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# Future perspectives for the Munich Metropolitan Region – an integrated mobility approach

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**Abstract**

Just like many other metropolitan regions, the Munich Metropolitan Region experiences population and employment growth. However, when taking a closer look, different spatial developments are taking place at the same time, namely concentration in central locations, de-concentration in smaller centers and dispersion in peripheral areas. Unguided development causes transport problems within the region. In order to develop appropriate planning strategies for sustainable urban mobility, the complex interplay between residence, workplace, and mobility choices needs to be understood. For this reason, residents and employees of the Munich Metropolitan Region were asked to reveal their preferences and trade-offs with respect to location choices and mobility. The survey results highlight how an undersupply of housing in central locations causes displacement effects towards more peripheral areas. Respondents try to optimize their mobility behavior and commuting distances, but are limited in their choices due to financial constraints. Urban environments with a high density of amenities and good public transport accessibility offer potential for more sustainable mobility patterns. We deduce three transport related policy implications: providing affordable housing in central locations, fostering integrated nodes and polycentrism, and enhancing intercommunal cooperation.

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*Keywords:* housing; working; sustainable mobility; commuting; integrated land use and transport planning

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## 1. Background and problem statement

The Munich Metropolitan Region (MMR), located in the south of Germany, offers an attractive labor market as well as a high quality of life. This results in continuous growth with respect to both population and economy. The City of Munich is the core of the region with the greatest number of jobs as well as the largest population. In 2015, the city had a population of more than 1.5 million, with an expected rise above 1.6 million people in 2018 (City of Munich, 2015).

There are downsides connected to these positive development trends and the region's prosperity. Population growth requires an increasing supply of housing. However, building activity cannot keep up with the number of people moving into the region. Especially in the most central locations, adequate housing is either not available or not affordable. As a result, certain population groups settle in suburban areas, where more floor space is available at a lower price. In turn, they are forced to accept lower accessibility as well as fewer utilities. These location choices have direct consequences on mobility behavior. A lack of local amenities or transit services causes longer trips and increases car dependency. This aggravates the problem of an overloaded transport system, resulting from fast growth regarding the total number of trips within the region. Existent transport systems were not designed to handle the additional demand during peak hours. Time and comfort losses as well as increased mobility costs are the outcome. These framework conditions call for a long-term strategy that aims to improve both mobility and land use planning in an integrated way in order to make urban mobility more sustainable. This is especially important with respect to commuting as to avoid congestion of the transport system in the main employment hubs.

Only if the interaction between location choices and mobility behavior is understood, planners will be able to match transport and land use and ensure sustainability. For this reason, the study "WAM – Residence Work Mobility" was initiated in cooperation with regional stakeholders in order to explore how residence, workplace, and transport interact in spatial terms (Thierstein et al., 2016). The study sheds light on the complex interplay and mutual influences of these three aspects. In order to be able to explain ongoing spatial developments on the macroscopic scale of the entire region, knowledge is needed about decisions that are made on the microscopic scale of single households. Of special interest for this study are households' location choices as well as the associated motives and consequences.

**Nomenclature**

| | |
|---|---|
| MMR | Munich Metropolitan Region |
| PT | public transport |
| PrT | private transport |

## 2. Integrating land-use and transport

### *2.1. Interdependencies between location choices and mobility*

As outlined in chapter 1, mobility planning cannot be considered as an isolated planning sector, but needs to be integrated with land use planning. As households make these decisions jointly, it is important to consider the interdependencies between land use and transport choices like residential location, job location, vehicle ownership, as well as daily activity and travel patterns in models and planning (Waddell, 2001).

There have been several studies in different contexts on spatial and transport-related factors influencing travel behavior. Pinjari et al. (2011) highlight how complex and integrated long-term, medium-term, and short-term choices made by households shape travel demand. With respect to residential location, it can be stated that people who live in compact urban structures travel shorter distances and will use PT or non-motorized transport. Those who live in suburban and rural areas need to cover large distances, resulting in higher motorization rates and a greater probability to use the car (Scheiner, 2006; Miller and Ibrahim, 1998). Location choices affect mobility costs through trip lengths and available transport options. This not only applies to the residential location, but also to the respective workplace.

Thus, when trying to explain time, distance, mode choice and costs of commuting, it is indispensable to consider both trip ends as influencing factors (Simpson, 1987).

Just as workplace and residence influence travel behavior, mobility can be a determining factor for workplace and residential location choices in reverse. Relocation is a measure to modify travel behavior, especially with respect to a daily commute. Employees who want to reduce time and money spent for commuting will try to spatially adjust residence and workplace. Spatial proximity is a prerequisite for using economic transport modes, like walking, cycling or local PT. Locations with higher accessibility to workplaces are more likely to be chosen as residence, leading to the assumption that people consider current and potential commuting situations in connection with their location choices (Ibeas et al., 2013). Thus, the commute is not a random outcome of location choices, but might actually be a main reason for choosing a specific location. There is disagreement in the literature about the magnitude of this influence. While one side argues that the journey to work plays a limited role in residential and workplace location choice (Bhat and Guo, 2004), a differing argumentation states that a certain budget with respect to commuting time and cost is in fact a deciding factor (Ibeas et al., 2013; Levine, 1998). The second position is supported by the co-location hypothesis, which states that employed persons relocate in order to avoid congestion during their daily commute. A maximum travel tolerance is one explanation for stable commute times and distances in metropolitan growth regions (Kim, 2008). However, metropolitan spatial structure might be able to explain commuting times better than personal travel budgets (Levinson and Wu, 2005).

### *2.2. Land-use strategies for sustainable mobility*

While there is doubt about the magnitude of mobility considerations' influence on location choices, it is clear that land use and transport policies are a means to affect travel behavior. The questions is: What strategies exactly should be enforced if one wants to transform urban mobility, especially in growing metropolitan regions like the MMR?

Density and diversity are two main aspects that are known to encourage short trips and non-motorized mobility. Boussauw et al. (2012) use the term "spatial proximity" to describe this mobility-influencing characteristic of a compact city, being high density as well as a mixture of functions and land uses. Densification thus might be one measure to ameliorate transport problems. While high residential density results in shorter commutes, an overconcentration of jobs in one center seems to have the opposite effect (Horner and Murray, 2003; Boussauw et al., 2012). Therefore, decentralization of employment is another solution to overloaded transport systems that has been discussed in the literature. Regional, dense sub-centers with employment opportunities rather than a suburbanization of housing are needed to avoid dormitory towns and reduce employees' trip lengths (Miller and Ibrahim, 1998). The underlying assumption is that people living in the region will co-locate residence and workplace to minimize their commute. However, despite decentralization of workplaces, increasing commuting times might be observed. Cervero (1989) blames this on an undersupply of housing, resulting in increased residential costs close to workplace hubs that shift workers to more rural areas. In the long run, the result will be dispersion instead of the desired polycentrism (Vandersmissen et al., 2003).

Nevertheless, the idea of a jobs-housing balance to overcome spatial disparities between residence and workplace seems plausible. Some questions remain regarding the assumption that households choose their residence in proximity to their workplace and vice-versa (Levine, 1998): Why would commute time be the main criterion for location choice? Is transport per distance unit expensive enough to make differences in commuting distances matter? What about differing housing qualities and costs? What about double-income households? The jobs-housing balance does seem to have an influence on commuting times, but it is unclear how large it is. A balance in the supply of housing and employment might be necessary, but not sufficient to reduce commuting distance. Measures of regional spatial structure, like concentrated development and compactness, appear to be more important than jobs-housing balance on the local level (Yang, 2008).

In order to find suitable strategies for the MMR, be it densification, decentralization, or jobs-housing balance, the link between spatial structure, location choices, and transport needs is crucial. The objectives of our study were to examine the relation of residence and workplace to mobility behavior, present development options for the MMR, and contribute to the discussion of strategic spatial development. The basis for the study are three tendencies in urban development, assumed to take place at the same time: concentration in central locations, de-concentration in smaller centers, and dispersion in peripheral areas. In order to explain these tendencies on the regional scale and discover the mobility behavior that comes along with them, individual decisions have to be understood on household level. A description of the methodology follows in chapter 3.

## 3. Study design

The interchange between choices of residence and workplace with mobility behavior was investigated from 2014 to 2016 within the MMR. Our methodology consists of several elements. A first step is to analyze the spatial structure of the MMR (chapter 4.1). This serves as a basis for generating hypotheses that try to explain the interactions between supply and demand with respect to accessibility, residences, and jobs, as well as the corresponding spatial development.

An online survey, recording the moment of spatial reorganization of private households, is the key element of the study. The target group consists of people who live or work within the MMR and have changed their residence or workplace in the previous three years. Respondents provide information about three different points in time: before relocation, during the search for a new residence, and after relocation. Spatial locations of residences and workplaces were geo-referenced using a web-interface. The transport-related section of the survey included questions on mode choice and frequency of different trips purposes, mobility costs, and basic information regarding car ownership or availability of a public transport ticket. In order to be able to follow financial trade-offs, we collected information on income and housing costs as well. The online survey was completed in April 2015, after four months of data collection.

Our data set consists of 7,302 respondents, who revealed their preferences, motives, and decisions. The respondents show diverse profiles with respect to housing, workplace, and mobility choices (chapter 4.2). Workplace and residence are chosen based on a bundle of different factors, including personal preferences and accessibility to destinations with different transport modes. As location alternatives differ with respect to not only one, but several factors, households have to prioritize and decide on a certain bundle of characteristics. By comparing previous and current situations, it was possible to investigate the role of residential and mobility costs for location choices. As housing is more expensive in central locations with better mobility options, people will have to trade-off residential and mobility costs within their financial budget. Given the context of the MMR with an extremely stressed housing market in the core of the region, an in-depth investigation of these trade-offs is of special interest (chapter 4.3).

Historically, and in many cases still today, similar studies were conducted with the use of stated preference approaches where individuals are asked to give their opinion on the importance of certain location criteria. Stated preferences can provide some insight into the importance of aspects in connection with location choices, like commuting time or housing attributes (Rouwendal and Meijer, 2001). However, only revealed preference approaches are able to show how households actually behave when certain parameters are present. Stated preference approaches tend to deviate from observed choice patterns, since respondents usually do not need to consider budgetary constraints. The chosen revealed preference approach combines respondents' locational data with data about transport connections, accessibility, socioeconomic structures, provision of amenities, and other spatial attributes. In combination with the information on housing and mobility costs, it is possible to estimate the actual valuation of location factors, which allows more to-the-point planning. Data from the survey can thus be used to derive needs-oriented land use and transport strategies in order to ensure sustainable development. This was done by formulating development options that are aimed at contributing to the discussion on strategic spatial development in the MMR (chapter 5).

It is important to keep in mind, however, the structural bias towards more affluent and qualified persons that often comes with voluntary internet surveys. For example, the participants in our survey on average have a higher formal qualification and household income, compared to the public statistics for the overall population of the MMR. Another bias is caused by unequal distribution paths of the invitation to participate, which was spread using postcards, direct information by cooperating municipalities, as well as social media, among others. Since we do not know our population base (all who relocated or changed their workplace), we were unable to normalize our results using official statistical distributions. Thus, our results need to be understood on the background of this important condition. Instead, we used spatial grouping of participants to generate units with a sufficient number of participants to identify broad trends rather than statistically accurate measurements. Also, while a change of residence or workplace is a decisive point in life that always reveals preferences, many people do not change residence or workplace frequently. Non-action can also be a representation of a preference, which is not included in our survey.

## 4. Empirical findings

### *4.1. Spatial analysis*

The MMR is a rather monocentric region with the main transport network having a strong focus on its core city Munich. At the same time, other central places like Augsburg, Ingolstadt, Landshut, and Rosenheim provide potential for a transformation towards a more polycentric structure (Kinigadner et al., 2015). In order to understand households' decision-making, the spatial context provided by the MMR needs to be known. The aim is to determine which spatial characteristics are valued by which household types as well as which mobility behavior comes along with these location choices.
In order to understand the spatial heterogeneity within the MMR, we applied a cluster analysis with 17 different indicators. This procedure allows the identification of municipalities that are similar with respect to settlement structure, density of services and urban functions, accessibility, monthly rent and accommodation costs and the usage of dwellings. Our analysis shows five different spatial typologies. Table 1 gives an overview on these different clusters with basic statistical information on the indicators.

A gravity-based indicator was used to measure the accessibility of each municipality. The attraction of opportunities located in other municipalities decreases with increasing travel time. Travel time by PrT or PT, respectively, is inserted into a negative exponential function to yield the resistance function. The resistance function is multiplied by the population or workplace potential to account for the decline in attraction. Summing up the weighted potential of all municipalities in reach, results in the considered municipality's gravitational accessibility.

Table 1. Indicators of the cluster analysis with mean values for the entire sample and each cluster (calculation: own elaboration; data sources: (Bisnode, 2009; Bayerisches Landesamt für Statistik und Datenverarbeitung, 2014; Immobilien Scout GmbH, 2014; Bayerisches Landesamt für Statistik und Datenverarbeitung, 2015; BBSR, 2015).

| Property<br>Medium value for each cluster | Medium value, total | urban, central | urban, decentral | Urban catchment area | Residencies in tourist areas | Peripheral locations |
|---|---|---|---|---|---|---|
| Settlement structure | | | | | | |
| Insurable employees per km² | 359,04 | 1849,93 | 438,30 | 33,59 | 89,44 | 20,49 |
| Population density: residents per km² of transport and residential area | 2392,71 | 5135,7 | 2752,7 | 1628,5 | 1605,5 | 969,2 |
| Number of commuters per 100 insurable employees at workplace | -45,62 | 11,5 | 8,3 | -49,0 | -75,9 | -146,6 |
| services and urban functions | | | | | | |
| Number of shopping facilities for daily needs per resident | 15,30 | 27,75 | 13,26 | 10,73 | 6,72 | 3,25 |
| Number of leisure facilities per resident | 10,83 | 14,91 | 10,92 | 9,70 | 8,18 | 5,32 |
| Number of cultural institutions per resident | 7,30 | 13,17 | 6,52 | 6,84 | 2,60 | 1,56 |
| Number of shopping facilities for long-term needs per resident | 47,44 | 87,20 | 41,92 | 29,99 | 19,60 | 8,79 |
| Number of schools per resident | 1,26 | 1,89 | 1,58 | ,73 | ,59 | ,39 |
| accessibility | | | | | | |
| Gravitational accessibility of population with MIV index | 74,65 | 280,9 | 94,6 | 63,2 | 136,4 | 61,6 |
| Gravitational accessibility of workplaces with MIV index | 80,98 | 321,6 | 93,1 | 61,2 | 139,1 | 58,3 |
| Gravitational accessibility of population with ÖV index | 133,34 | 610,9 | 151,7 | 43,5 | 152,2 | 33,8 |
| Gravitational accessibility of workplaces with ÖV index | 141,27 | 663,3 | 147,6 | 39,6 | 153,9 | 32,6 |
| Accommodation costs | | | | | | |
| Average buying values (EUR/m²) | 455,19 | 943,80 | 226,74 | 219,99 | 251,34 | 69,64 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Monthly basic rent in €/m² | 9,04 | 12,20 | 7,46 | 7,73 | 8,12 | 6,12 |
| usage of dwellings | | | | | | |
| Percentage of holiday or second homes of total no. of residences | 0,63 | 0,17 | 0,32 | 6,28 | ,0037 | 0,53 |
| Percentage of residences occupied by owners of total no. of residences | 44,86 | 30,09 | 42,72 | 45,72 | 55,33 | 67,77 |
| Percentage of residences rented for occupational purposes (including rent-free) of total no. of residences | 51,33 | 67,40 | 53,44 | 43,59 | 41,09 | 27,72 |

Figure 1 represents the outcome of the cluster analysis in a spatial visualization. The geographic center of the MMR is classified as 'urban, central' and contains the City of Munich including its urban hinterland and the City of Freising. These areas are characterized by a high density of amenities, population, and employment as well as an above average accessibility. Residential costs are extremely high. Employment centers, like the Munich and airport region, attract a high number of commuters, resulting in a positive net commuter flow.

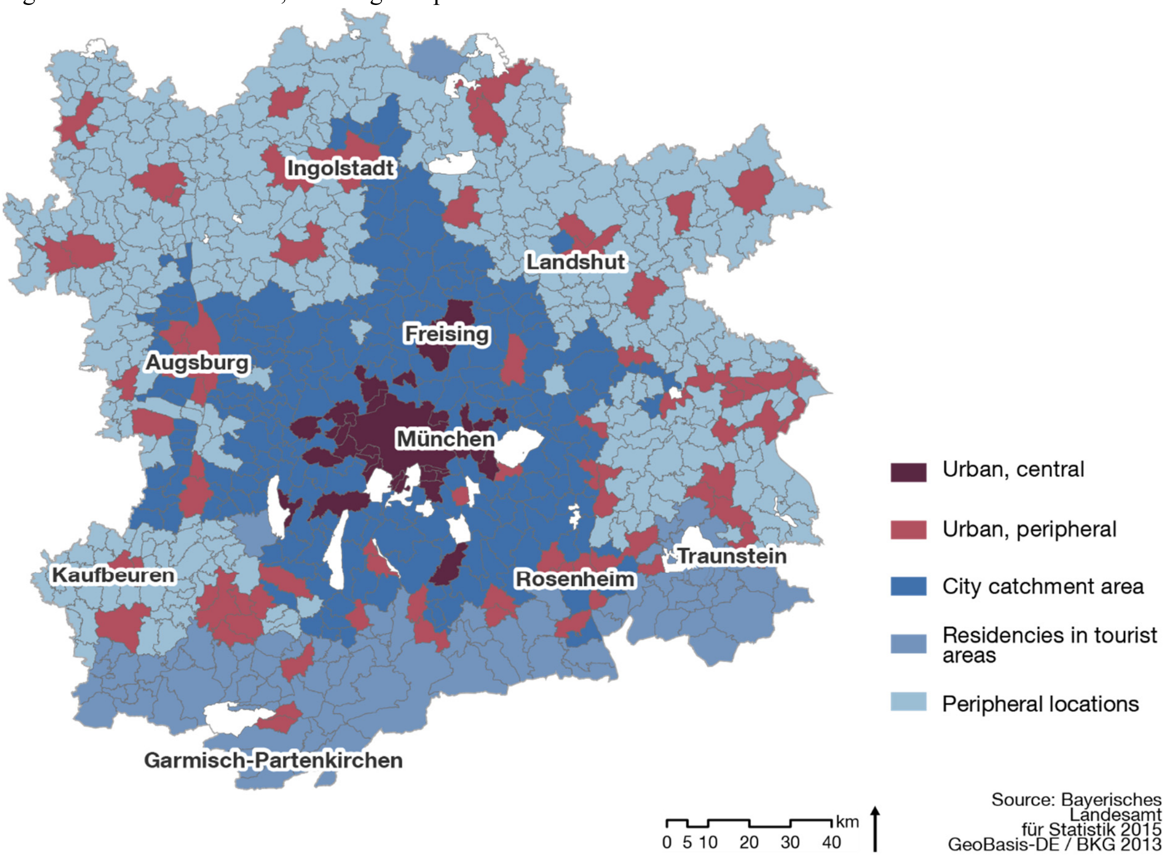


Figure 1. Spatial typology of the MMR based on a cluster analysis (Thierstein et al., 2016).

'Urban, peripheral' municipalities differ from 'urban, central' municipalities mainly with respect to accessibility. They are similarly dense, but its accessibility is downgraded by the applied gravity-based measure due to a certain distance to Munich and its large employment and population potential. At the same time, centers in neighboring metropolitan regions are too far away to carry weight. Residential costs are a lot lower than in 'urban, central' areas. Affordable housing in combination with a high density offers potential for polycentrism.

The less dense surroundings of bigger cities like Munich, Augsburg, Ingolstadt, and Rosenheim appear in Figure 1 as ‘city catchment area’. An especially low employment density causes a negative net commuter flow. Instead of jobs, a lot of resident-owned housing can be found here. Housing costs are higher than in ‘urban, peripheral’ areas, as most of the ‘city catchment area’ contains the Munich hinterland with a high accessibility to amenities and jobs provided in the prosperous city.

‘Residencies in tourist areas’ are located along the Alps in the southern part of the MMR. As a popular area for holiday homes, housing prices are higher than in ‘peripheral locations’. Due to a mostly touristic use, population and employment density is low. At the same time, the amount of shopping and cultural amenities is above average.

The fringe areas of the MMR are mainly ‘peripheral locations’. They have the lowest density and least service amenities. Also accessibility and net commuter flow are way below average. Just like with the ‘city catchment areas’ there is a high percentage of resident-owned housing. Larger distances to urban centers result in the lowest residential costs within the region.

In order to complete the picture, we investigated recent dynamics from 2011 to 2014. Most municipalities in the MMR have shown population and employment growth within this time period. Positive development predominately takes place in the region’s core around the City of Munich. However, there is also disperse growth in peripheral areas, where the existing transport system provides insufficient accessibility levels. In the case of Ingolstadt, positive workplace development in the core city results in population increases in the suburbs with low PT accessibility (see Figure 2). The opposite is true for Augsburg, where population growth is comparatively low, despite high accessibility. Dispersion into car dependent regions distant from main public transport infrastructure instead of polycentrism can be observed throughout the MMR. Development patterns like these call for a better match between urban development and provision of public transport and service amenities.

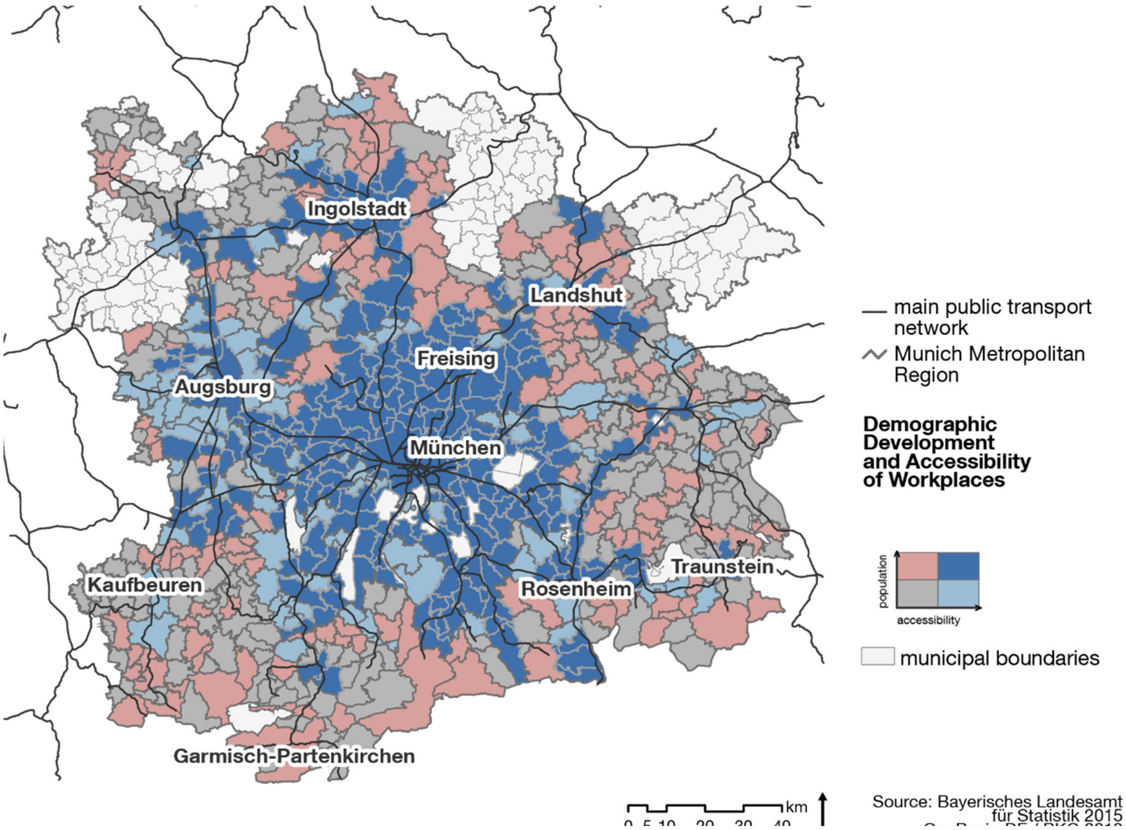


Figure 2. Population development and accessibility to workplaces in the MMR (Thierstein et al., 2016).

Summing up, the MMR has a very heterogeneous structure and development. In urban centers we observe an increase of population and employment, but at the same time there is dispersion into less accessible spaces. As suggested in our hypotheses, concentration in central locations, de-concentration in smaller centers, and dispersion in peripheral areas are taking place simultaneously within the MMR. Causes and effects of spatial dynamics, which need to be understood in order to influence spatial development, will be analyzed in chapter 4.2.

*4.2. Spatial choices and mobility behavior*

Essential findings regarding land use and transport choices and their effects on mobility are outlined in this subchapter. Respondents' stated preferences and relocation reasons were compared to their revealed preferences in order to be able to understand tradeoff processes. PT accessibility is among the most frequently named relevant spatial criteria for location choice. Respondents who stated that non-satisfactory PT offers were a main reason for changing their residence, in fact reduce their use of PrT by one half after relocation. More use of PT and non-motorized mobility paves the way for lower travel expenditures, which were stated as main relocation reason by about 10 % of respondents. Commute does in fact have an influence on location choice in this case, not only determining the new location, but even catalyzing the relocation (chapter 2.1). The result is a reduction in commuting times by one third and a reduction in mobility costs by one fourth.

Respondents who want to reduce their commuting time or distance face different options: They can either change their residence according to their workplace location or change their workplace location according to their residence. Many households optimize the spatial relation between workplace and residence by changing both locations simultaneously. In our survey, job changes caused by long commutes result in more peripheral job locations than before. While many of these employees remain car dependent, trips are indeed shorter when both residence and workplace are located in decentral areas. Thus, suburbanization of workplaces can in fact be a successful measure to keep commutes short (see chapter 2.2).

However, centralizing the residential location turns out to be more effective than decentralizing the workplace location. Mobility behavior and mobility costs change more with a residential than with a workplace relocation. Workplaces are mainly chosen based on career perspectives instead of the opportunities they offer to optimize mobility behavior. The residence has an effect on accessibility to diverse destinations and thus the overall mobility behavior. A more central residence results in more walking, more biking, and more PT use with respect to all trip purposes. Personal mode shifts and a reduction in trip lengths cause a drop in mobility costs. As can be seen in Figure 3, switching to PT or non-motorized modes saves more money than sticking with the car and only reducing travel distances.

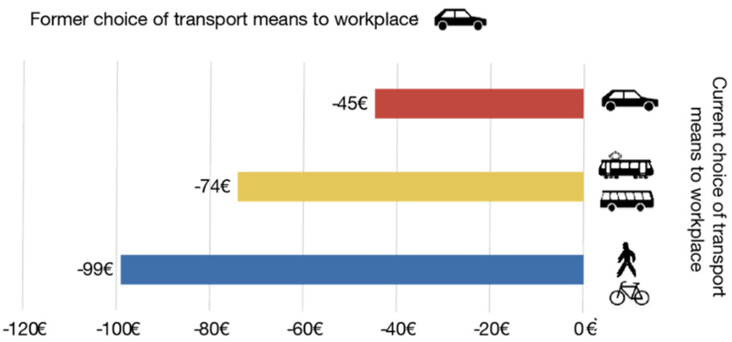


Figure 3. Monthly savings on mobility costs for respondents who wanted a shorter and cheaper commute (Thierstein et al., 2016).

Mobility plays a major role in households' decision-making. In addition to PT being named an important location choice factor, roughly 85 % of all respondents find walkability and bikeability of their neighborhood rather important. However, not all realized relocation choices are influenced by this stated preference. Handy et al. (2004) conclude from their literature review that it is unclear whether neighborhood design influences travel behavior or whether travel preferences influence location choices. By combining stated and revealed preferences, our study proves that both causalities exist: Respondents with a strong stated preference for walking, cycling and PT have already used these transport modes more than the average before changing their residence or workplace. They relocate in such a way that they are able to sustain or amplify this behavior. Even if housing quality related reasons like insufficient accommodation size are involved, these respondents do not settle in locations with extremely low accessibility. They are aware that they have to choose central, dense, and mixed residential and workplace locations over peripheral locations or suburbs in order to realize their desired mobility behavior. A sufficient provision of amenities nearby is a prerequisite for non-motorized mobility. Adequate PT accessibility is only granted in very central locations. People with a preference for eco-friendly mobility tend to centralize and can mainly be found in the bigger cities of the MMR. Thus, personal mobility preferences determine where households settle. Inversely, an urban environment may induce eco-friendly mobility, even if this is not explicitly desired. Relocations due to insufficient leisure, cultural, and service facilities cause a shift from 'city catchment areas' or 'peripheral locations' to 'urban, central' or 'urban, decentral' areas. These respondents use more PT, walk and cycle more, and reduce their use of PrT at the same time. The changes in mobility behavior are similar to the respondents who relocated due to insufficient walking and biking infrastructure. This group however, uses more walking and cycling because residing in an urban environment eliminates the need to use a car – not because they consciously aimed for it.

The influence of central, well supplied areas on relocations cannot only be observed on the scale of the MMR, but also within municipalities, for example the City of Munich. Optimization within the city causes movements between different districts, namely from outer districts to more central districts. Concentration in the city core comes with a better mixture of uses, more amenities, and good conditions for non-motorized mobility. Density of amenities and PT accessibility are roughly correlated, also enabling more use of PT after the relocation and reducing car dependency even more.

Functional diversity and the amount of gastronomical and cultural facilities, amenity value of public space, pedestrian and bicycle friendly environment, and job perspectives in knowledge intensive sectors are main driving forces of the spatial concentration of residence and workplace. Many respondents prefer a residence or workplace in the urban, dense areas of the region, saving time and money spent for mobility. Corresponding land use patterns represent a trend towards reurbanization. However, despite reurbanization tendencies, suburbanization can still be observed. Urban centers grow, but also the urban catchment areas grow.

Suburbanization is mainly triggered by families, homebuyers and newcomers to the MMR. About one third of the survey participants are unhappy with accommodation size or quality, many of them young families. Despite a high stated preference of pedestrian accessibility to service amenities and shopping facilities, this group shows a very strong tendency to leave compact spatial structures. When buying desire or insufficient housing quality are drivers of the relocation, we observe a decrease in accessibility and longer distances to urban centers. Due to a limited financial budget, people end up with more peripheral residences where accessibility to amenities and PT is low. In return, PrT is the dominant travel mode and car availability is higher for this group after relocation. PrT use was rather high before the relocation, but it even rises at the expense of walking, cycling, and PT. Since families are attached to their car, which can be explained by a greater need for flexibility, accessibility by PrT to their residence is important. However, the car is not only desired but also required. Homeowners and families tend to have longer commutes compared to those who rent, while individuals prefer central locations close to their workplace or to PT services (Büttner et al., 2014). Longer distances to employment centers are accepted in return for a bigger home or in order to buy a home. Our study confirms longer trips to work or other activities as well as higher mobility costs and more PrT use by homeowners and families.

The survey reveals a broad diversity of spatial choices. There are households that try to reduce travel times through co-location, but there are also households that choose high housing quality over lower transport costs. Still their preferences fit urban qualities, leading to the assumption that some of them would have preferred to reside more centrally if adequate housing was either available or affordable. Also newcomers to the MMR tend to move to locations with higher accessibility to shopping amenities and other services, but oftentimes cannot realize this desire due to the tense housing market. Housing costs and mobility costs need to be brought in accordance with limited financial budgets. Very often the trade-off turns out in favor of lower housing costs, without seeing the danger in underestimating transport costs (Korsu, 2012). The complexity of cost trade-offs will be deepened in chapter 4.3.

### 4.3. Trade-offs between housing and mobility costs

A main finding of our survey is a qualification of one of the main tenets of urban economics, the spatial equilibrium. Respondents of the survey, especially newcomers to the MMR, face the question whether they should move to a location close to urban amenities and centers or if they should move farther out. Locations close to centers mean lower mobility costs, especially as they often coincide with workplace locations, but since demand for housing close to these centers is higher, these locations will also fetch higher rental or purchase prices. Of course, living close to urban centers also comes with disamenities such as noise, and a more 'rural' setting might have the advantage of short distances to 'unspoilt' nature, but on aggregate, demand for urban locations remains higher.

Depending on the willingness of residents to pay for proximity to such amenities, their "welfare is equalized across space" (Glaeser and Gottlieb, 2009, p. 2), i.e. location arbitrage becomes theoretically impossible. It is important to note here that mobility costs do not only include the actual price for a PT ticket or the use of PrT, but also the time spent on commutes and other journeys, since this time could also be spent more productively for work or recreation. Hence, according to this spatial equilibrium model, there is an 'optimal' combination of mobility and housing costs depending on individual preferences of each respondent, particularly their valuation of free time.

The application of the theory of spatial equilibrium to urban land uses by Alonso (1964) included three types of expenditure that households must distribute their resources on: commuting (to a monocentric employment hub), land, and a composite good of all remaining expenditures. It was further refined by Muth (1969) and Mills (1967). All models have in common that they imply important consequences for urban and mobility development: Close to urban centers, higher demand for living space leads not only to higher land values – and, in turn, housing prices – it also leads to smaller dwellings, while at the same time building density is higher. On the other hand, dwelling size increases with distance to centers, while land and housing prices as well as building density drop (Brueckner, 1987). Urban economists see this as the major force behind the classic density and price gradients in our city-regions that are heavily interrelated with our mobility patterns. Figure 4 shows the price gradient for the MMR, based on offer data by the online real estate broker Immobilien Scout GmbH (2014).

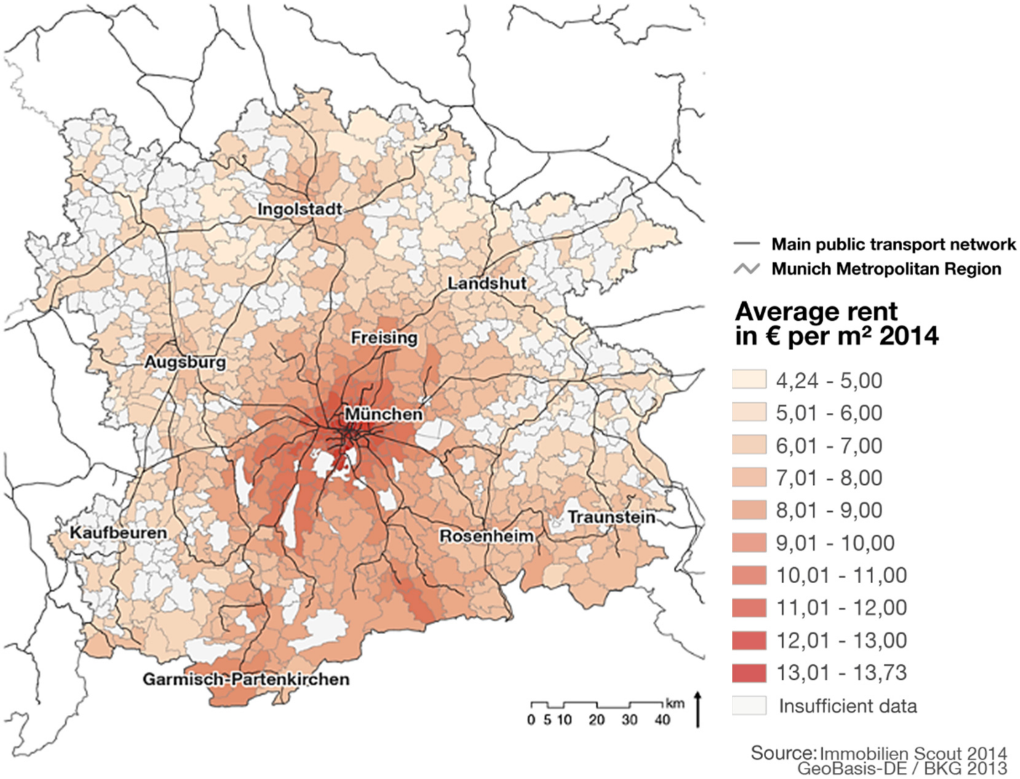


Figure 4. Average rent in € per $m^2$ , 2014 (Thierstein et al., 2016).

Responses in the survey have confirmed the model with a clear tendency of growing dwelling size with increasing commuting time. For each additional minute of work commute of the answering household member, dwelling size increased by approximately 4 m². While answering household members with a dwelling size of 40 m² or less had an average work commute of 40 minutes, this time rose to 80 minutes in households with more than 200 m² of dwelling size (n=5.061). Astonishingly, however, the same correlation did not hold for overall rental price and commuting time. For all rent price categories except the very low and very high brackets (less than 350 € and more than 2.500 €), average commuting time is a little above 50 minutes (n=3.389). When looking at property instead of rented homes, the average commuting time rises to 67 minutes, with a higher variation of commuting time between house price brackets, but also no obvious linear relationship between the two (n=1.274).

This leads us to conclude that, as a qualification of the Muth-Mills model, residents in the MMR trade off dwelling size with distance from centers while keeping overall housing costs as well as free household income (composite good) equal. This can be attributed on the one hand to the very tight housing market in the region, allowing landowners to leave renters almost no premium for the cost of commuting, on the other hand to the strong economic standing of the MMR with many households able to afford large dwellings. The tendency to increase dwelling size with income can clearly be seen in our survey results, with an almost linear correlation (Figure 5). It also shows that, among the participants of our survey, on aggregate, dwelling size topped commuting time as optimized variable after income increases. Finally, it also shows the dilemma of public housing policies. For the lowest income brackets, among them households in social housing as well as many students living in shared accommodation, commuting time is very low, while dwelling size is still at about 40 m², giving these households a favorable ratio of commuting time to living space. The least comfortable ratio however can be found in the income bracket that just falls short of qualifying for subsidized housing, between 1.000 and 1.500 € per month.

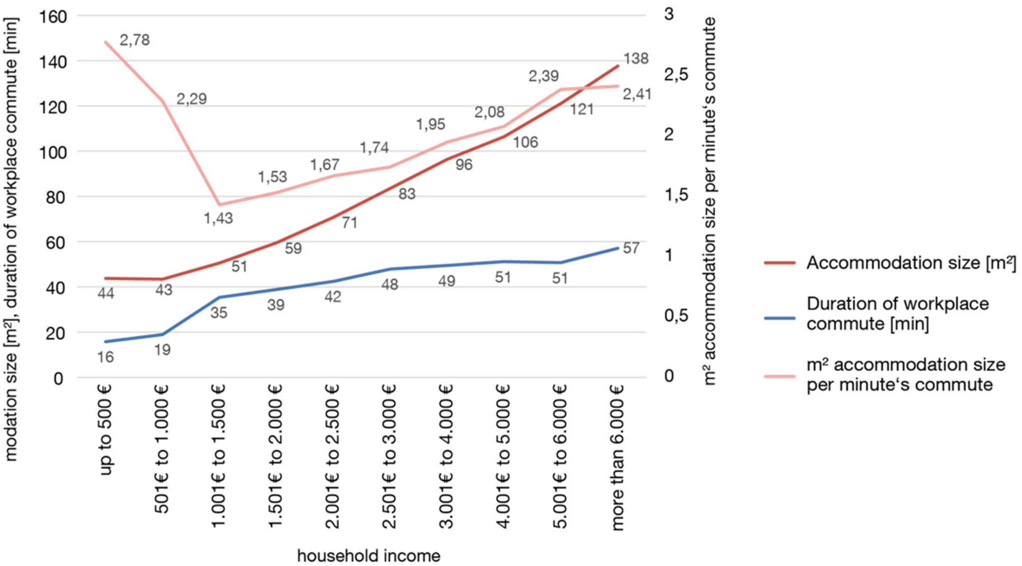


Figure 5. Relation between dwelling size and one-way commuting time, depending on household income (Thierstein et al., 2016).

## 5. Policy implications

### *5.1. Affordable housing in central locations*

Despite some limitations, as discussed in chapter 2.2, our study points towards the need for a better jobs-housing balance in order to ensure sustainable mobility patterns in the MMR. On the one hand, the spatial analysis indicates a current imbalance by highlighting the region's diversity with respect to population, employment, and accessibility (chapter 4.1). One the other hand, our findings on households' spatial choices and mobility behavior prove that co-location of workplace and residence is used as a strategy to decrease the commuting distance. Respondents who want to reduce their commuting expenses either choose a less central workplace location in dwelling zones or move to more central residences located in employment hubs (chapter 4.2).

The second option showed to be more popular among the survey respondents. Municipalities that are classified as 'urban, central' in the spatial analysis do not only offer better job perspectives. Functional diversity, good accessibility, as well as a high density of gastronomical, cultural, service and leisure facilities make them an attractive residential location. People who value the advantages of urban environments or prefer to live in proximity to their workplace tend to concentrate in central locations. Concentration is highly desirable with respect to mobility perspectives, as urban residences in dense, mixed surroundings close to local PT nodes encourage the use of walking, cycling and PT for diverse trip purposes (chapter 4.2).

However, the demand for housing rises as more people urge into central locations. An undersupply of housing increases residential costs in turn. The analysis of average rent prices in the MMR emphasizes high housing costs in central locations, especially in the Munich area, and price gradients towards more peripheral locations (chapter 4.3). Housing shortages and high housing costs cause displacements, which is not only known from the literature (Cervero, 1989), but also shown in our survey. If residences in the most desired locations are barely affordable, households need to settle for a compromise. Residences in urban centers go along with proximity to workplace locations and lower overall mobility costs. At the same time, dwellings are more expensive and offer less floor space. Households need to trade-off mobility and housing costs according to their individual preferences and needs. In many cases this trade-off yields choices in favor of peripheral locations where housing costs can be minimized or housing size can be maximized. Dispersion into peripheral areas is considered an undesired spatial development, due to negative effects on travel behavior, namely longer commuting distances and a higher car-dependency.

An evaluation of stated preferences highlights that many respondents who settle in peripheral locations do in fact value urban qualities like proximity to shopping facilities and PT accessibility. This implies that some of these households would have chosen a more central residential location if they could have afforded it. One solution for making central locations affordable is to provide more supply to equal the demand. Cervero (1996) suggests that adding more housing in or near job-surplus cities as well as producing housing appropriate to the earnings and preferences of workers helps to reduce commuting distances. Further attractive housing quarters should be created along public transport axes connecting to employment centers (Zheng and Sun, 2011). However, there are also barriers to a more intense area usage in the region's core. Munich as the main employment hub has used most of its available building space, and a further increase in density is politically difficult. The transport infrastructure is close to reaching its capacity limit. The region's center will not be able to accommodate all households striving to live in an urban environment that encourages sustainable mobility patterns. Adding more housing to locations that offer a high density of employment and amenities might not be enough to change development patterns in the MMR. Rather, the opposite approach of adding jobs and amenities to less expensive housing locations seems to be more promising in the case of Munich. Upgrading smaller cities within the MMR points into the direction of a polycentric development, which will be discussed in chapter 5.2.

### *5.2. Integrated nodes and polycentrism*

The recommendation for a polycentric urban structure with integrated nodes of urban development is a second important policy implication of our study results. The spatial analysis (chapter 4.1) highlights the gradient between Munich and other cities with respect to employment, accessibility, and cultural diversity. As a result, growth mainly concentrates in the MMR's core. While concentration in central locations proved to have positive effects on mobility behavior (chapter 4.2), further attraction of employment and population is not desirable. A monocentric distribution of workplaces leads to higher land prices in the center and lower urban density and amenity levels in the sub-centers. Housing shortage and corresponding high prices shift residents to city catchment areas (chapter 4.3). In fact, this means longer commutes to employment locations in the city center and a reduced probability that household preferences can be satisfactorily matched. Polycentrism can relieve the housing and business space market of the central city in a region, and within it, the city center. Therefore, we recommend a multi-scalar polycentrism: Within cities, strong local centers are important, just as regional centers around a central city can help to take some pressure away from it.

Polycentric metropolitan regions also seem to support more sustainable travel over monocentric metropolitan regions. Relocating workplaces to more peripheral, residence-dominated areas results in shorter commutes (chapter 4.2). This finding supports the idea of a mitigation of qualitative and quantitative jobs-housing-mismatches as a means to tackle transport issues (Cervero, 1989). However, simply balancing employment and housing offers will most likely not suffice. In order to reduce car-dependency, the spatial diversification of attractive job opportunities should be accompanied by providing attractive PT offers. Respondents not only state that PT accessibility is very important, they in fact change their mobility behavior if an adequate PT offer exists (chapter 4.2). A transport network that is only geared towards one center instead of offering diverse, capable tangential connections fosters a monocentric urban form. The challenge is to improve PT services in order to connect multiple centers and to develop attractive local transport networks. Upgrading existent PT nodes with respect to higher densities combines accessibility and amenities, thus providing the basis for regional centers to attract medium-sized and smaller enterprises as well as skilled labor. Urban qualities of sub-centers with main railway stations such as Augsburg, Ingolstadt, Landshut, and Rosenheim need to be amplified. The development of dense, diverse, high-quality residences and employment centers fosters polycentrism and contributes to non-motorized mobility.

As our findings in the MMR have shown differences in spatial behavior of households (chapter 4.2), diverse preferences need to be accounted for. Dwelling size, willingness to sustain longer commutes and distance from the residence to central places increases with income. At the same time, households with high incomes prefer single-family houses to multi-family houses, and ownership to renting. Responsible transport planning goes hand in hand with land use planning, and considers these preferences. On the land use side, it offers a variety of housing types catering to different preferences, to maintain a social mix. The immediate surrounding of urban centers with amenities around main transport hubs is thus ideal for dense, mix-use multi-family housing with a mix of rental and freehold apartments, especially taking into account affordability (chapter 5.1). Farther away from these hubs, urban density can decrease with land prices. This way, preferences for higher income households can still be accounted for while most inhabitants, including those with lower incomes and high dependency on public transport enjoy high accessibility levels. A polycentric structure with a strong public transport system can best accomplish these requirements, since it maximizes the space that comes into question for such an approach.

These are not new ideas. Indeed, a polycentric spatial configuration and integrated transport and land use planning, often termed ‘transport-oriented development’ have been at the heart of several planning models of the last decades, dating back as far as the ‘Central Place Theory’ by Christaller (1968) and its normative adoption, for example as “decentralized concentration” model in several continental European spatial planning programs. Despite being known for its notion of monocentric market-areas, the theory encompasses polycentric structures on the higher spatial levels, where sub-centers fulfil some central functions of an associated higher-order center (Parr, 2013, p. 7).

Recent treatments of the topic stress that Christaller’s approach is too hierarchical and highlight the importance of relational and network-based spatial phenomena to explain especially private-sector-driven urban development today (Camagni, 1993; Castells, 1989; Meijers, 2007; Taylor et al., 2010). Polycentrism must thus be understood not only as the existence of strong sub-centers alongside an urban core, but as system where areas can be served by more than one center, encompassing complementarity and specialization, abandoning some of the less realistic constraints of the Christaller model and creating a mesh of interconnections within a metropolitan area.

Nevertheless, an assessment of the urban and mobility pattern in the MMR must lead to the conclusion that it is still relatively monocentric in its current characteristic (chapter 4.1), and much remains to be done, despite recent analyses that point to a polycentralizing development (Lüthi et al., 2010; Kinigadner et al., 2015).

Current urban economic development characterized by globalization is a key driver towards a polycentric spatial configuration especially on an interregional scale, but also locally: This economic shift results in a re-organization of value creation and innovation processes and comes along with an upscaling and a greater ambiguity of spatial interdependencies (Pred, 1977). It becomes more difficult to establish an efficient public transport system, which often relies on a hierarchical organization pattern, but at the same time it shows us which steps need to be taken to cultivate the existing system for the future. Plans that rely on the assumption that commutes must lead to or via the center need to be seen more skeptically.

### *5.3 Intercommunal cooperation*

A spatial analysis of the MMR highlights the diversity with respect to structure and function (chapter 4.1). Organizational structures do not necessarily match these functional structures. For this reason, we suggest 'variable geometries' in order to foster sustainable development on the local as well as the regional level. Land use and transport planning needs to take place on multiple scales, with cooperation on the horizontal as well as the vertical level. Cooperation beyond the boundaries of the MMR and multiple memberships should be encouraged. Urban structure, land use policy, and transport services have to be compatible among different spatial scales: Neighborhood bus services, trams, and trunk railway lines must correspond to low to medium density residential neighborhoods, mixed-use neighborhood centers, and regional as well as supra-regional centers.

Main centers within the MMR need better connections, not only radially, but especially tangentially. High quality PT services on the regional level help to reduce car mileage. Following the argumentation of Milakis et al. (2015), regional-scale interventions are more effective than local-scale interventions due to lower travel distances on the local level. However, the importance of small-scale policies cannot be neglected with respect to solving local transport problems.

Obviously, location specific transport problems need to be solved on a local scale. Limited size and competence make it difficult for municipalities to handle challenges on their own. Also close interactions with neighboring communities call for more small-scale regional networks. Variable geometries enable to deal with arising transport challenges more competently. Housing, employment, and other opportunities need to be taken into account across institutional borders. Complementary, interdisciplinary approaches will yield the most suitable multimodal and integrated mobility concepts. Integrated land use and transport strategies on smaller scales are a powerful tool to steer mobility towards sustainability.

## 6. Conclusions and outlook

The WAM study revealed households' preferences and trade-offs with respect to locational qualities and mobility behavior given a certain spatial context. Different motives result in different spatial choices that cause different developments in turn. Our findings not only yield explanations for the current spatial tendencies, but also indicate possibilities to influence development in the future. The study provides a basis for strategic debate on promoting integrated nodes of urban development and provision of PT infrastructure.

Integrated planning of employment and housing supply in the MMR is needed on multiple spatial scales. The provision of adequate housing quality and quantity is essential. Better allocation of urban amenities and high quality mobility services will increase the attractiveness of smaller cities and pave the way for transformation. Accessibility throughout the MMR needs to be improved by establishing attractive PT services both between and within employment and residential centers.

Our study serves as a basis for developing more concrete planning strategies on regional and local levels. The suggested strategies are aimed at guiding politicians towards choosing a proper path for sustainable urban mobility. It is the responsibility of regional stakeholders to make use of the findings by implementing them in their planning practice. In the future, the MMR might be an example of how urban mobility can be channeled towards sustainability, despite major pressure due to strong growth.

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