noticed that you don't use them, and just go to the train station by bike or car. But if you have something to say about it, I'm happy to hear it. Any further information is always helpful.

Speaker 2 (7:24 - 8:01)
There are also buses that run here. There is a city bus, but it drives quite a detour. That doesn't make much sense to me. But there are also benches, where people sit and then you can gather and be taken with you. I haven't tried that personally yet, but there are such approaches. And we have a new project where David is also very important. It's called DREAMS. Have you heard of it yet?

Speaker 1 (8:01 - 8:02)
No, not yet.

Speaker 2 (8:03 - 8:43)
You have to look on the website or talk to David. It's in the Wolfrathshausen area, where I live. There is a model community and there was already the first meeting where the mobility officers from the city of Wolfrathshausen came to our office with Benjamin

Büttner. David was also there and a few other colleagues. I also took part in the meeting. There is also a workshop here in the city that is being held to promote the whole mobility story. A lot is being worked on.

Speaker 1 (8:44 - 9:44)
That's exciting. But it's nice to hear that there are also in corners that are further out of Munich. That means there are a lot of offers for everyone. Of course, the S7 if we take a look at the S7, for example, at what extent do these greater gaps in time impact your daily activities or your mobility needs?

Speaker 2 (9:46 - 9:47)
My needs?

Speaker 1 (9:47 - 9:48)
Yes, exactly.

Speaker 2 (9:51 - 10:34)
Temporal Accessibility N
Mobility Behavior, Travel
Well, yes, but I have my fixed working hours and I have my appointments at the TUM. And then I just have to be in at that time and can't somehow follow any other schedules. And then I just hope that everything works out. In this respect, I have my requirements or also my appointments. But mainly I travel with the public transport to get to work. So my private appointments are actually more here in the environment.

Speaker 1 (10:35 - 10:37)
I see. That's good to know.

Speaker 2 (10:37 - 10:39)
Mobility Behavior, Travel Pa
That's just for professional use.

Speaker 1 (10:40 - 10:46)
And that means, as I understood it correctly, you also plan around the clock. Exactly.

Speaker 2 (10:48 - 11:30)
Temporal Accessibility N
Temporal Accessibility Cl
Temporal Accessibility Chal
But it's also difficult for me to answer within a day, how it shifts in the day. I actually haven't experienced issues up to now. Except if you come somewhere at three o'clock at night, which is not the case with me now. But in this respect, it is actually distributed regularly. For example, my son has been working and traveling for a long time and he has a job at the airport now. And it might happen that he has to start at five o'clock. And that is of course

Temporal Accessibility Chal

a problem because it is outside the main service hours. But that's the case everywhere, that you just can't get travel with public transport at these hours.

Speaker 1 (11:32 - 11:52)
That would have been my next question. Do you think that this change over a 24-hour time span also affects other groups of residents or individuals?

Speaker 2 (11:55 - 12:16)
Yes, there are people who don't work in core hours from eight to five o'clock, but have shifts, have to start very early or very late. And they do have a problem. You can't expect them to drive a car or organize themselves in a different way.

Impact per Socio-Economic

Speaker 1 (12:17 - 12:18)
Exactly, yes.

Speaker 2 (12:18 - 12:22)
If it's outside the core hours. In any case.

Impact per Socio-Economic

Speaker 1 (12:23 - 12:56)
So we talk a lot about employees. That would be based on... which people, especially if we look at the socio-economic or socio-demographic characteristics, whether it's age or the economic status of the household or the professional background, which groups of people would it affect the most? In your opinion. There is no right or wrong.

Speaker 2 (12:57 - 13:19)
Yes. People who actually can't switch to alternative methods like private car use or have co-driving opportunities are already disadvantaged. I think so, yes. Or someone who doesn't have a driver's license and people like that.

Perception on (Under-)Pr
Impact per Socio-Econon

Speaker 1 (13:19 - 13:37)
Exactly, yes. And if you look at age groups or economic status of households or professional or educational backgrounds, how would you define these groups of people? In your opinion.

Speaker 2 (13:40 - 13:46)
Yes. People who simply don't have the budget to afford a car.

Perception on (Under-)Pr
Impact per Socio-Econon

69 Speaker 1 (13:47 - 13:48)
70 Yes, yes.

71 Speaker 2 (13:48 - 14:05)
Impact per Socio-Econon
Perception on (Under-)Pr
72 They are already disadvantaged. Because that's the way it is here in the country. Although, yes, disadvantaged. In this respect, I actually think it's quite nice that we have greenery around and I also take it into account. And I don't feel disadvantaged by it.

73 Speaker 1 (14:07 - 14:07)
74 Yes, yes.

75 Speaker 2 (14:08 - 14:50)
Perception on (Under-)Privi
Socio-Economic/-Demogi
Perception on (Under-)Pr
76 And it's difficult for me now with groups of people. But if you live here, then you've actually already made the choice. Okay, I commute and I'm still outside. And that's more our area. These are just families. The father works in Munich and the rest is somehow here too. And the children go to school here. And that's already a choice they've made. And when the children study and then go abroad or somewhere else, they don't stay here.

77 Speaker 1 (14:52 - 15:05)
78 Yes, okay. That's interesting. That would have been my next question. How would you describe the environment, so demographically or economically speaking?

79 Speaker 2 (15:06 - 15:22)
Mobility Behavior, Travel
Socio-Economic/-Demogi
80 Many people also work here. They don't have to take public transport. The people who live here and who are now socially disadvantaged, they work here. They find a job here.

81 Speaker 2 (15:22 - 15:35)
Socio-Economic/-Demograp
82 And it's just mostly not high-quality jobs. Because the interesting companies are in Munich, I guess I can say so.

83 Speaker 1 (15:37 - 15:39)
84 Thank you very much for this answer.

85 Speaker 2 (15:39 - 15:41)
86 Yes. I hope I can help you.

87 Speaker 1 (15:42 - 16:29)
88 No, absolutely. Sometimes I may not react so strongly to your responses. But that's because I just take notes of

them. As I said, there is no right or wrong. It's just about your own opinion and your own view. I think every further input I get anyway is super exciting. And it always deviates a bit from what you expect yourself. And I always find that so interesting. Sorry, I don't want to waste too much time. Exactly. Now comes a question that can be a bit tricky. Don't worry. It's basically a question of definition. What does fairness or social justice mean to you in terms of temporal accessibility of rail-bound ÖPNV? Could you define it for yourself?

89 Speaker 2 (16:29 - 17:01)

Fairness and Equity Percept

90 Yes, actually for all age groups and people an access that well, it doesn't have to be the S-Bahn in front of the door, but a tolerable distance, we're also talking about the 15-minute city, in which the maximum you can expect is to reach the station within 15 minutes from the place of residence.

91 Speaker 1 (17:01 - 17:58)

92 Yes, okay. Thank you very much. Yes, exactly. How fair would it be, according to this definition, this temporal accessibility? So how this accessibility changes throughout the day. How fair would you rate it in and outside of Munich? For example, you can compare different times of day whether it's main time of day, side time, low time of day, night time, I don't know. So the question would be how fair you would rate it, and you can also look at my scope, which is actually the whole metropolitan region of Munich. I don't know if you know exactly this demarcation. I can show it to you. But exactly. It's pretty big, but a lot of rural, a lot of urban.

93 Speaker 2 (18:00 - 18:57)

Fairness and Equity Perc

Perception on (Under-)Pr

Fairness and Equity Pe

Impact per Socio-Ecor

94 I have a hard time with the term fair. Because Munich is best supplied with tram, bus and the intervals or distances of the stops are sometimes only a few hundred meters. For us it's two kilometers from one to the other. But what does fair mean? I have made the choice that I don't want to live in the city and take it for granted. And that's why I have a hard time with the term fair. Because that would be unfair. And it's not. Because it's a choice I made. And if I wanted, I could move to Munich. But there are a lot of people who may not have the choice to choose where they can live. And then for those people fair and unfair is more important.

95 Speaker 1 (18:58 - 19:14)
96 And if we look at these people who may not have the choice, like us, to move to Munich, how fair would you judge it at different times of the day?

97 Speaker 2 (19:17 - 19:18)
98 In Munich?

99 Speaker 1 (19:19 - 19:23)
100 Yes, in and around Munich, for example. For people who may have less flexibility.

101 Speaker 2 (19:24 - 20:01)
Fairness and Equity Percept
102 I think it's okay. But there are so many possibilities. There are night buses. There are many possibilities. And of course the 49 euro ticket is a great It's going to be expensive. I think it's going to be 56 from January. But it's a great achievement. And here you can talk about fair and unfair. Because it allows many, many people to be more mobile and to make bigger trips with the same budget. So that's a very important aspect.

103 Speaker 1 (20:02 - 20:31)
104 Definitely. Super interesting. Thank you very much for the answer. I mean, if we're still talking about fairness, is there still, if you look at different times of the day, are there certain times of the day where, for example, in which the accessibility to the ÖPNV of certain groups of people could be more or less fair?

105 Speaker 2 (20:33 - 21:19)
Fairness and Equity Perc
Impact per Socio-Econon
106 So I think at rush hours, it’s unfair for people with a disability or with a wheelchair. Because there's a lot going on. And because they’re being pushed and pushed. And that's where it's difficult. Because they may also have to go to work and be on time. And that's where it's difficult. I had an example a few weeks ago with the S7 on the way back. In the middle of it everyone had to get off and go to the other track. And there were a lot of stairs and steps. And there I really saw an older woman with crutches. And that was really a stress for the woman. And that's unfair.

107 Speaker 1 (21:19 - 21:19)
108 Yes.

109 Speaker 2 (21:23 - 21:52)
Impact per Socio-Econon
110 Or also people with small children who then go by public

Impact per Socio-Ecor
Fairness and Equity Pe
Reflection on potentia

transport during rush hours. That's not always fun either. Yes. The buses are also small. It would be great to have more space for the commuters. That maybe during the rush hour, a longer tram or a bigger bus or more wagons are attached to the train, for example.

Speaker 1 (21:53 - 21:55)
Yes. Definitely.

Speaker 2 (21:56 - 22:43)
Impact per Socio-Econon
Fairness and Equity Perc

And many are also afraid of physical contact. Covid is over. But now that the winter comes, many people wear masks again in public transport. And many are afraid of contact and want to stay in a corner, and don't want to be in the crowd. And if there are such people or ... If I think about it, the list is getting longer. People who now have an immune weakness or are sick, they are really disadvantaged. And that's where it's unfair. In the rush hours I think that they are then disadvantaged.

Speaker 1 (22:45 - 23:15)
Yes, that's very interesting, I think. It's funny because almost all interviewees so far also mentioned the rush hours. And I actually didn't expect that. But it's also a temporary barrier to accessibility. Although you think you can reach the most at these times. I'll show you in a moment. At least that's the way it is quantitatively. Logically, you can theoretically reach the most during rush hours, because most trains run everywhere.

Speaker 2 (23:16 - 23:19)
But there's a lot going on.

Speaker 1 (23:19 - 23:59)
Yes, there's a lot going on. And not everyone can reach everything at any time. No, exactly. First of all, thank you for this first part. In the last part I will now share my screen. Let's see if that works. Can you see my screen right now?

Speaker 2 (23:59 - 23:59)
Yes.

Speaker 1 (24:04 - 25:12)
Where can I start? I'll briefly explain how I did the first part of my analysis. I basically did two different quantitative analyses. The first one is to create an index for temporal accessibility. Kind of an evaluation. To

create an index. The darker the point, the closer the value goes to zero, the higher the temporal accessibility over a 24-hour day. The brighter the point, the worse the temporal accessibility over 24 hours. As you can see here, Munich is very dark. As you said, around Mühldorf you can see brighter points. Temporal accessibility is worse. This is what Munich looks like when I zoom in.

Speaker 2 (25:14 - 25:22)
In the northwest, there are a lot of free spaces.

Speaker 1 (25:22 - 26:33)
Yes, there are a lot of free spaces. These are all SPNV, rail-bound stops. There's no bus in there, but the accessibility is also calculated with bus. I used SPNV as a starting point. Munich is very dark. There are a few brighter spots here, especially in the corners. This is the metropolitan region. Of course, the centers like Augsburg, Ingolstadt, Donauwörth are also dark. What I did in the next step I correlated it with socio-economic variables and made a linear model. The result was a profile of a person with particularly high accessibility. We're talking about middle- to very high-income people, mostly relatively young, around 30, who don't own a car and have a university degree. That's the profile.

Speaker 2 (26:33 - 26:36)
That's a special group.

Speaker 1 (26:36 - 28:55)
Yes, that's a special group. We'll come back to that in a moment. I did a second analysis. I categorized the stations after their reachability. There are cluster algorithms that will look at it and create categories. I got five categories. I'll show you the categories. This is category 1. I named it Rural, because it's in the rural area. Then there's category 2. It's mainly Augsburg and outside stations in Munich. I won't describe all of them. It goes to the center until we get to the last category. These are the major stations, Stachus and so on. You don't have to remember the stations. I looked at who can reach these stations. Then I created graphs. I'll briefly explain what it looks like. I'll make it small. Let's make it easy to understand. Basically, I calculated how high the difference to the mean value is. The mean value is the total value of all residents. Don't pay attention to the numbers. It's the same order as here. All graphs are

structured in the order from most outside to inside. As you can see, the percentage difference is particularly high among Germans. That means there are many Germans who can reach these rural stations and few foreigners who can reach them. As you can see, there is a trend. It goes down again. More and more foreigners can reach these inner-city stations better than Germans in this case. Of course, this is very general. These are small percentage differences.

Speaker 2 (28:55 - 28:59)
Critical Reflection
It's interesting that there is a difference between Germans and foreigners.

Speaker 1 (29:01 - 29:59)
This is due to data sets. Census data sets have these data. I calculated this. This is between Germans and foreigners. There are several things. I also have female and male residents here. The trend can be very interesting. Maybe you can think about it. I don't know. Here, for example, it seems that both of these rural stations tend to reach zero. But if you look at the trends, male residents tend to reach the center and not the sub-centers in the other stations. But it looks different. What else can I show you? We have the same trend for the age. Exactly. You can clearly see that these two blue bars are 20 to 30 and 30 to 40. That shows that there are much fewer rural inhabitants than the average. They live around these rural stops. And still far above the average in the inner-city ones. There are linear upward trends. And you can also find the opposite trend for the elderly. For example, between 50 and over 80, it stretches downwards.

Speaker 2 (2:35 - 2:36)
Where are they? There. Okay.

Speaker 1 (2:37 - 3:15)
Yes, there are quite some bars. I know. But if you look at the brown one, for example, between 70 and 80, it also goes down. That means you can assume that they are more likely to reach the rural stops. You can look at it again in a moment. But now I would like to ask you after this little rough explanation. Are you surprised by any of these results or do they actually come as expected?

Speaker 2 (3:19 - 3:32)
That's hard to answer now. But it must have been a lot of

work. But it's really hard to judge quickly.

Speaker 1 (3:32 - 3:36)
Or was there a particular...

Speaker 2 (3:36 - 3:48)
Critical Reflection
What surprised me with this... What surprised me is that there is a difference between Germans and foreigners.

Speaker 1 (3:52 - 4:15)
Yes, that it is not completely even. Ideally, there would be no difference. But okay. Well, I know there were a lot of results. That was a bit overwhelming. But was there anything else that surprised you? Or are you more equal and think, yes, that's it.

Speaker 2 (4:16 - 4:18)
Can we look at that again with men and women?

Speaker 1 (4:19 - 4:22)
Yes, gladly. That's with men and women, for example.

Speaker 2 (4:24 - 4:32)
Yes, okay. But what is down? What does it mean down? Can you explain that to me again?

Speaker 1 (4:32 - 5:06)
Exactly. We basically always look at the difference to the average value. Basically, I first looked at the general percentage of men and women in this region, which I have now completely analyzed. And then I just looked, okay, and how is it with the people who can now reach this kind of station? In other words, basically, if it goes down, it means that a below average number of men can reach this specific type or cluster of station.

Speaker 2 (5:10 - 5:11)
Disadvantaged, practically.

Speaker 1 (5:11 - 5:48)
Exactly. It's practically disadvantaged. So basically for this station cluster. It means that, of course, there are such small differences, because we are still talking about a very large population, but the differences are there. It means that, men are disadvantaged in the first four clusters, i.e. from rural to almost inner-city. But here, somehow, in the very inner-city, it's the other way around. And these disadvantages can also be found here

with Germans and foreigners or with the age groups.

Speaker 2 (5:52 - 5:57)
Okay, so that's interesting, but the fact that I should analyze this in detail now, that's hard for me.

Speaker 1 (5:58 - 6:24)
No, no, that's not it either. It was just a matter of whether something surprized you or whether something caught your eye. But if that's not the case, maybe it just shows that it's not so ... You also said that it was a specific profile. I don't know if you expected this profile or not?

Speaker 2 (6:25 - 7:01)
But maybe you could just make several profiles from the profile, i.e. a student... And then from me a family where the woman is also busy with the children. So very different profiles. Because now this resident with a university degree and around 30 is representative. That's the question.

Speaker 1 (7:01 - 7:18)
Basically, these are the variables that have correlated the most. So they just fit best into the model. Which also shows that this profile of this resident has the best time availability.

Speaker 2 (7:20 - 7:40)
Impact per Socio-Economic
Fairness and Equity Perc
But he is preferred. He has a university degree. He doesn't need a car because he has other options. He is young, he is definitely healthy and he is at the top of the status. So he is not disadvantaged.

Speaker 1 (7:41 - 8:45)
Exactly. I'll get to that in a moment. But before I get to that ... In general, the results I gave you, are they comprehensible to you? Yes, of course.

Speaker 2 ()
Approval
Yes, of course.

Speaker 1 ()
Okay, okay. That's just a matter of form. Let's get back to this typical student, who in your opinion is not disadvantaged. According to these results, are there groups of people who are particularly disadvantaged or particularly preferred? According to these results. You can also tell me what you would like to see again.

177 Speaker 2 (8:46 - 9:42)

Perception on (Under-)Privi

178 Yes, but you can also say in general. Education opens many doors. And that's also a budget thing, of course. That's the point, I think. And health. And that's important. So health is also a quality of life. And if you are sick, that limits you. And we also have a new project, it's called Inclusive Spaces. You can also take a look at our website. So it's also about the justice of the disabled. There was also Lea Zuckriegel, which was even at the Paralympics in Paris. And we are now also doing business cards with blind writing. And a great project.

179 Speaker 1 (9:42 - 10:17)

180 Yes, that's nice, that's great. Yes, I think then, as you say, health also plays an important role. I'll definitely take a look. And if you, for example ... So after your answer, disadvantaged people would not fall into these categories. Therefore according to these results, they would also be potentially disadvantaged. Did I understand that correctly?

181 Speaker 2 (10:17 - 10:18)

Fairness and Equity Percept

182 Yes.

183 Speaker 1 (10:18 - 10:47)

184 Then, yes, this question may sound a bit redundant. But now, also after you have perhaps looked at these results a bit. How fair, so how equitable would you actually assess the entire situation in the Munich metropolitan region, if we look at the temporal accessibility?

185 Speaker 2 (10:48 - 11:18)

Fairness and Equity Percept

186 So I think there is always room for improvement. But there is an incredible amount going on in the Munich area. There are a lot of initiatives. The city of Munich is also very active. And Green City and all the organizations and many mobility organizations. That a lot is really being done. But we are on the right track, I would say now.

187 Speaker 1 (11:19 - 11:30)

188 Okay. Yes, no, great. And is there anything else you would like to add, would you like? Well, you don't have to.

189 Speaker 2 (11:30 - 12:14)

Reflection on potential Impr

190 Exactly. Yes, there is room for improvement. And there are so many innovative ideas. That is incredible. And I am

Reflection on potential Impr

also so grateful that we have such great projects at the Lehrstuhl. And we are also with the EIT, with the EU , we also have many projects. There were now a few colleagues back in Barcelona. And you can also learn from other cities. So that is so squarely implemented in Barcelona. Or in Paris, SUVs are not allowed to enter. So that you also learn from other cities and then implement it with us.

Speaker 1 (12:15 - 12:25)
Yes. Yes, thank you very much for this final sentence.

A.3.5 Interview 4 (I4)

1 Speaker 1 (0:00 - 0:26)
2 Can you describe your mobility behavior in general, when you use public transport? For example, what are your usual travel times, how often do you use public transport, how easily can you reach places with it?

3 Speaker 2 (0:27 - 1:42)
4 Well, I drive to work in Munich and drive my car from Attenkirchen to Freising, which is about 15 kilometers, and from there I use public transport, either S-Bahn or trains, because from Freising I go by train, the regional trains. And I'm about, it depends on when the changeover times are, an hour to one and hour and fifteen minutes, up and down, sometimes a little longer, because then I'm only one, one and a half hours. And yes, in principle, otherwise I don't use public transport that often. Every now and then, when I'm on a bus, on a trip, although the buses here don't come often. If I go to Munich on the weekend, I drive from Freising by car and then take the S-Bahn to Munich. Because the day tickets are ideal for that, because you pay 14 euros per person and then you can drive all day.

Mobility Behavior, Travel Pa

5 Speaker 1 (1:43 - 1:57)
6 So that would be mainly for your professional path?

7 Speaker 2 (1:58 - 2:13)
8 Exactly. Or if I'm in Munich and drive somewhere, then I use the S-Bahn, the tram, that's great. I think it's practical when you live in Munich, you can maybe save money. That's how I feel. I would say the offer is relatively good. Of course, I don't live in Munich, but ...

Mobility Behavior, Travel Pa

9 Speaker 1 (2:14 - 2:35)
10 Okay. So how would you rate your general experience with the ÖPNV (Public Transport)? Especially in the area where you live, for example.

11 Speaker 2 (2:36 - 3:14)
12 Actually good, in principle. So in principle, I have a positive opinion. The delays that are sometimes given by the S-Bahn, well, they are being complained about a lot, but in the end I don't feel them that much. It happens from time to time. So I'd say 95% of all trains have small delays. Yes, yes. With the S-Bahn, that's actually normal. So with stops, I say a 5-10 minute delay is acceptable.

Temporal Accessibility Need

13 Speaker 1 (3:15 - 3:31)

14 Yes. Okay. Thank you very much. Are there certain times of the day when it is a bit more difficult to use the ÖPNV, or where you see certain difficulties in the availability of the ÖPNV?

15 Speaker 2 (3:32 - 4:26)

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Reflection on potential Impr

16 Actually, I wouldn’t say so. For example, the connection to Munich is ideal, because there are trains and the S-Bahn. Of course, in the morning the S-Bahn is pretty full. If you're unlucky, you have to stand. Yes, yes. Also in the train. I suppose there are trains, regional trains, then there are, I think, too few carriages. I don't understand that either. If you already know that so many people are driving and the trains are full, then you could add more carriages. Then it would be more relaxed. But the S-Bahn probably won't be able to add more, the stations have probably too little capacity in terms of train lengths. But that's just the way it is. There will be a free space at some point, because there is a constant change in the S-Bahn. Yes.

17 Speaker 1 (4:26 - 4:47)

18 So that means mainly rush hours are difficult times of the day. And mainly because of comfort? Mainly because of the driving comfort?

19 Speaker 2 (4:47 - 4:49)

Temporal Accessibility Chal

20 Yes, because of my own comfort.

21 Speaker 1 (4:50 - 4:52)

22 Okay, comfort. Anything else?

23 Speaker 2 (4:53 - 5:14)

Temporal Accessibility Chal

24 Well, no, actually not. It doesn't fit either, because punctuality is fine for me. There are exceptions, of course. Sometimes I come to Freising in the morning and then everything is standing still. Then you think about what to do. Do you drive with the car or do you drive back? You can do whatever you want. Of course, I understand when there is a winter onset. I'm a technician and I understand when something breaks in winter. Because that's normal with technology. You have a little understanding for that. It takes 2-3 hours until it's repaired. And then everything is fine again. Every 6-7 days you get used to it.

25 Speaker 1 (5:40 - 5:46)

26 So that means the main difficulties are in addition to the

rush hours frequent disturbances?

Speaker 2 (5:47 - 5:50)
Yes, that's clear. But I don't see it that bad.

Speaker 1 (5:51 - 5:59)
But otherwise, over the entire time span of 24 hours, would you say there are no specific other times?

Speaker 2 (6:00 - 6:30)
Temporal Accessibility Need
No, not at all. When you drive during the rush hours you don't have a problem. You always get space. And then the punctuality is probably better. Of course, the S-Bahn runs all day. Always the same time. The U-Bahn runs at the same time. In principle, you always have the same traffic. It's not a lot of people, but the U-Bahn always runs at the same time.

Speaker 1 (6:31 - 6:39)
What does it look like at night for you?

Speaker 2 ()
Temporal Accessibility Need
I rarely travel at night time.

Speaker 1 ()
That also makes sense.

Speaker 2 (6:42 - 8:13)
Reflection on potential Impr
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Mobility Behavior, Travel Pa
In Altenkirch, in the last 2-3 years, they improved the services so that buses go almost every hour to Freising. That has definitely gotten better for those who take the bus. But I don't do that because there's a risk that I miss the bus when I arrive at the bus station in Freising, this is annoying especially when I finished work, I'd have to stand there for 45 minutes waiting for the next one... so I always drive my car. At least from the first part. But I have to say, I like taking the S-Bahn because you can read a newspaper or look at your cell phone or sleep. I find that pleasant. I can just sit and wait, it's more relaxed and calm. I think that's an advantage. When I drive my car, when I sometimes drive my car, I've always been annoyed by Munich. By the time you manage to leave Munich, well it's probably fine with the autobahn I guess, but it always takes a 15 to 20 minutes longer just to get out of the city, especially in the evening traffic. I was annoyed and that's why I've been driving with the S-Bahn for many years. With the ÖPNV.

41 Speaker 1 (8:15 - 8:18)
42 But good insight. Thank you very much for that.

43 Speaker 2 (8:19 - 8:40)
Mobility Behavior, Travel
Socio-Economic/-Demog
44 There are many people in Munich. What I often notice in Munich are my colleagues who live in Munich. There are people who have never taken an U-Bahn or an S-Bahn, where they live in Munich. They are car drivers. There are people who like that. Of course, they have their reasons. Exactly. I don't know.

45 Speaker 1 (8:42 - 9:56)
46 I don't know either. Thank you very much for this first insight. I would go on. If we look at your own availability of different infrastructures. For example, you want to reach your workplace. Or, for example, everything that is a private matter. For example, if you want to go to the park or somewhere in nature to relax. If we look at that, are there any changes in your accessibility during the day if you want to reach these place? For example, if you want to reach this place, let's say, how does it change during the day? Do you notice any changes during the day if you want to reach this place?

47 Speaker 2 (9:57 - 12:02)
Temporal Accessibility Need
48 No, I don't. The workplace has been over 20 years and always the same. Car, S-Bahn, train. The connection is optimal for me. It got better during my studies. In the 90s there was no connection to the subway. It was a bit more complicated. But now it's better for me. It was a positive improvement. In our environment there are bakeries, butchers, where you can walk by bike. Because I work in Freising I can always go to a supermarket by car. So I can do a lot of things. For example, when I drive home I go to a hardware store if I need something. Usually I don't drive to Freising to get something, I rarely do that. I don't drive to Freising by car. If I do, I can do it as part of my commute. I always go to a supermarket with my wife. It's only 5 km away. In Au or Zolling. There are no shops yet. Now a beverage market is closed. Before there was always a beverage market, bakeries and butchers. Now there are no more. Now you have to go to Zolling or Hau. That's the problem in such a village. That's the problem when the shops close, you need a car. Do you know Appersdorf?

Temporal Accessibility Chal

49 Speaker 1 (12:25 - 12:27)

50 I know Au and Zolling.

51 Speaker 2 (12:28 - 12:36)
52 It's only 4 km from Attenkirchen. There's nothing there. 500 people live there. There are no shops, nothing, people always have to drive their car.

53 Speaker 1 (12:37 - 12:39)
54 You're completely dependent on the car.

55 Speaker 2 (12:42 - 13:35)
56 Attenkirchen is still relatively well connected by bus to Freising. And as soon as you are 3-4 km from Attenkirchen, there are buses, but they only run twice a day. That's exactly the problem. But the question is how much they use it. There are also costs. Is it necessary to drive seven times a day despite the buses being almost empty? You have to adjust the concept. You have to work with the app and then the driver looks for his route and stops. For Example, he could have an approximate route and knows where to go and where to stop.

57 Speaker 1 (13:35 - 14:21)
58 It's like these ride-sharing-taxi services?

59 Speaker 2 ()
60 Something like that.

61 Speaker 1 ()
62 Yes, I understand. Your own needs seem to be well satisfied then. My next question would be, how does it look when we have a look at other groups of individuals in general? Especially when you look at their socio-economic or socio-demographic background. Do you think that these differences in the time availability can affect different groups differently?

63 Speaker 2 (14:23 - 14:29)
64 Different groups differently? You mean ...

65 Speaker 1 (14:29 - 14:59)
66 If you compare different age groups or if people own a car or economic status or how much they can afford, I mean with different groups of individuals, do you think that these variations in the availability over a day can affect different groups differently?

67 Speaker 2 (15:03 - 15:11)

Temporal Accessibility Chal

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Reflection on potential In

68 Do you know if certain groups would use more often?

69 Speaker 1 (15:12 - 15:51)
70 You can see that but I think it is primarily about the status quo as it is right now and maybe which groups benefit or are disadvantage by temporal variations in accessibility. That would be my next question actually. I think it would be good to know if you think that these changes in the availability over a day can affect different groups differently? Do you think that certain groups can be more or less affected?

71 Speaker 2 (15:53 - 16:10)
72 Yes. I have to think about groups of people for example. What do you mean by groups of people for example?

73 Speaker 1 (16:11 - 16:23)
74 For example you can consider their economic status, their age, their occupation or educational background and so on.

75 Speaker 2 (16:25 - 17:28)
76 Normally the people who make money use the ÖPNV more. I mean there is for example at BMW, where I work, there are many who work at BMW and they usually make a lot of money but then it is probably too stressful. I notice when I drive my car that it is too stressful. I think the ÖPNV would allow people who have a lot of traffic but also people who make a lot of money and could afford to drive a car every day to make a switch. And of course when you consider people who don't make that much money, they can afford the new Germany ticket now which is amazing I have to say, I benefit from it because I used to pay 140€ a month and now I only pay a gift.

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77 Speaker 1 (17:30 - 17:35)
78 That is not bad. That is a good price drop.

79 Speaker 2 (17:39 - 20:04)
80 Of course it can still be expensive, but now it's within a good range. Before I drove in Munich and I had to change the tariff. Do you remember? Before I paid almost 180€ for a month. That was almost my budget limit but I still accepted it because the car was always more expensive and you have to change a lot of wear parts. And then a tarif change happened and I dropped to 110€. I thought that was nice. And this aspect is of course you see,...

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there are a lot of people in the S-Bahn who don't make that much money. Yes. There is a difference. And with the U-Bahn, when I drive to Am Hart, I see a lot of non-german nationals taking the U-Bahn. It has often been said as a joke, that in principle socially weaker people only drive U-Bahn or ÖPNV, but that's not true because if you look at me or BMW, a lot of people drive ÖPNV. But there are people who don't take public transport if it takes too long. My colleague for example who is in Kranzberg and he has to take a Bus to the S-Bahn and then he has to change trains again. And he said, he's tried to do it before. He's crazy. For example there was a line to Munich and I don't know if it was organized differently back then. Now, he would possibly take the bus to the S-Bahn. But time is the issue, that's something that you have to keep in mind. You always appreciate time. And where I live, it's still ideal.

Speaker 1 (20:07 - 20:33)
No, that answers my next question. But that means you think that especially socially weaker people are more affected by these changes in the daily routine. That means, especially if you look at income-weaker groups or people with a migration background, for example, they are more likely to be potentially disadvantaged?

Speaker 2 (20:35 - 20:47)
Yes, but of course, they don't have a car. Especially migrants who come and don't have a driver's license are easily disadvantaged – in the countrysides anyway.

Speaker 1 (20:49 - 20:58)
Do you actually have many, maybe not in Attenkirchen but maybe in Au as well, are there many people with a migration background there?

Speaker 2 (21:00 - 21:42)
Yes, we have in Attenkirchen, in Attenkirchen there are two houses, with people from nigeria and another house with Afghans, there are about 10-12 people in these houses. And there are also in a small village nearby, there is a house where they are all students, although some of them also partly work here. We have four rooms. There is an Austrian in there, a French, a Kyrgyz, and an Indian.

Speaker 1 (21:54 - 21:55)
Interesting.

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91 Speaker 2 (21:56 - 22:22)

92 But they work there. They have jobs. They study there. They have an apprenticeship. And noone has a car except the French one, but he works for a gardening company, so it's the company's car, not his own. The other three don't have a car. But they always drive by bus. One drives to the airport, and the other to Freising. They are satisfied with that. From that point of view. They have chosen the apartment because it is cheaper. And they take the driving time by bus. And in the morning it is relatively good. There are three or four buses per hour because there are school buses. In the holidays it would be a bit worse, the bus would run hourly.

93 Speaker 1 (23:10 - 23:55)

94 Yes. But an interesting insight about these students. Many thanks for that. Now, this is a kind of definition question. There is no right or wrong. Of course there is a direction. But if we talk about social justice, what does it mean for you now, and you can also roughly define it for you, what does social justice and equity mean for you in terms of temporal accessibility by the RPT?

95 Speaker 2 (23:57 - 23:59)

96 Equity in temporal accessibility?

97 Speaker 1 (24:01 - 24:02)

98 Yes.

99 Speaker 2 (24:03 - 25:56)

Perception on (Under-)Privi

100 Ah, I know, you mean the social classes. Yes, because the people with, let's say, privileged people have money and can drive easily by car. And, of course, you can say that people who have less money may not have a car, are disadvantaged, which in return restricts their opportunities to go shopping or go on vacation or go on a day trip or something and their general accessibility. If I imagine that I have to get something quickly and I don't have a car or something, then I have to plan my whole day around those timetables. Because, of course, the time it takes to get to the station, to get on the bus, to get from the station to the shop... For example, with the car to the parking lot, I could be back in an hour. With the bus, 3-4 hours for the same thing. That's the point, exactly. And so, if that's the question you're asking yourself, then, of course, it's very rough. The social

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component is being reflected here again and again. Like I said now, if you can't afford the gasoline, because you don't want to drive that often, because it's expensive, even if you have a car, you don't drive that often. People who have money always drive for every possible small reason.

101 Speaker 1 (26:01 - 26:16)
102 That means, if we sum it up, exactly, if we look at it in terms of justice in the temporal range, what would be the ideal for you?

103 Speaker 2 (26:17 - 27:35)

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104 Ideal? The ideal would be, of course, like I said before, that we have an ÖPNV that possibly covers a lot of places, that drives in smaller areas a little more often, but yeah hypothetically. Of course, you have to weigh that directly with the costs. As I said before, with a kind of call bus, so that people just call... or they don't even have to call anyone, they just say, I want to be picked up there. But it would of course make sense. Because, when you look back, there used to be a train, earlier even a railway line from Mainburg to Freising. It was a bit cumbersome, but I could imagine that something like that continues as an S-Bahn, as an S-Bahn to Attenkirchen, maybe even further. Of course, you have to think about that, how many people would actually use it.

Reflection on potential In

105 Speaker 1 (27:37 - 27:48)
106 You can imagine, for example. Yes, that you then create more capacity.

107 Speaker 2 (27:52 - 28:32)

Reflection on potential Impr

108 The bothering thing with the bus is also, that he drives through all possible small stations in Freising. Because Attenkirchen, well that's my wish, I have to say. It doesn't matter how much capacity it takes, but my wish is that, since Attenkirchen is relatively big, you could be in the train much faster if he only stops three or four times.

109 Speaker 1 (28:34 - 28:34)
110 Yes, yes.

111 Speaker 2 (28:35 - 29:27)

Reflection on potential Impr

112 You have to think about that. But it's a thought when you get into future concepts. For example, there are always eight stations. It would be smarter if one line takes over 4 stations, and another one the other 4. So that smaller

Reflection on potential Impr

stations could be serviced hourly, and more important stations every 30 mins. But it would still be faster if the bus wouldn't stop so often.

Speaker 1 (29:28 - 29:59)
Thank you very much for this insight! Then I would go back to this fairness and stories. It's a general question. It can be a bit tricky to answer. But in general, if we look at Munich and its surroundings, how socially fair would you rate the temporal accessibility situation? So if we really look at how often and how well you can actually reach places over different periods of of the day, and if we now also include our socio-economic groups, how would you rate the situation in and around Munich? And you can, for example, compare different times of day, so, for example, peak hours, night hours, I don't know, everything is possible.

Speaker 2 (2:29 - 4:00)
Temporal Accessibility Need

Okay, I would say around Munich, the S-Bahn area is well-developed, I think we have good temporal accessibility there. And of course, when you talk about cars, if you now take the car-based transport concept, you could set up reasonable parking spaces at the terminus stations of all lines, so that people can come here as a starting point, then you have a reasonable, good area with almost 100 km, I would say, length/width. And in this area there is a good connection, you can travel there, you don't have to go to Munich, you can travel there if you want to go to Freising, or Tegernsee I think, or not to Tegernsee, but you can go to Ammersee, you can make an excursion to Ammersee by public transport, I don't know, something like that, for example. It works relatively well there, I haven't done it yet, but if you look at the schedule, it takes longer to get there than by car, but if you, for example, make an excursion, you take this extra time into account. I have to say that again, this is the case for Munich. If you are outside of Munich, of course, it gets more difficult, there is already a clear delimitation there. Once you leave the S-Bahn area, the level temporal accessibility really drops, then you need a car.

Temporal Accessibility Cl

Speaker 1 (4:01 - 4:24)
And that means, if you include different groups of people, then you would say that in the interior of Munich it is fairer than in the outside area?

Fairness and Equity Percept

Speaker 2 ()
Yes, definitely.

Speaker 1 ()
And in your opinion, are there certain times of the day when the situation would be more or less fair, for example?

Speaker 2 (4:25 - 4:26)
More or less fair?

Speaker 1 (4:26 - 4:27)
Yes.

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Fairness and Equity Perc

Speaker 2 (4:29 - 5:30)
Yes, I would say, if you compare groups, when the S-Bahn is full, for example, in the morning, then of course people, if they don't get on the S-Bahn anymore, then they don't get to work on time, and then they usually have a big problem if they are not on time. And this usually affects socially “weaker” more heavily. They have to be there on time. If they have to start at 8 o'clock, then they have to be there on time. Therefore, they might say, okay, tomorrow is a bit hectic and overcrowded, or they might be train cancellations, then I drive an hour earlier. And that might be a disadvantage, more travel time. You could take that into account. But apart from peak hours, I would say it's better.

Speaker 1 (5:31 - 12:11)
Okay, great, thank you very much for these answers. I would now show you a few results of my research in the last part, and then you can reflect on it a bit. The second part, which I'm doing now, are these interviews. The first part is quantitative, so everything related to numbers, and what you can measure with available data. What I did, for example, I have selected all rail stations in the Metropolitan Region of Munich, so that's what you're seeing right now, and then I calculated a kind of indicator of their temporal accessibility. That means, it's about the variation of accessibility, which is divided by the general accessibility in relation to the day. Formulas aren't important either. What can be interesting to know is that the darker the point, the better the time accessibility, the brighter, the worse. As you can see, Munich is pretty dark, and Augsburg, Ingolstadt is dark, but in the east of Munich, Mühldorf and so on, you have brighter points. If

you zoom in on Munich, everything is very, very dark. You can assume that the time accessibility is very good, and that's the general region. I think Freising is now also, for example, still part of it, which is still quite black, or quite good, quite dark. But here in the east, less so. What I did with that is that I correlated it with socio-economic data. In Germany, there are surveys that provide these informations. Then I can determine who lives where. I correlated that and created a kind of linear model to estimate which person groups or which characteristics meet the highest temporal accessibility. That's what it's all about. This is the profile of a person with very high temporal accessibility. This person has a middle- to very high income, is relatively young, around 30, has no car and usually has a university degree. I'll leave it in the room for a moment. I'll show you something else in the mean time. What I did in the second part is that I categorized. Basically, I looked at the temporal accessibility and one category, which you can see here in front, are basically all stops everywhere except Munich and Augsburg and Ingolstadt. And if you go on like this, I'm not going to explain every category now. It's all just rail traffic. And if we go on now, all categories are now categorized from the worst to the best availability. And we just go through like this. I don't say every category, but you can see it yourself. You go from the outside to the inside. And what I did, I also looked at socio-demographic things, measured who has which availability. There are three categories that I made myself. One was gender-related, there are data on it, one was migration background and the third was age. Basically, I'm not going to tell you much about the graph, but if the bar goes down, it means that this person has a worse temporal accessibility and if it's positive, this person group has a better temporal accessibility in this category. The bars are arranged according to the same order that I just showed you. So really left the outermost and right the innermost. For example, this is man and woman. Men are usually more negative and outside the innermost then positive. So there is more temporal accessibility in the innermost stations. For foreigners, you can see in the rural area, most of the places tend to have more Germans than foreigners. But if you go to the innermost, you have a trend that goes up. And the opposite trend is actually with Germans. There are also age-related trends. For example, the two blue bars are age groups between 20 and 40. You also go significantly

worse. Significantly fewer people basically live near these stations in the rural area, but significantly more of these groups of people live in the innermost station areas. This trend goes up. You can see the opposite trend with people between 50 and over 80. These are the other brown, green bars. It all goes down. These were some results. You don't have talk about everything. I'll just show this again. I think my first question would be, did any result surprise you or did it come as you expected?

Speaker 2 (12:11 - 12:33)
Well, let me think {reflects on results, inaudible mumbling}.
So this profile has a very high temporal accessibility, I see..

Speaker 1 (12:33 - 12:54)
Exactly. He can reach all the places he wants to reach over the span of an entire day. So this profile of this person. Exactly. He is ... It doesn't mean only these people, but that's who is most likely to have good temporal accessibility.

Speaker 2 (12:56 - 13:07)
Socio-Economic/-Demograp So this profile often lives in the city and uses the ÖPNV...

Speaker 1 (13:08 - 13:16)
Exactly. But in general, would you say that's surprising? You want to ...

Speaker 2 (13:21 - 14:42)
Critical Reflection
Approval
That means, I understand, socially weaker group of individuals are not included in this profile. Yes, I can actually imagine that. But I haven't seen it that way now. I mean, some of them live in the city, some outside. There are still, let's say, old houses with old rent prices. I mean, Socio-Economic/-Demograp sometimes I ride my bike in Am Hart, and there are still these older settlements in which the rent prices are not so expensive. In which people are perhaps part of the social weaker ones. Perhaps for example the saleswomen or the painters or whatever, they live there. They maybe even live there because they don’t have a long ride to work and they mostly rely on their bike or Socio-Economic/-Demograp subway. But I can imagine that these people often live in the city more or less. People with more money like to go to the mountains on saturdays or sundays or often visit someone far away.

142 Speaker 1 (14:44 - 14:49)
143 Yes. Interesting. What would you say if we look at the age groups?

144 Speaker 2 (14:50 - 14:55)
145 I have to ask again. The left one goes from the outside to the inside.

146 Speaker 1 (14:55 - 15:06)
147 Yes, from the outside to the inside. The blue ones are the young ones. That's about the age of ... Exactly, the blue ones are the young ones.

148 Speaker 2 (15:06 - 15:07)
149 They represent a 10 years range, right?

150 Speaker 1 (15:11 - 15:13)
151 Yes, exactly, one bar represents a 10 year range.

152 Speaker 2 (15:13 - 15:17)
153 Ah okay I understand, it says 10 to 20. Upwards it's 80.

154 Speaker 1 (15:18 - 15:18)
155 Exactly.

156 Speaker 2 (15:18 - 15:26)
157 That means the accessibility of the blue ones is bad.

158 Speaker 1 (15:27 - 15:46)
159 Exactly, that means that very few of these people reach these stations. That means that in the rural area there are very few 20 to 40-year-olds who reach these stations.

160 Speaker 2 (15:47 - 15:58)
161 Ah, okay. I understand. They don't use it much. In rural areas mainly the very young ones use it, who are schoolchildren. The green ones are schoolchildren, 10 to 20. And the older ones as well... it's logical!

Approval

162 Speaker 1 (15:59 - 16:06)
163 Because these groups usually drive by car. The 10 to 20 ones, 20 to 30-year-olds. And in the city, the 20 to 40 year old ones mostly use public transport as they are more conscious about the environment as well Because they are a bit unconscious of people. So for example the people who typically vote for the green party (ecological

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party of germany). But yeah I can absolutely imagine that it's like this. But it's interesting at the same time, because the people described by this model are also people who could probably afford a car, but they decide not to. On the other hand I must say, the traffic in the city... Puh, it's not for everyone (In German, means that it's tough). Because you always have a traffic jam. It's just annoying.

Speaker 1 (17:29 - 17:51)
I agree. Okay, okay, wonderful. Thank you for commenting on that. You already said that income-weak groups are potentially, according to these results, disadvantaged. Are there any other groups that come to mind or not?

Speaker 2 (17:52 - 18:00)
Disadvantaged in terms of temporal accessibility?

Speaker 1 (18:03 - 18:20)
According to the results now. Let's take a look at that. Disadvantaged, yes. Yes, yes, yes. Yes, there are a few disadvantages. In any case, the disadvantaged ones are more or less independent on the public transport... What was the question?

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Speaker 1 (18:35 - 18:56)
The question would be if there are other groups, type of persons or socio-economic characteristics that come to mind of people who could be potentially disadvantaged?

Speaker 2 (18:56 - 19:17)
Not really... Okay maybe for the disabled. They are always disadvantaged because of course often in the bus they need help to enter, or also sick people who have to walk to the bus stop. It's difficult for them because they somehow also have to get to the bus stop, etc... They are always disadvantaged unfortunately. It's a topic of its own.

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Speaker 1 (19:19 - 19:54)
Yes, it's their own topic. That's true. The physical accessibility is also a big problem. Then I'd ask another question but I want to see if you have a different opinion on the results or not. In general, if you look at the whole system in Munich, how fair would you rate the general fairness in relation to temporal accessibility?

176 Speaker 2 (19:57 - 19:58)
177 General social equity?

178 Speaker 1 (19:59 - 19:59)
179 Exactly.

180 Speaker 2 (20:01 - 21:09)
181 In principle, I would say, everyone has the same starting point from where they live. Everyone has, no matter where they live, everyone has a certain distance to a station. That's maybe from a spatial perspective. That's the same for everyone. I think there is a real difference between richer and poorer areas, because sometimes richer people want to build further away because it's a bit quieter or have newer buildings in area that are not as busy with buses. But usually it was in areas with already existing bus stops, or areas with none, but it doesn't really matter because these people would drive their car anyway. And then as I said before, the social equity here depends mainly on the income class of the residents.

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182 Speaker 1 (21:10 - 21:11)
183 From the income, yes.

Fairness and Equity Percept

184 Speaker 2 (21:11 - 21:44)
185 Because if you need a car and the income is weak, you have to pay the cost of the car when you want to access the closest bus or railway station in rural areas. Usually you want to access railways and not buses, but of course buses are possible too. But yeah, then you need a car. For me, that's the main problem – when someone is car dependent.

Fairness and Equity Percept

186 Speaker 1 (21:48 - 21:53)
187 So that means you would feel relatively fair in Munich?

188 Speaker 2 (21:53 - 22:05)
189 Spatially, definitely, because everyone has the same spatial accessibility. But yeah the socio-economic aspect, well that depends on the areas. As I said before, there are some people who never drive a car because they live in the city.

Fairness and Equity Percept

190 Speaker 1 ()
191 Okay, wonderful. That's all I wanted to know. Thank you very much!

Declaration of Academic Integrity

I hereby declare that the thesis submitted is my own unaided work. All direct or indirect sources used are acknowledged as references. This paper was not previously presented to another examination board.

Tokyo, 04.12.2024

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