Studien zur Mobilitäts- und Verkehrsforschung

Gebhard Wulfhorst
Stefan Klug *Editors*

Sustainable Mobility in Metropolitan Regions

Insights from Interdisciplinary Research for Practice Application

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Mobilität ist ein Basisprinzip moderner Gesellschaften; daher ist die Gestaltung von Mobilität im Spannungsfeld von ökonomischen, sozialen und ökologischen Interessen eine zentrale Herausforderung für ihre Institutionen und Mitglieder. Die Schriftenreihe Studien zur Mobilitäts- und Verkehrsforschung versteht sich als gemeinsame Publikationsplattform für neues Wissen aus der Verkehrs- und Mobilitätsforschung. Sie fördert ausdrücklich interdisziplinäres Arbeiten der Sozial-, Politik-, Wirtschafts-, Raum-, Umwelt- und Ingenieurswissenschaften. Das Spektrum der Reihe umfasst Analysen von Mobilitäts- und Verkehrshandeln; Beiträge zur theoretischen und methodischen Weiterentwicklung; zu Nachhaltigkeit und Folgenabschätzungen von Verkehr; Mobilitäts- und Verkehrspolitik, Mobilitätsmanagement und Interventionsstrategien; Güterverkehr und Logistik.

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Sustainable Mobility in Metropolitan Regions – Insights from interdisciplinary research for practice applications

Preface

Gebhard Wulfhorst and Stefan Klug

The contributions of this book are selected outcomes from an international group of young scientists researching in the field of sustainable mobility in metropolitan regions. The scientists belong to the mobil.LAB Doctoral Research Group "Sustainable Mobility in the Metropolitan Region of Munich", co-funded by the Hans-Böckler-Stiftung (HBS) and hosted at Technische Universität München (TUM) in its first phase from 2011 to 2015.

The research is based on individual case studies from the metropolitan region of Munich. The studies focus on different aspects of sustainable mobility from different disciplines, at different spatial scales, using different methods. They contain on-the-ground solutions and ways of improving the process and transition to sustainability. Each of the contributions includes multiple insights of theoretical knowledge, methods used to assess sustainable mobility, the way how to study and how to conceptualize sustainable development. However, the scope of the chapters differs according to the state of the research.

Moreover, a common understanding of sustainable mobility in metropolitan regions has been developed as a framework within the research group. Each contribution acts within this framework but specifies the definition within a certain context. In consequence, the knowledge and experiences from the interdisciplinary research network are shared in order to generate strategies and actions to address, promote and support sustainable mobility in metropolitan regions. The book therefore is orientated toward the practice level. It should help to put the ideas on the table and inspire the debate about sustainable development in general and options of future mobility solutions in particular.

The **introduction** to this book highlights some framing aspects of one common topic: "Sustainable mobility in the metropolitan region of Munich". In the following parts of the book, the key findings of young scientists from various disciplines are presented.

The first part of the book is dedicated to **innovative policy approaches** for sustainable mobility. When speaking of sustainable mobility the spatial dimension is crucial. The locations of different land use, such as housing, shopping, employment and leisure have huge impact on mobility behavior. When properly estimating the environmental effects of the built environment also induced impacts on transport need to be considered. John E. Anderson suggests an expanded life cycle approach, which involves the assessment of the interactions between the building scale and the urban scale. For the region of Munich the method illustrates that induced impacts constitute approximately 50% of all impacts of the built environment. In the latter part of the chapter Anderson suggests recommendations to the diverse stakeholders and actors on their particular role in the incorporation of the induced impacts. Stakeholders are also a central element of the contribution by Chelsea Tschoerner who highlights the term of 'sustainable mobility' from the governance perspective. The concept does have different meanings depending on the procedure of communication. By doing interviews and analyzing historic media she shed light on the production, reproduction and transformation of the concept in everyday politics and policy-making on a municipal level. The case of Munich is used to develop a more general understanding, which can be applied to other metropolitan regions.

The second part of this book focuses on **specific target groups**. Leisure activities generate by far the most trips and account for about one third of all trips being made. Therefore it is important to evaluate how this aspect of mobility can become more sustainable. Diem-Trinh Le-Klähn investigated a case study of tourists' use of public transport in the region of Munich. She elaborates policy implications for both transport and tourism management and suggests marketing strategies, which can be also transferred to other cities of similar conditions. Another segment of mobility is the subject of the contribution by Katrin Roller. She focuses on corporate mobility under the aspect of its social impact. The working world is very closely linked to the need of mobility. Additionally to the need of daily commuting often business trips are required from employees. When and by what does this become a burden? The author specifies the factors that strengthen and those, which limit stresses and strains of commuting, business travel and the need to change between several work places. The interrelation of housing and mobility is the subject of latter two contributions of this part. Based on the recently completed research project "Residence, Work and Mobility (WAM)" carried out by a research group of Technische Universität München, two specific cases are considered. Lena Sterzer discusses the interrelations between residential location, mobility and mobility-related discrimination with a particular focus on low-income groups. Low-income groups are very much affected by high real estate prices so that they have to compromise not only on quality of their residence but on its location. This can have far-reaching

consequences on their mobility behavior. On the other hand, also other milieus have certain requirements on housing and mobility options. Juanjuan Zhao focuses on the knowledge-based workers' interdependent choices regarding residential location, workplace and mobility.

The third part deals with individual **options of change** towards sustainable mobility.

Benjamin Büttner suggests new local and regional development strategies in function of mobility costs. Based on a GIS-based vulnerability assessment he analyzed the potential and risk of specific locations within the region of Munich towards a sharp increase in mobility costs. Accessibility indicators are set up and used to estimate the resilience of residential locations. Potential solutions on the individual level as well as strategies and measures on the level of public authorities to prepare for future scenarios of mobility costs are presented.

As a matter of fact, the most sustainable modes are walking and cycling. Both modes show very low environmental impacts, are less costly from the individual's perspective than driving and do have positive social impacts, such as individual well-being and public health. One important concept to foster the use of bicycles and improve the environment for pedestrians is neighborhood mobility – but how to assess the improved conditions of walking and cycling? Matthew B. Okrah puts his focus on the macroscopic four step travel demand modelling which is often the base for local transport planning. Due to the size of the transport zones, trips by bike and on foot often start and end in the same zone. Therefore these trips have been neglected for a long time in classical modelling. Taking in account soft modes on an appropriate level will give perspectives for a new generation of urban travel demand modelling.

However, when considering walking and cycling as a chance to make mobility more sustainable, also technological innovations have to be taken into account. Recently the electrification of vehicles became a major issue, not only because of the technological progress, but also because of the rising oil prices and the risks of fossil fuel as a finite resource. While the public focus is on electric cars, a real boom can be found for electrically driven or supported bicycles (pedelecs). The main advantage is an extension of the usage possibilities and therefore of mobility options. However, the acceptance of electric vehicles depends very much on individual mobility perceptions, which is the focus of Jessica Le Bris' contribution. She did in-depths investigations of adaptation and use of pedelecs and her analysis confirms the hypothesis, that pedelecs are a serious mobility option for local, regional and active mobility and a wide range of different social groups. She derives general promotion strategies about the acceptance of electric bicycles.

In the last part of the book, two chapters intend to draw **conclusions** and give an **outlook** on future perspectives. Stefan Klug, together with Julia Kinigadner and Montserrat Miramontes, two additional doctoral candidates associated to the mobil. LAB research group, give a review and synthesis of the individual contributions, regarding the common objective of sustainable mobility in metropolitan regions. Basically, the insights from interdisciplinary research discussed in this book show that for implementation in practice, the cooperation of multiple stakeholders is key.

In this perspective, the mobil.LAB doctoral research group will continue to act as an open lab, involving not only young researches and senior scientists but also practice partners, such as public authorities on the local and regional level, private firms and decision makers, and the civic society. Gebhard Wulfhorst and Sven Kesselring give their perspectives on future activities in the field of sustainable mobility in metropolitan regions, targeting the focus of "shaping mobility cultures" – as an outlook on the upcoming phase of the research group.

Sustainable development of mobility in metropolitan regions is an ongoing and complex process. This book can only be a piece of the puzzle, providing some insights based on scientific observation, experience and analyses. It may help to provide some useful orientations to the practice level – far beyond the metropolitan region of Munich.

It's up to you to make a change.

We are very grateful that this project of publishing selected results of the individual research studies in one common book has become a reality. This book is a product of many people.

We therefore owe our respect first of all to the Hans-Böckler-Stiftung, generously supporting all the work being done – not only by the financial support of the fellowships and the program, but also based upon the personal relationships, namely with Werner Fiedler and Dr. Gudrun Löhrer.

The quality of the book has been highly enhanced by the fruitful feedback provided by reviewers who were officially integrated into the process from science and practice. Each of the chapters in general got comments from two reviews from both fields. We want to thank André Bruns (Frankfurt), Roman Frick (Zurich), Markus Friedrich (Stuttgart), Regine Gerike (Dresden), Karst Geurs (Enschede), Anette Haas (Nuremberg), Sven Kesselring (Geislingen), Georg-Friedrich Koppen (Munich), Hartmut Krietemeyer (Munich), Manfred Neun (Brussels), Werner Nüßle (Munich), Hiltraut Paridon (Dresden), Malene Freudendal-Pedersen (Roskilde), Johannes Schlaich (Karlsruhe), André Stephan (Bruxelles), Oliver Schwedes (Berlin), Stephan Schott (Munich), Stefan Siedentop (Dortmund), Claus Tully (Munich) and Marc Wissmann (Munich). You did a great job. We hope you like the result.

We are grateful as well to the editors of the series of this book for their support in accepting our manuscript, to Carina Ruppert and André Prescher for their help in editing the contributions, to Enago for the English proofreading service and to Springer VS for all layout and publishing efforts.

Last but not least, we want to express our thanks to all the authors for their ineffable commitment. You will be rewarded!

Munich, 21st March 2016
The editors *Gebhard Wulfhorst, Stefan Klug*

Contents

Abbreviations

BMW	Bayerische Motorenwerke
CO_2e	carbon dioxide equivalent
EMM (e.V.)	European Metropolitan Region of Munich (association body)
GHG	greenhouse gas
Gt	metric gigaton
HBS	Hans-Böckler-Stiftung (Hans Böckler Foundation)
HCT	Human capital theory
IAA	Internationale Automobilausstellung (Frankfurt Motor Show)
IMU	Institute of Media Research and Urbanism
LEED	Leadership in Energy and Environmental Design
MiD	Mobilität in Deutschland (Germany's national travel survey)
MVV	Münchner Verkehrs- und Tarifverbund (Munich Transport and Tariff Association)
MVG	Münchner Verkehrsgesellschaft (Munich Transportation Corporation)
P+R	Park and Ride
Ph. D.	Philosophy Doctor
ppmv	parts per million by volume
PrT	Private Motorized Transport
PuT	Public Transport
R&D	Research & Development
SCOT	Schema de Cohérance Territoriale (French planning document for metropolitan regions)
t	metric ton
TAZs	traffic analysis zones
TUM	Technische Universität München (Technical University of Munich)
VKTs	vehicle kilometers traveled

Sustainable Mobility in the Metropolitan Region of Munich: An Introduction

Gebhard Wulfhorst and Stefan Klug

This book, *Sustainable Mobility in Metropolitan Regions* is the product of the first four years of collaborative work by the mobil.LAB doctoral research group, an "impact hub" within a larger research network (cf. Wulfhorst et al. 2014). It brings together multiple studies on aspects of sustainable mobility in the metropolitan region of Munich, which we have used as our reference case.

We hope to contribute to fruitful exchange between researchers and practitioners in various disciplines. This book is based on insights from many sources: interdisciplinary research, quantitative and qualitative observations, scientific analyses, varying perspectives, individual experiences, and common learning. We seek to provide practical insights that will support improved orientation, explain multiple interactions and feedback, contribute to policy choices and decisions, and provide useful direction in a complex world. We look forward to hearing from readers as to whether they find our work to be on the right track.

How do we understand and conceptualize sustainable mobility in metropolitan regions? In this introductory chapter, we begin by mentioning each of the key terms contained in the book title, to draw a comprehensive picture and set up a framework for the individual contributions.

1 Sustainable Development

Recognizing sustainability as literally the *ability to sustain*, we see that two perspectives must be interlinked. From a bottom-up perspective, at the individual level, we have an intrinsic motivation to stay alive and healthy—to survive. From a top-down perspective, at the system level, we urgently need to develop a common understanding of how to sustain the whole system, so that the sum of everyone's

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individual actions does not undermine it. Therefore, if we want to survive as a global society, we have to work on sustainable development.

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This is how the Brundtland Commission (WCED 1987) defines the term, with a central focus on the essential needs of the poor and the limits of growth (cf. Meadows et al. 1972). The concept originates in the knowledge base and experience of forestry management (cf. von Carlowitz 1713).

In this sense, the concept of sustainable development is not a choice, and there is no need to discuss whether we support it. What we do need to discuss and agree upon, probably over and over again in every region and every generation, is what we consider relevant for the sustainability of our system, our planet, our society, our mobility. How do we define sustainable development at a normative system level, in the long run? How do we implement the process in our daily decisions, at an individual level, in day-to-day practice? And finally, as probably one of the most important aspects of this whole discussion, how do we create the necessary link between our individual decisions and effects on the system?

Often, we fail to take system effects into account in our individual behavior because we ignore the dynamic feedback that might involve more time or more complex mechanisms than we are able to consider. In consequence, what we urgently need is a framework of understanding and regulatory conditions that help us to develop collective wisdom for integrating intrinsic economic motivations, social welfare, and environmental boundaries into each and every decision.

Individual benefits and shared values are relevant building blocks of this framework. Rather than balancing between the different dimensions of sustainable development—often referred to as economic, social, and environmental dimensions (cf. WCED 1987; Hardi, Barg 1997; Dresner 2002), we follow orientations that are based on an interwoven system:

- Economic aspects include individual return on investment and profitability. It must make sense, from an individual perspective, to make an effort to select sustainable choices. Factors on the system level, such as incentives, restrictions, economic regulations, and taxes, must guide our decisions in sustainable ways.
- Social aspects refer to the ways in which German and other Western societies have learned to frame economic decisions from a social-welfare perspective, according to whether they contribute to conditions of societal prosperity.
- Environmental aspects set clear, non-negotiable boundary conditions regarding how we treat our ecosystem. The thresholds of this system have to be respected. We must translate these environmental conditions—from global climate change

to local noise pollution—into market conditions that enable people's health and well-being.

Figure 1 highlights this understanding by showing an inclusive approach that contains all three layers within one system.

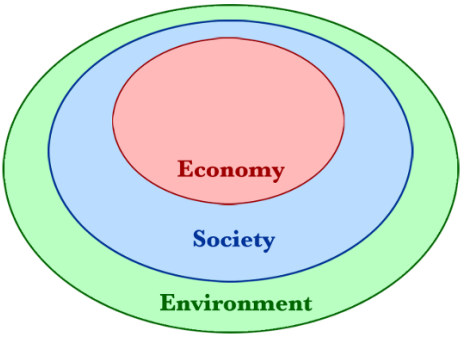

Fig. 1 Sustainability as a concept of three concentric circles (Helleman 2012)

As the figure illustrates, the environment establishes the boundaries for our development; the society and the economy evolve within it (SRU 2002; Weber-Blaschke 2009; Weber-Blaschke et al. 2004). This idea is slightly different from the so-called triple bottom line introduced by John Elkington in 1994. The triple bottom line is an accounting framework with three different and quite separate divisions (social, environmental, and financial), also referred to as the "three P's" – people, planet, and profit (cf. Slaper, Hall 2011).

We have consciously chosen to give a priority and hierarchy to the three dimensions, preferring this construct to a balanced trade-off between the dimensions, as there is no economy without society and no society without a habitable environment.

Considering the transport sector, Gerike (2005) has argued for giving a (normative) framework to market allocation processes that help to overcome the "imperfections" of a free market. The upper and lower borders of a social task field and a resource task field, as shown in Figure 2, guide the development of a framework suitable for governing the market allocation task.

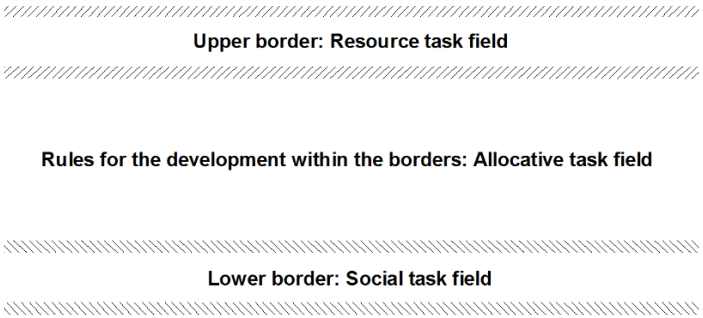

Fig. 2 Development corridor for sustainable transport development (Gerike 2005, p 11)

However, this understanding should not lead us to view sustainable development as conservative, or as implying a total or virtual freeze on new development. On the contrary, the concept inherently assumes change, adaptation, and dynamic processes that take place within the framing conditions and our understanding of them. Sustainable development takes into account past trends and the current and expected future situation of the framework, including such factors as environmental conditions, technological innovation, and social change. We will have to remain reflexive, reactive, active, and creative in order to seek appropriate solutions to each specific challenge.

Sustainable development is an ongoing, open process of mutual understanding and common learning, which also includes experimental implementation and evaluation (cf. Wulfhorst et al. 2013; Gerike et al. 2013; Witzgall et al. 2013).

2 Mobility

The system that we are looking at is the mobility system in metropolitan regions. Mobility takes the individual perspective. We understand mobility, first and foremost, as the ability to move (cf. Chandler et al. 1990, Hansen 1959, Handy 1994). In this way, it has intrinsic value and is a driver of change. It is considered to be a movement imbued with meaning (cf. Adey 2010, Cresswell 2006), corresponding to a given purpose.

Mobility enables us to perform activities at different locations, to participate in social, economic, and cultural exchange, to discover, to learn, to experience something new, and (hopefully) to achieve long-term objectives.

There are different types of mobility:

- Social mobility (i.e., one's ability to change one's position within a social system, based on such factors as education, employment opportunities, and household or family composition), which can be reflected by status symbols like a fancy car or other related values, preferences, habits, and routines of lifestyle and social context.
- Long-term spatial mobility decisions (such as choices of residential or workplace location, intentional migration, or forced displacement).
- Medium-range mobility decisions (such as car ownership, car sharing membership, purchase of a public transport pass, or getting a new bicycle).
- Everyday physical mobility decisions (i.e., choice of travel mode, destinations, and routes for daily trips).
- Virtual mobility, or new mobility options driven by technological innovations (such as "mobile communication" and related information and communication technologies).

Given this range of meanings, some social scientists refer to *mobilities* as an inclusive social concept covering these diverse layers and the variety of motivations for, conditions of, and expressions of mobility (cf. Canzler et al. 2008, Urry 2007, Witzgall et al. 2013).

Based on this understanding, we start our research with the classical concern for short-term, physical mobility behavior (from the transport planning perspective, basically measuring mobility in terms of the number of trips, taking into account the diversity of activities at different locations and the respective trip purposes). We then open up our reflection and discussion to multiple disciplinary perspectives on the phenomenon – including diverse terms such as *mobility practice*, *discourse*, and *arenas of mobility*, as well as the various related policy dimensions.

As a starting point for our research program, we intended to focus on the following distinct aspects of transportation (cf. Figure 3):

- Transport system: What options are provided by the land-use and transport system (accessibility)?
- Transport behavior: How are those options being used, and what are the benefits for the individual user (behavioral research)?
- Transport culture: What are the reasons behind the behavior, and what needs are being satisfied?
- Transport policy: How can the system be assessed and evaluated, and what recommendations can be given to improve sustainability performance at the level of a metropolitan region?

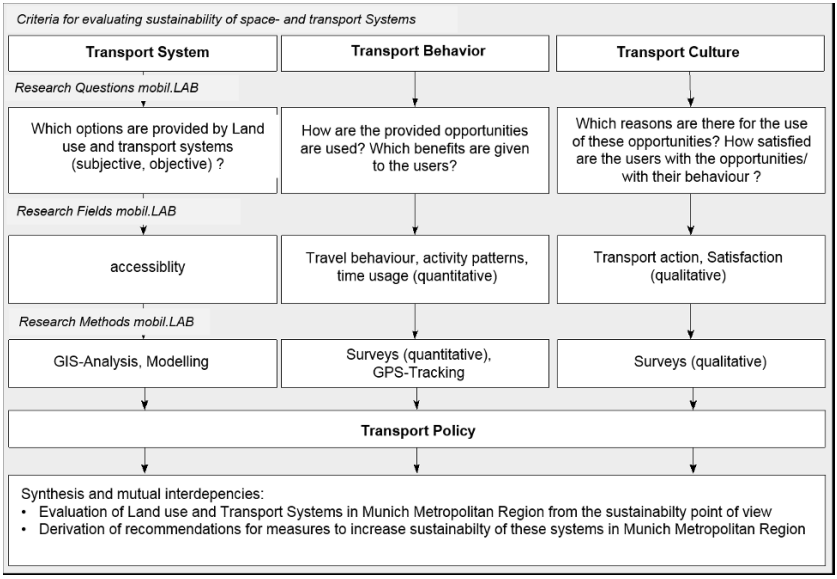

Fig. 3 Topic areas addressed within the first phase of the doctoral research program

We will see that we need to develop a more comprehensive understanding, taking into account not only mobility behavior but also the conditions of spatial structure and transport supply, the impact of cultural preferences and lifestyle orientations, and policy-making and governance processes. In this book, we will further develop this approach to the extent of considering a *mobility culture* (cf. outlook by Wulfhorst and Kesselring in Part IV: Conclusions and Outlook).

Transport (or *transportation*) at the system level enables *traffic*, which is the observable phenomena of items—such as vehicles, people, or data bits—moving around in the transportation network. Transport is the collective result, a derived demand of realized individual mobility decisions in the long term (household context, location choice, car ownership, etc.) and in the short term (number of trips, modes, destinations). It is the physical exchange of persons, goods, and information between different places (cf. Pirath 1949).

Transportation is a critical segment of sustainable development for the following reasons:

- It is a constitutional element within our economic system (not only because of the need to transport people and goods so that they can participate in a market, but also because of the huge importance and impact of related industries and energy markets).
- It creates, by its very nature, social equities and inequities (related to network configuration, access conditions, costs, and impacts on social inclusion or exclusion).
- It produces environmental damage (such as noise, air pollution, fine particles, land cover change, and CO_2 emissions).

To highlight just one of the many crucial points of debate, the transportation sector is responsible for about one-fourth of all CO_2 emissions on a global scale (cf. ITF 2010). Often the related embodied greenhouse gas (GHG) emissions that we should include in a life-cycle approach are not even considered (e.g., for vehicle materials and manufacturing, or embodied energy and emissions in transport infrastructure). With many sectors (housing, energy, industry) introducing successful climate change mitigation strategies, the impact of the transportation sector could grow still further in relative as well as absolute figures. Despite many achievements in efficiency due to regulation and technology (such as reductions in CO_2 emissions per kilometer of vehicle travel), overall GHG emissions from transportation have increased substantially since 1990. The efficiencies are partly counteracted by the upsurge in larger vehicles with additional features such as air conditioning. The more important effects, however, are generated by several system factors:

- more trips (an increase in overall mobility, driven on a global scale by population growth and economic interaction);
- higher motorization (more access to cars, motorcycles, buses, and airplanes;
- more car traffic (associated with reduced shares of walking, cycling, and public transport use on a global level);
- low occupation rates (related to considerable inefficiencies in private, public, freight, and passenger transport, including a growing tendency to drive alone); and
- longer trips (a continuous increase in distances covered, at higher speeds, within an expanding system of global travel).

Therefore, some people say that today's transportation is unsustainable. Perhaps it will not be sustainable tomorrow. We certainly need more sustainable mobility (cf. Banister 2008), but there is much more to address than the idiomatic logics of *avoid*, *shift*, and *improve*.

In the developed world, many challenges have been addressed and tackled on the local level. We have seen progress in traffic safety with the general introduc-

tion of seat belts and increasing airbag configurations – at least for the car driver and passengers, although issues related to the safety of cyclists and pedestrians, especially the elderly, remain. Most local air pollutants (SO_2, CO, NO_2, PM_{10}, $PM_{2.5}$, PAH) have been significantly reduced with the broad implementation of catalysts and specific filters. And technological innovations, such as electric vehicles, might help to address our fossil fuel dependency as well.

The most relevant impact of transport, however, that will remain a key challenge on the local level is the competition for urban space. As this most valuable resource of a city is definitely limited, conflicts are predictable. Congestion and parking problems are a common feature in prosperous and attractive places, and in most cases the solutions to keep these places attractive will not involve providing more space for traffic. Even beyond this narrow consideration, questions of how to address multiple transportation needs and local activities in an urban environment remain some of the most interesting tasks in this field, as they will require designing, negotiating, and balancing case-specific solutions to satisfy multiple stakeholders.

We will not be successful if we limit ourselves to reinventing city-friendly transportation (after having failed with car-oriented cities) – not even with electric cars! We need to understand, explore, and promote the fact that transportation and mobility are foundational for the development of urban places, including both small towns and global cities.

Transportation networks and services provide access to locations, at which specific urban functions emerge. The connection between these different places and activities again relies on transportation. Both urban functions and transportation are integrated within the concept of accessibility, which is a key element of land-use and transport dynamics.

Accessibility describes "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) (at various times of the day)" (Geurs, van Wee 2004). If we want to provide sustainable mobility, then we have to search for sustainable accessibility (cf. Le Clerq, Bertolini 2003; Wulfhorst 2008). Accessibility does have an influence on the long-term development of the mobility system and, in that way, on the daily choices of travelers.

We can recognize that providing accessibility for different user groups, by sustainable means of transportation and on multiple spatial scales, is a continuous challenge. Accessibility is a powerful concept for sustainable land-use and transport strategies. However, as accessibility is a compound variable made up of different components, we cannot address it directly by planning. We need to refer to either the transportation system or the spatial structure in order to change the key framing conditions. In addition, we need to consider individual abilities to take

advantage of the access provided, as well as the access conditions of specific services in coherence with the activity schedule (e.g., hours of operation).

As we look toward the future, it is worthwhile to consider the impact of uncertainties – for example, changes in transportation or housing costs – on planning philosophies and implementation strategies. Often we will not be able to predict the future reliably, so we will instead have to prepare for various potential scenarios. Moreover, we will have to make sure that the decisions made today will still be effective in these potential contexts. Our planning procedures and decision-making processes should reflect this flexibility, taking into account different projected future scenarios. They should enable adaptive measures, depending on the framing conditions, in order to keep us on track toward sustainable mobility.

Especially in our time, where technological and social innovation are creating a completely new system of mobility (e.g., contributing to the popularity of car sharing and ride sharing), we must remain creative in order to incorporate new opportunities and some critical threats into the task of designing the future (cf. Bertolini 2012). Accessibility instruments can help to support this planning task, starting from problem statements across strategy making, scenario evaluation, and reformulating expected outcomes (cf. Figure 4).

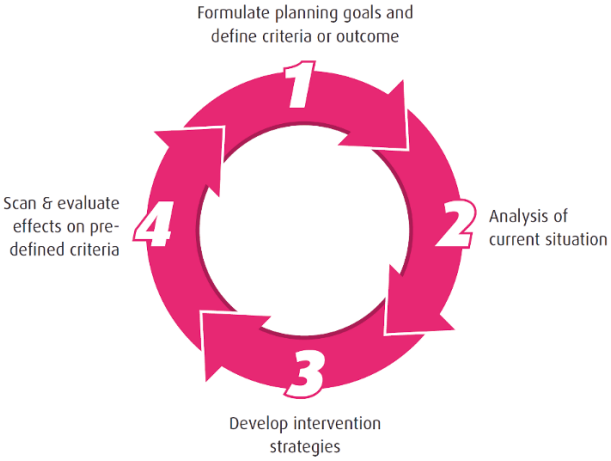

Fig. 4 The planning feedback cycle (cf. te Brömmelstroet et al. 2010)

In that sense, one key to sustainable development of mobility is to preserve options. Some paths into the future, such as car dependence, could turn out to be too high-risk. Probably we need to focus much more on reinvesting in independence. Autonomy or even autarchy will be difficult to achieve, but sufficiency might prove to be a much more important success factor than efficiency.

We have to ensure room and time for the individual fulfillment of needs, from basic needs to love and self-esteem and on to self-actualization and (following Maslow's hierarchy) even beyond to self-transcendence (i.e., altruism and spirituality). Translated to land use and transport, these priorities could well mean valuing our local identity (home) and slow travel – in other words, "slow down and stay"!

3 Metropolitan regions

We have focused our research program on the spatial scale of *metropolitan regions* and more specifically on the metropolitan region of Munich as a reference case. But how do we understand and contextualize this term, which needs a definition and a delimitation?

Perhaps the specific term can be related to a European policy concept. Starting from the *European city*, a classical notion of a community-based, free place of proud citizens, going by the functional terms of the *city region*, as defined by Boustedt (1953) based on commuter flows, the concept of European metropolitan regions has gained importance in discussions dating back to the German spatial planning documents of the 1990s. It has been enlarged as a normative concept within the European Spatial Development Program in 1999 and materialized in Germany's "visions and strategies on spatial development," as agreed upon by the conference of ministers of spatial planning in 2006 (Aring, Sinz 2006). The concept is supposed to strengthen major German city regions at the international level (BBSR 2011).

The European Metropolitan Region of Munich (EMM e.V.) has been formally founded as a governance cooperation between public and private partners. Situated in the south of Germany, this region occupies close to 40% of the total area of the Free State of Bavaria and is home to almost half of Bavaria's over 12 million inhabitants (see Figure 5). Due to its favorable employment opportunities, the region continues to attract more people each year, contributing to population growth and economic prosperity. Munich, Germany's third-largest city, with about 1.5 million inhabitants, is located in the center of the region. Other secondary cities (such as Augsburg, Ingolstadt, Landshut, Rosenheim, and Kaufbeuren) are linked with Munich and support the outstanding efforts to be competitive on the international stage.

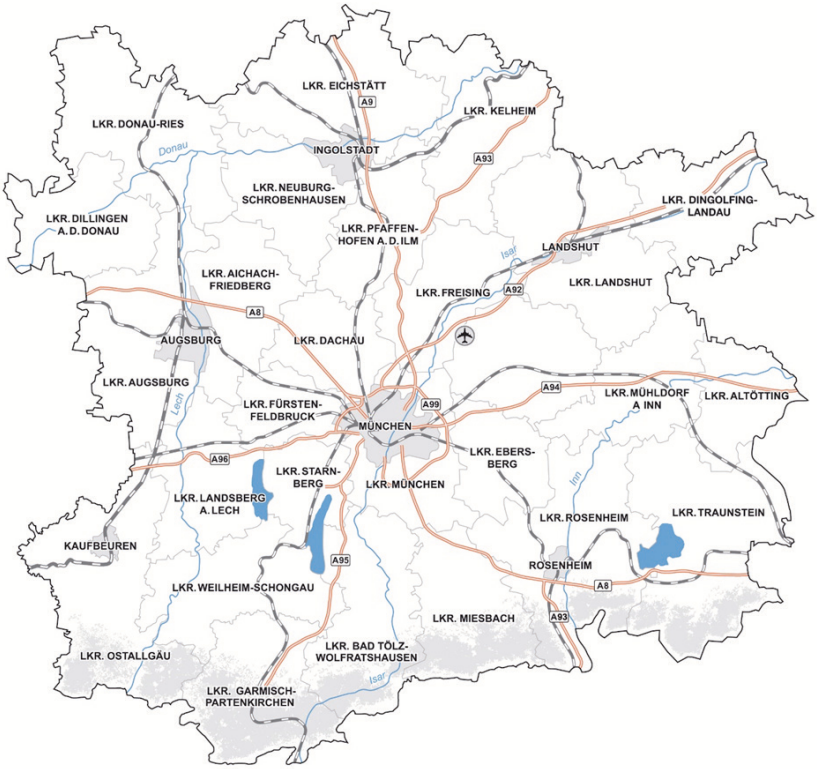

Fig. 5 The Metropolitan Region of Munich (EMM)

Moving far beyond its political conception and the normative vision, we have sought to look at the Munich metropolitan region as a reference case of complex, open, functional, relational interaction in a network. The formation of metropolitan regions itself can be interpreted as an outcome of the increasing global competition between cities (Blotevogel 2002).

We find that it is difficult to make a sound distinction between metropolitan areas and related terms, such as *megacities* (which usually have more than 10 million inhabitants) or a *megalopolis*, a dense and widespread urban agglomeration at the global scale. A *metropolis* is considered a global hub that might be connected not

just physically but also functionally with other cities on multiple scales. The term *megacity-region* has also been used for a similar phenomenon (cf. Hall, Pain 2006).

Metropolitan areas are understood as places with a large variety of metropolitan functions that are densely concentrated. Such areas could also include more peripheral and rural districts and sites on a regional level (cf. Munich, Augsburg and Ingolstadt). Probably this definition is a better match for our European understanding, as it can also encompass metropolitan political structures.

Metropolitan regions could emerge on many scales, but it seems important that they should exhibit certain *metropolitan functions* (cf. Blotevogel 2002), including decision and control functions, innovation and competition functions, and gateway functions. Just as city regions should show a surplus of importance in the respective commuter flow, metropolitan regions should reveal their position in a global network of competing places.

Our challenge is to overcome the systemic dilemma of defining an institutional territory by means of closed administrative boundaries and a clear spatial reference and instead to align our understanding with a functional territory made up of interwoven, open, and dynamic networks of nodes and places. We need to study how mobility is being produced in such spaces. We need to study how mobility is producing such spaces (cf. Lefebvre 1974). And we need to study how governance conflicts are dealt with on these multiple scales of action.

Change is taking place at higher speed in metropolitan regions. We have used the metropolitan region of Munich as a case study in this regard, hoping to learn from it and to transfer our learning to many other places in the world. We want to enable and ensure this transfer of results.

4 Sustainable mobility in metropolitan regions

So what is the underlying system, the generic code of mobility in metropolitan regions?

Transportation, as a physical exchange between different places through spatial mobility, refers to space, to a built environment, to a territory. This spatial reference calls for an integration, a synthesis of the various aspects of mobility. All these different needs, expressions, and means of transportation are realized in one single spatial context, from the local starting point (one's doorstep) across the transportation network's elements (road segment, street corner, railway station) to the destination (location of urban functions).

Mobility takes places on various scales (as we live locally but are connected globally) within the urban neighborhood, in a regional framework related to international and global exchange.

Metropolitan regions are generally built around transportation hubs. The Munich region historically has been transformed and shaped by trading corridors. In the 12th century, a bridge crossed the Isar in the vicinity of Freising, the seat of Archbishop Otto; this wooden bridge was burned down by Henry the Lion, and rebuilt where Munich is today. From the beginning, intra-regional conflicts had to be solved by external support (Emperor Frederick I, known as "Barbarossa", had to come to Augsburg to sign the agreement between Freising and Munich in 1158).

Within that same context of trade and exchange, metropolitan regions today are gaining importance and seem to be the most relevant scale of analysis for our daily mobility patterns. Metropolitan regions are the daily activity spaces in which we make decisions on how to live, work, shop, and spend our leisure time. They consist of a metro-polis ("mother city"), or sometimes more than one, and many "children" around them; the children have growing personalities of their own and are not just secondary centers. The region has a central urban structure as well as rural and peripheral locations. It is a functional entity, defined by mobility patterns, in need of concise actions across various institutional framework conditions.

Major decisions on sustainable mobility will play out on two scales:

- on the level of the metropolitan region: where we should proactively develop efficient transit networks and services between centers, so that urban development can concentrate on high-quality public transport hubs (transit-oriented development); where we need to invent, discuss, and install innovative and fair mobility pricing schemes (competitive with the cost and convenience of private car use); and
- on the level of the urban neighborhood: how to improve the conditions for walking and cycling (which could easily become the modes of choice for more than 50% of all local trips); create places to live, work, shop, obtain services, and relax (an urban mix of functions and densities); and provide a high quality of public spaces (urbanism, landscape architecture, etc.).

Sustainable mobility in metropolitan regions will rely on cooperation in a network.

Along with scientific discussions, the research presented in this book treats aspects of sustainable development from case-study perspectives. Each contribution in the book sheds light on its own selected aspects of sustainable development in metropolitan regions. We do hope that the contributions will inspire you and provoke ongoing reflection and discourse on how we can move on – together.

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Part I
Innovative Policy Approaches

A Governance Approach to Sustainable Mobility

Chelsea Tschoerner

Abstract

Sustainable mobility has become an important catchphrase in transportation policy and planning. Yet, at the same time, it is an inherently normative and political concept, which raises questions of governance. This chapter outlines a means to think about sustainability from a governance perspective. The term governance is conceptualized in the chapter as, on the one hand, a set of structures developed collectively to order and shape societal progress, and on the other hand, as a set of processes among diverse actors collectively engaged in shaping society. Drawing upon the works of political theorists and other writers in the field of governance and interpretive policy analysis, this chapter aims to (1) conceptualize governance in the context of the debate on sustainable mobility, and to (2) connect the socio-political context of Munich with these key ideas and concepts concerning governance. At the end of the chapter, the example of the governance of cycling promotion will be briefly elaborated in order to connect these key conceptual frames to an empirical context. The chapter closes with arguing for the importance of studying the dynamic processes through which various forms of governance are socially constituted. It also highlights how not only knowledge, but also values, beliefs and power, play a key role in governance processes for sustainable mobility.

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1 Introduction

Sustainable mobility has become an important catchphrase in transportation policy and planning. Seldom do debates on specific measures or modes of transportation today fail to include the terms "sustainability" and/or "mobility." This situation is due to the increasing need to address the negative environmental, social, and economic impacts of present mobility patterns (Banister 2005), as well as to develop new approaches to understanding what entails, shapes, and governs movement — not only of humans and goods but also of information (Urry 2007; Sheller et al. 2006). The popularity of the concept of sustainable mobility represents society's growing awareness of these two phenomena. Nevertheless, when we try to define this concept, and especially when we attempt to operationalize it in everyday practice, it is often difficult to find the "right" or "best" answer. As Farrell et al. (2005) and Meadowcroft (2007) have observed, the concept of sustainability is inherently normative and political, thereby necessarily raising questions of governance. Governance here refers not only to the *structures* we develop to order and shape societal progress, but it also to a specific set of *processes*. Structures may be seen as institutions, rules, and norms shaping not only policy-making but also society and the economy, whereas processes describe how actors come together, engage in defining goals, and implement their visions of sustainable mobility in practice.

To consider these abstract concepts related to governance more directly in terms of everyday policy practice, this chapter outlines how a "governance approach" could help to operationalize a complex, often ambiguous term like sustainable mobility in both research and practice. It begins by outlining the concept of governance, in terms of structures and processes, and then describes the relevance of governance in developing an understanding of sustainable mobility. Following this, the case of cycling promotion in Munich is used to apply and connect the outlined ideas about a governance approach in an empirical context. The ultimate goal of this chapter is to demonstrate how a governance approach could benefit the analysis of sustainable mobility, particularly by revealing dynamic structures and processes that highlight the normative and political nature of the concept of sustainable mobility.

2 The concept of governance

The term governance is often associated with positive social impact. For example, good governance is seen as reducing corruption; effectively incorporating public opinion; or improving the speed and efficiency of governmental policy and pro-

jects. Here, the structures or the institutions through which public policy is made, or through which change occurs, are emphasized. Governance in this sense has to do with the "built-in" ways of thinking and operating that shape our collective ability to make decisions and implement change. The term *institution* is important here, and is not the same thing as an organization per se. Rather, in the context of governance and political theory, an institution is a collection of norms, shared ideas, and rules for acting (both legal and inherent). In other words, it is those elements that can inhibit or enable collective action. March and Olsen (2006: 3) define an institution as

> "a relatively enduring collection of rules and organized practices, embedded in structures of meaning and resources", which can remain relatively stable despite individual turnover or preferences, or external events and circumstances".

The concept of governance, following Pierre and Peters (2000), is often conceived in two ways. Governance, in this institutional sense, is viewed as specific *structures* that shape the way in which actors (individuals and groups) make decisions. However, these structures are not a natural occurrence. Rather, they are produced by and a product of humans, in their social interaction with each other. From a constructivist perspective, the term structure refers to the idea that how we engage in politics and decision-making is based on socially constructed and shared understandings or ways of doing. The social construction of meaning reflects how we, as collective and interacting actors, simultaneously call upon and reproduce ideas through everyday practices. As Anthony Giddens (1984: 2) explains:

> "The basic domain of study of the social sciences … is neither the experience of the individual actor, nor the existence of any form of societal totality, but social practices ordered across space and time".

Thus, the ways in which we engage in shaping and changing the social system in which we live (here seen as processes of governance) are not based on individual interests or attitudes, nor on a given world of structure implying a defined cause and action. Rather, "[i]n and through their activities agents reproduce the conditions that make these activities possible" (ibid.). We can see this pattern in, for example, an elected politician's right to vote in a legislative body: he (or she) uses his (or her) position to influence policy, which is not simply a given but rather the product of a specific democratic system and voting process. Or we might see it in the planning of physical infrastructure, as administrative officials refer to their city's traffic code and planning documents to sketch out and implement a measure, such as defining the width of a new street or the placement of bicycle lanes.

This definition of the social nature of governance also hints at the second way in which Pierre and Peters (2000) describe governance: in terms of process. In contrast to structure — although it is better to consider these terms as two different emphases in the study of governance rather than as two contrasting ideas — processes of governance describe how actors steer and coordinate action. In other words, how we govern relates to the dynamics of political debate (including defining the problem and solution) as well as policy- and decision-making. For example, new forms of governance arise as private and public actors interact in partnerships to carry out policy to build road infrastructure. Governance as process has more to do with the changing nature of decision-making, which, as many argue, is less centered on the authoritative action of governments and increasingly influenced by the practices of non-governmental actors. Recent examples of such non-governmental influences have included public protests, such as those against the construction of Stuttgart 21 in Germany; the activities of global philanthropic organizations such as the Bill and Melinda Gates Foundation in the United States; and, less transparently, the role of the private sector in shaping electric mobility policy in Germany.

Beyond considering governance as structure and process, many key thinkers in the field argue today that the 'state' (that is, the modern-day idea of a nation-state) must be a starting point for any discussion about governance. Although the sovereign nation-state has been the key institution governing both economy and society since the Peace Treaties of Westphalia in 1648, the last half-century has witnessed a significant shift in this regard owing largely to globalization and neo-liberal reform. Governed by ideas of deregulation and the free economic market, neo-liberalism has substantially altered the state's historical position as the sole governing institution (Bevir 2009; Pierre, Peters 2000). This change can also be seen in the provision of infrastructure and services for modes of transportation, as Docherty and Shaw (2012) explain in their discussion of the governance of transportation policy in the United Kingdom.

In sum, national governments are no longer the only players governing the economy and society at large. The private sector, organized civil society, the media, and even new forms of governmental organization, such as the European Union or United Nations, are increasingly important players in processes of governance. Thus, a governance approach today must be rooted in (1) the changing role of the state, (2) the changing nature of institutions including social structures and norms, and (3) the changing processes through which the state interacts with other actors and governs or steers the direction of societal development (Meadowcroft 2007; Pierre, Peters 2000; Bevir 2009).

2.1 Relevance of the governance concept for sustainable mobility

Governance is a dynamic concept, as becomes readily apparent when we begin to analyze processes and structures of governance in a given context. Further, when applied in the analysis of political processes, they become meaningful and relevant to policy-making. In governance for sustainable mobility, actors identify new problems and solutions, form new policy, implement new measures, and expand and grow their coalitions in interaction with new actors. These are all important attributes in the politics of sustainable mobility, and they play an important role in actors' efforts to define the nature and direction of policy. As this section will argue, a governance approach can contribute to research on sustainable mobility by its ability to (1) identify and discuss how specific social, political, economic, and environmental institutions shape our understanding and identification of sustainable mobility; and (2) enable analysis of the processes through which we debate, contest, decide on, and implement the key ideas, concepts, and categorizations of sustainable mobility.

Sustainable mobility is often referred to, in both research and practice, as a static concept rather than as a dynamic, socially-constructed idea which is reproduced and transformed in practice. This more static understanding often derives from transportation studies, which tends to interpret the role of policy and planning as the provision of infrastructure and services for modes of transportation, as well as the organization of urban transport systems through concepts and ideas of traffic flow, bundling, routing and the separation of modes of transport. In everyday policy-making and practice though, sustainable mobility is not simply a fixed idea that must be implemented in a particular way. The term 'sustainability' often has little to do with the key ideas outlined in the Brundtland Report (*Our Common Future)* or with a specific quantifiable model for measuring the extent of sustainable mobility in a given urban area. Rather, it is a political concept, which is dynamic and changes over time as new actor constellations come to shape the debate. Policy-makers evoke specific narratives or stories to argue for and make sense of the key problems and policy issues they face, and sustainability is often a key term they call upon to label or make sense of specific issues. Scientific research such as models, or specific people such as experts or interest groups, shape the debate as they define sustainability in this way or that way. Knowledge, and relatedly, the power to define what 'the problem' is play a key role in policy-making. For example, academics and scientists involved in policy-making — whether presenting the results of a specific study to politicians at a City Council session or compiling a report commissioned by the local planning department — shed distinct light on

what sustainable mobility is or could be in practice. The concept is thus less tied to abstract ideas and more to the everyday push and pull of the policy process. In governance terms, decisions are based on dominant structures (such as economic and planning norms or cultural understandings of mobility) and normal, routinized processes of interaction, such as expert decision-making isolated from any form of public comment, a vote by elected officials in a council session, or a structured public debate over a project currently in progress. By studying these processes, we can reflect on both what sustainable mobility means as it is produced in practice and how these practices of decision-making and political input are structured. By reflecting on how specific arguments and ideas are accepted (or rejected) in public debate, we can address the power dynamics of governance. Is planning democratic? Are all stakeholders involved to an equal extent in shaping policy, or is there a clear imbalance of power and input? Whose "expert" input defines the terms of a given policy? What types of arguments do those involved acknowledge as legitimate?

Today, efforts to better understand the concept of sustainable mobility in the transportation sector often result in the establishment of indicator systems and other types of frameworks for measuring sustainable mobility as a fixed object or goal of policy. In such models, sustainable mobility is defined in "neutral" terms and there is no consideration of the term's *construction* and *use* (Gudmundsson 2004). By referring to an indicator's construction and use, Gudmundsson highlights the need to consider questions of governance. This includes the processes through which actors define and develop specific concepts, the forces (or structures) that shape how these definitions are made, the processes through which such definitions are used and the ways in which their use shapes and changes policy at large.

> "This would require research … into the construction and use of indicator systems more broadly. Among the questions for this research could be: How have existing indicator systems been established and which forces have shaped them? How are they used and by whom? To what extent have indicator systems made a difference in policy-making, and under which institutional circumstances has that been the case?" (Gudmundsson 2004: 213)

One further difficulty with defining a concept like sustainability in neutral terms is that the key ideas underlying the concept are usually developed by experts and are then (ideally) implemented, tested, or audited in specific settings by an entirely different set of actors. Here there is a large gap between the concept's *construction* and its *use,* i.e., between the contexts in which actors develop key concepts in decision-making and those where the decisions are implemented. Although expertise provides a key role in organizing and developing the best solutions to everyday problems, it can become disconnected with the real world. In everyday policy

practice, politicians and local administrators, along with other actors, debate and decide on specific solutions in response to real-life problems. Although abstract concepts such as sustainable mobility can shed light on problems in relation to transportation and mobility, they are rarely reflected upon in everyday practice for the purpose of identifying problems. Rather, actors react to a complexity of societal and political processes, including increases in traffic accidents, weather patterns, and popular activism. Policy is thus established and implemented in real-life settings, and the term sustainability is often defined in terms of a given solution — for example, "X is sustainable" — rather than itself being a key factor in the creation of policy. Sustainability is thus often identified and incorporated into policy through these practitioners, who make the concept and policy at hand meaningful through their given skills, their knowledge, their lived experiences, and their interpretation of the world around them.

In sum, many researchers argue that the term sustainability should be understood as a process, rather than as a definition or foundation for policy thinking (see, for example, Meadowcroft 2007; Farrell et al. 2005; Vergragt et al. 2007). Consistent with this understanding, the concept of sustainable mobility should be seen as an approach that practitioners could utilize to steer society and to govern for sustainable development. Voß and Kemp (2006: 4) elaborate on this understanding:

> "Sustainability cannot be translated into a blueprint or a defined end state from which criteria can be derived and unambiguous decisions taken to get there. Instead, it should be understood as a specific kind of problem framing that emphasizes the interconnectedness of different problems and scales, as well as the long-term and indirect effects of actions that result from it".

Their approach to governance for sustainable development is a reflexive way to study sustainability. Here they argue that despite the need for a solidified, clear, operationalized term, in terms of indicators or other frameworks, the concept is, in reality, developed through the everyday pressures and problems that decision makers face. As a result, in actual practice, the sustainability of a given concept or set of goals often does not structure the debate. Rather, specific definitions and understandings of sustainability evolve *within* the debate, in the context of real-life policy-making, including its politics and its inherent definitional power struggles. This kind of problem framing is shaped by and dependent on the institutions, norms, and rules that actors utilize, as well as the constellation of actors involved in the debate and the socio-historical context in which policy is debated and defined. When specific arguments make sense (that is, when they fit within the problem framing of the debate), they tend to stick, become integrated into policy documents, and become a key element of planning (Hajer 1995). In Munich, this

pattern can be seen in the increasing promotion of cycling, its identification as a mode of transportation, and its integration into everyday policy practice.

2.2 Connecting Munich with a governance approach: The case of cycling

To many policy-makers, practitioners, and cycling advocates, the bicycle is an environmentally friendly mode of transportation that should be promoted due to normative concerns related to environmental degradation, urban quality of life, public health, and climate change. The bicycle produces virtually no emissions when used, requires less physical space than other transportation modes for its use and storage, involves relatively low costs, and is a healthy form of "active" or human-powered mobility. As it is most often described as a mode of transportation, it has naturally become an object of transportation policy. In addition, its use is often described in relation to other modes of transportation, i.e., as an alternative to using private cars or public transportation.

In Munich, the promotion of cycling in public policy dates back to the 1980s (Koppen 2014). The postwar period (from 1945 until roughly the 1980s) is commonly referred to as the period of car-oriented planning (*die autogerechte Stadt*) in Munich. Car-oriented planning prioritized the organization of urban space for the flow and efficiency of motor vehicles at the expense of other modes of transportation (Schmucki 2001). As the environmental movement grew in Germany during the 1970s and 1980s, cycling was advocated at the grassroots level as an important, environmentally friendly, and emission-free mode of transportation. Yet, at the same time, urban cyclists were forced to share traffic lanes with vehicles or sidewalks with pedestrians, as the city often lacked the proper infrastructure or regulation for cycling in traffic. This limited their mobility and safety in traffic, and although some infrastructure for cycling existed, it was built only sporadically, and mostly in areas with leftover space and funds for bicycle paths. Everyday cyclists were labeled as "rambos" or "rowdies" in their interactions with users of other transportation modes. These cyclists were often described as reckless and dangerous, lacking basic morals or a proper understanding of traffic rules.

This situation began to slowly change in the 1980s, as Munich policy-makers identified cycling as a relevant object of planning. This was due in part to transport planners' changing discourse. In relation to a growing environmental movement, two oil crises and an increasing recognition of the limits of car use in dense, urban centers, they began more strongly articulating for the promotion of alternative modes of transport. For the first time, policy-makers began to frame cycling as a

partial solution to problems of urban traffic and pollution. In the 1990s, plans for a citywide cycling route system were formally approved. Nevertheless, the choice of routes and their implementation in practice were highly contested. In many cases, the implementation of cycling routes did not limit the mobility of cars in the urban system in any way. In the 1990s, for example, after a two-way cycling path was implemented in the Leopold street in downtown Munich, it became politically controversial. The conservative party (particularly from the State of Bavaria) argued that it was unsafe, and it was eventually reversed in order to 'make cyclists safer' by essentially limiting their mobility. What could in part be seen is that the route had limited the free flow of motorized traffic and this was in particular what was controversial.

At the same time, the 1990s saw a larger shift in urban planning in Munich. Urban planners developed, in close relation with the public and other relevant stakeholders, an overarching policy document that would function as a mission statement for planning and policy in Munich. The "Perspective Munich" redesigned the engagement of transportation planners and other experts with the public in many ways (Koppen 2014). In the early 1990s, the Social Democrats in the City Council formed a coalition with the Green Party, the latter of who had strong agenda for the promotion of cycling. It was in the 2000s, though, that larger changes in policy for cycling took place. Here we see a number of key factors, that in relation to each other, influenced a larger shift in policy: (1) an increasing social acceptance for cycling; (2) new policy at the federal level, specifically the traffic code, that fostered the safety of cyclists in road traffic being implemented in the context of Munich; (3) a changing approach of the media, from being critical of policy to promote cycling to being critical of those policy which do not promote cycling enough or in the right way; (4) a changing structure of the local administration and new personnel (from 2008 onwards) directly responsible to promote cycling; and finally, (5) the development of new international partnerships, particularly the international recognition of cycling in Munich which took place from their hosting of the Velo-City Conference in 2007.

Although much has been done to promote cycling in Munich, policy remains highly contested among both politicians and the general public. Many of the key problems confronting cycling promotion are not due to a lack of political will, as all parties agree that it is important to encourage cycling. Rather, the key barriers for improving cycling infrastructure and the culture of cycling lie within the mobility system itself. This includes on the hand the institutional field and planning practices to encourage cycling and on the other hand the norms and practices of everyday mobility; two key elements of the mobility system. Many debates on cycling in Munich focus on whether, where, and how bicycles should be integrated into main traffic

arteries and axes. These streets, which usually carry the majority of urban traffic, function as key routes on which traffic is bundled and organized. Traffic arteries and axes function to improve the flow of traffic and relieve congestion as well as reduce traffic in neighborhood areas. However, in urban areas, housing is not necessarily restricted to low-traffic neighborhoods and is often found along key axes. In the postwar period, development of major traffic arteries was promoted as a means to improve traffic flow, and by the 1970s and 1908s, they were even more essential to reduce congestion, noise, and air pollution in residential neighborhoods. During this time, one-way streets were created throughout the city to further streamline traffic flow in neighborhoods.

In the 1980s, cycling was first written into transportation planning documents, albeit largely as a forgotten and unimportant mode of transportation. It was not taken into consideration in traffic calming measures, which during this period focused primarily on reducing traffic in neighborhoods rather than promoting alternative means of mobility, such as cycling. For example, cyclists were often hindered from free movement in neighborhood areas by the prevalence of one-way streets, which forced cyclists either to engage in circuitous travel or to walk their bicycles. The efficiency and speed of cycling were thus poorly exploited, and cycling, even though mentioned in policy as a solution for traffic problems, was overlooked among traffic calming measures. In 1997, changes in the national traffic code provided a framework by which advocates could push more directly for the opening of one-way streets to cyclists traveling in the opposite direction. Nevertheless, the transition of many streets is an arduous political process to this day. These streets, in a way, remain a remnant of the traffic calming measures of the 1980s.

When we talk about sustainability today in terms of cycling, we are no longer simply speaking of reconciling economic, environmental, and social interests. Rather, we are talking about a reflexive process of policy development based on a grounded, context-dependent understanding of the dynamics of policy itself. This includes the contexts in which specific policy issues are problematized, specific groups of actors come together, specific understandings of how to enable mobility are debated and defined, and key mechanisms for promoting sustainable mobility are debated, decided upon, and institutionalized in practice. Institutionalization here refers to the key rules, norms, and institutions of policy-making as well as how practitioners and citizens "do" policy and "live" mobility on an everyday basis.

3 Conclusion

Cycling promotion in Munich provides an interesting case study that sheds light on how governance plays out in practice. The city has adapted new approaches to planning for cycling, as described above, that have led to significant changes in how cycling is lived and experienced. Whereas 20, 30, or 40 years ago the transportation sector discussed movement in terms of *traffic*, today it is discussed in terms of *mobility*, thus shifting the focus from modes of transportation to ways of getting around. Nevertheless, although Munich can be called a good example of sustainability policy in the transportation sector, the case also reveals the inherent power of institutions and everyday norms in planning. In particular, ideas concerning what is sustainable are not fixed in documents and guidelines but are produced, reproduced, and transformed by politicians, by the local administration, by interest groups, and by activists in political processes of agenda setting, policy-making, and implementation. Thus, in practice, sustainability is more often implemented in the context of political power than, for example, in the idealized terminology of an agreed-upon document, such as the existing policy documents on cycling in Munich. As described above, the efforts to integrate cycling into main traffic arteries have demonstrated how powerful social, physical, and planning structures can limit approaches to cycling promotion. In this way, developments in Munich illustrate the dynamics between governance structures and everyday political processes and help us better understand the opportunities and limits of governance for sustainable mobility.

What insights emerge from this review of governance in Munich? By considering how the dynamic between actors' practices and key social structures shapes such actions, we can develop a better understanding of the opportunities for and limits of efforts to shape or steer the direction of planning and practice in the transportation sector today. One key insight offered by a governance approach to promoting sustainable mobility is that it allows for a clearer analysis and consideration of the social, historical, and systemic factors steering the direction of change. By highlighting those socially constituted ways of doing things, we can identify where knowledge, expertise, and rules are expressed or taken for granted, and we can reflect on how, if, and to what extent these need to be reconsidered or revised. Of course, a governance approach does not provide the right answers, nor does it provide fixed models of "good governance." It is up to politics — that is, the dynamic interaction of private-public partnerships, political debate, protests, public participation, and closed roundtable sessions — to decide on what should change. Nevertheless, by reflecting on the embedded social structures that shape not only planning practice and everyday mobility but also the processes of political

debate and decision-making—such as who is allowed to speak — these previously taken-for-granted or "neutral" categories are called into question and critically examined. The key question of integrating bicycle infrastructure in main traffic arteries is no longer based on whether cyclists can reach their destination quickly, whether other routes are available, or even whether accommodating cyclists affects the flow of car traffic. Rather, such debate on integration needs to assess why cycling is not in this location, why cyclists are here not safe, what the norms and practices are that e.g. maintain flow of traffic in urban areas, and *if* and how these ideas (e.g. commuting via the private car) align with key goals and visions for sustainable mobility.

Sustainable mobility, as Meadowcroft points out, deals with larger questions of values and beliefs. This means that some people's definitions will prevail while those of others are silenced. Thus, it is not only important to consider *what* and *how* but also *why*. Who is defining sustainability and in what way — the media, academia, the public by referendum, or the private sector? What implications does this have for transportation planning and practice? As Meadowcroft (2007: 302; emphasis in original) eloquently elaborates:

> "But who is to do this 'steering'? In a fundamental sense, governance for sustainable development implies a process of '*societal self-steering*': society as a whole is to be involved in the critical interrogation of existing practices, and to take up the conscious effort to bring about change. Thus it involves not only actions and policies to orient development along certain lines, but also the collective discussion and decision required to define those lines. Value choices — about the kind of society in which we want to live, about the kind of world we want to leave to posterity — lie at the heart of governance for sustainable development. At base, it is not a technical project, although technical expertise is essential, but a *political* project. For, while the concept indicates issues that should be of concern, *its practical bearing cannot be established independent of the concrete life circumstances of a particular society* and the needs, interests, values and aspirations of its members".

In sum, a governance approach to sustainable mobility recognizes that efforts to realize this concept are inherently political, involving ongoing processes of definition, redefinition, and conflict. Nevertheless, it is by reflecting on the structures that shape such processes of definition and redefinition as well as on the nature of these processes themselves that we form a base from which to reflect on, critique, approve, or improve our governance practices, thereby critically assessing whether the direction in which we are going is where we truly want to go.

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Policies to Achieve Environmental Goals in the Built Environment

John E. Anderson

Abstract

The built environment is a primary source of environmental impacts. In particular, the building and transportation sectors are critical sources and thus have been extensively investigated. However, most research on environmental impacts of the built environment focuses on two scales of analysis: the building and urban scales. Consequently, inter-scale impacts are omitted, revealing a critical research gap. Therefore, a new category, called induced impacts, has been developed to capture the environmental impacts resulting from the interactions between the building and urban scales via transportation.

Using induced impact results in the urban region of Munich, this chapter outlines specific policy recommendations to achieve environmental goals. The work critically examines existing policies focusing on the built environment. The author then provides ten policy recommendations in six areas: government directives, building rating systems, urban-scale projects, urban form development, stakeholder action, and relating actions to environmental goals. The chapter focuses on existing policies at various levels (national, state, regional, and local) in Germany and the United States. Recommendations encompass various scales within the built environment: building, district, city, and region. The author outlines strategic actions to ensure a more holistic quantification of environmental impacts within the built environment — a prerequisite for achieving environmental objectives.

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1 Introduction

According to the Intergovernmental Panel on Climate Change, it is "extremely likely" that anthropogenic emissions are responsible for the increased atmospheric concentrations of greenhouse gases (GHGs) that are leading to climate change (IPCC 2014a). Environmental goals for climate change mitigation require the stabilization of CO_2 in the atmosphere, with an acceptable CO_2–equivalent concentration at 450 ppmv (parts per million by volume) (IPCC 2014a, Hansen et al. 2011). This level would correspond to a global average temperature increase of 2.0°C above pre-industrial levels, and it would require a 72% reduction in global CO_2 emissions by 2050 from the base year 2010 (IPCC 2014a). Attention is focused on CO_2 as it represents the vast majority of anthropogenic GHG emissions — 76% of overall GHG emissions in 2010 (IPCC 2014a).

In 2010, total greenhouse gas emissions were 49 Gt CO_2e for a global population of 6.9 billion people, or 7.1 t CO_2e per person (IPCC 2014a). However, median per-capita GHG emissions vary enormously between low-income countries (1.4 t CO_2e per person per year) and high-income countries (13 t CO_2e per person per year), using 2013 World Bank classifications of national income (IPCC 2014a). Achieving CO_2e stabilization at 450 ppmv (i.e., a 72% reduction of 2010 GHG emissions) would result in annual emissions of 13.8 Gt CO_2e. For an estimated population of 9.3 billion in 2050, this number represents just 1.48 t CO_2e per person.

2 Environmental impacts from the built environment

Within discussions on combating climate change, the built environment has been identified as a major source of energy use and accordingly of CO_2 emissions (IPCC 2014b). The building and transportation sectors accounted for 59% of global final energy use and were responsible for 54% of greenhouse gas emissions in 2010 (IPCC 2014b). Furthermore, CO_2 emissions are expected to increase by 50–150% in the building sector and by 100% in the transportation sector by 2050 (IPCC 2014b).

Considerable research has been conducted on reducing environmental impacts within the built environment, ranging from life-cycle assessment (Crawford 2011) to vehicle emission profiles (Reyna et al. 2015). However, as the present author has demonstrated in a previous review article, this research is strongly divided between two scales of analysis: individual buildings and the urban context (Anderson et al. 2014a). This research division is problematic for several reasons. First, it ignores the typical pattern of construction: new buildings in existing cities. Looking at

building-specific results ignores the building's surrounding urban context. Similarly, urban-level findings are of limited use, because the built environment of nearly all cities is thoroughly established and cannot be radically altered; major new urban-scale projects are very rare.

However, research is starting to address the gap in inter-scale analysis of the built environment. The author has presented a detailed literature review elsewhere (Anderson et al. 2014a). By way of brief summary, Stephan et al. (2012, 2013a, 2013b) developed a comprehensive life-cycle energy analysis framework to evaluate the multi-scale impacts of residential buildings, accounting for embodied, operational, and transportation energy. This framework has been used to reduce the total life-cycle energy demand of residential buildings (Stephan, Stephan 2014). Heinonen and Junnila (2011) expanded the typical analysis boundaries to account for consumption within the urban structure. Heinonen et al. (2013) then examined how lifestyles change with the level of urbanization and the resulting greenhouse gas implications of these changes. Fuller and Crawford (2011) analyzed the impact of development patterns on energy demand.

The author has also contributed to research on multi-scale analysis of the built environment (Anderson et al. 2015), including the introduction of a new impact category, called "induced impacts" and designed to capture the environmental impacts resulting from the interactions between individual buildings and the larger urban context. A detailed case study has determined the induced impacts for the urban region of Munich.

Based on these emerging results, a new research question emerges: what practical and policy recommendations can be derived from inter-scale analysis of the built environment in order to achieve actual environmental goals? This chapter seeks to answer that question. The next section presents the detailed results for the multi-scale analysis of the Munich urban region. After that, policy recommendations are presented, beginning with an explanation of the methodology used, followed by the identification of six policy areas where the results are applicable. Then each policy area is investigated in detail and specific recommendations are given. After a discussion of the study's findings and limitations, the conclusions are summarized and areas for future work are identified.

3 The significance of a multi-scale approach in the urban region of Munich

The category of impacts of the built environment referred to as induced impacts (Anderson et al. 2015) accounts for building embodied impacts, building operational impacts, transportation embodied impacts, and transportation operational impacts. Building embodied impacts include the embodied impacts of building materials, the construction process, and the demolition process. Building operational impacts comprise heating, hot water, and electricity use over the life span of the building. Transportation embodied impacts consist of embodied impacts for vehicles (i.e., automobiles, subway trains, trams, and suburban trains) as well as infrastructure (i.e., roads, public transportation tracks, tunnels, stations). Finally, transportation operational impacts stem from the operational phase of transportation (i.e., tailpipe emissions) for private and public transportation; nonmotorized transportation modes are assumed to have zero impact.

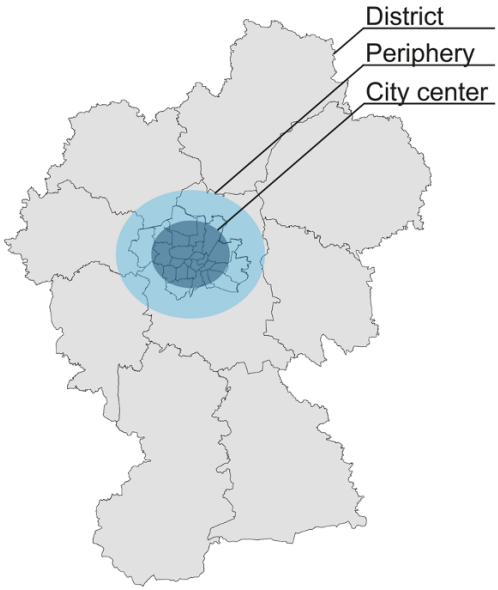

Fig. 1 Three locations within the urban region of Munich: city center, periphery, and districts (Anderson et al. 2015).

The author and his colleagues assessed these four impact groups using life-cycle inventory data (Anderson et al. 2015; Anderson 2014b: 202). They evaluated three locations within the Munich urban region: the city center, city periphery, and outlying rural districts (see Figure 1). The variation of locations allows for the assessment of changes in building type, building size, construction materials, building energy use, transportation modal split, transportation infrastructure, and urban form. A life-cycle-based methodology was applied to determine the variation in impacts at the three locations. The holistic findings for the three locations studied are presented in Figure 2.

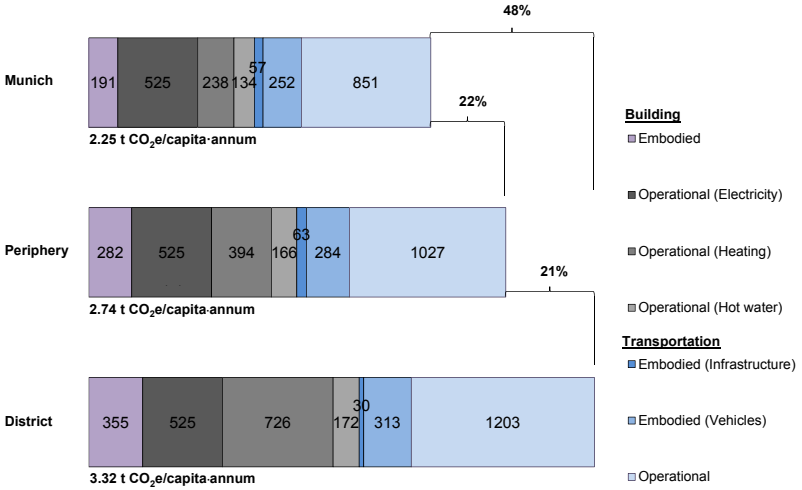

Fig. 2 Cumulative results of all environmental impacts for three locations within the Munich urban region: city center, periphery, and district (outside the city). The findings include induced impacts and illustrate the significant savings attained by city-center households. Units are kg CO_2e per person per year unless otherwise noted (Anderson et al. 2015).

The per-capita totals for each region, also shown in Figure 2, indicate that emissions per person in Munich city center are 22% lower than at the periphery and 48% lower than in the districts. In Munich, emissions arise from building embodied (9%), building operation (40%), transportation embodied (14%), and transportation operation (38%) impacts. Therefore, the induced impacts, captured through

transportation, represent 52% of all emissions. Had a holistic and comprehensive analysis not been carried out, over 50% of total emissions would have been missed. This result illustrates the necessity of multi-scale analysis. It should be acknowledged that embodied emissions may be slightly underestimated as the analysis used process data instead of hybrid analysis (see Crawford 2011 for more information).

Separate analyses were then carried out for various building types at each location (see Figure 3). The results illustrate that the city center has the lowest impacts given a constant building type. The multi-family house generates lower impacts than the row house, which in turn has less impact than the single-family house. The difference is due to building compactness, which results in an efficient use of materials and energy. In addition, the multi-family house has lower living space demand (in m^2/person) than the row house, while single-family houses have the highest demand.

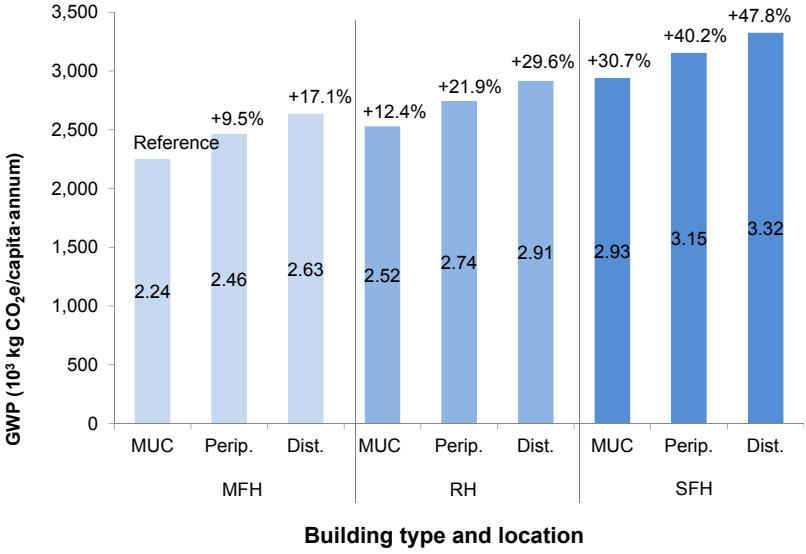

Fig. 3 Variation in greenhouse gas emissions for each building type at each location. The city-center locations (MUC) always have the lowest emissions for each given building type. Abbreviations are as follows: MUC = Munich city center, Perip. = periphery, Distr. = district, MFH = multi-family house, RH = row house, SFH = single-family house (Anderson et al. 2015).

These findings are comparable to those of Fuller and Crawford (2011), who found that transportation is the best way for inner-city residents to reduce their emissions. The importance of transportation was also shown by Stephan et al. (2013b), whose analysis found that embodied impacts were responsible for 21.6% of emissions, operational impacts for 42.4%, and transportation for 36.0%. These results again illustrate the crucial importance of incorporating transportation within a holistic analysis.

Research on induced impacts provides an integrated, multi-scale, and holistic means to capture environmental impacts in the built environment. The analysis of the Munich urban region demonstrates the need to include these impacts. But what policies and recommendations can be drawn from these findings? How can all stakeholders integrate recognition of induced impacts into their efforts to achieve environmental objectives? The following section explores the policy and practical implications of induced impacts.

4 Policy recommendations to achieve environmental goals

Innumerable steps have been taken to mitigate environmental impacts resulting from the built environment. However, we do not know if existing policies are adequate to fully address multi- and inter-scale impacts (i.e., induced impacts) or to achieve the required environmental goals (i.e., stabilizing the global temperature increase at 2.0° C). This section reviews common environmental policies for the built environment in light of the findings presented above on induced impacts. In addition, new policy recommendations are outlined to enable the incorporation of induced impacts into policy and practice. Only through the inclusion of induced impacts in practical applications will it be possible to meet environmental targets.

The recommendations cover six policy areas: government directives, building rating systems, urban-scale projects, urban form development, stakeholder action, and relating actions to environmental goals. Government directives, the first policy area, are undertaken at a variety of levels—global, national, regional, and local. These directives include both legal mandates and market-based incentive programs, along with numerous other governmental policy levers to achieve desired outcomes. Second, building rating systems include both mandatory and voluntary tools used to promote environmentally friendly practices in the construction sector. These systems *aim* to provide environmental improvements, although there is no guarantee that the anticipated improvements will actually result (Humber et al. 2007).

Third, urban-scale projects are large-scale activities undertaken within an urban context (e.g., the development of major new transportation systems or infrastructure, or a massive building construction project). Fourth, urban form development is concerned with changes in the structure of cities and the resulting impact on the environmental performance of the built environment. Fifth, stakeholder action refers to the actions of diverse stakeholders and how they affect environmental performance. Stakeholders in the built environment include, among others, engineers, architects, planners, developers, owners, builders, regulators, and investors. Finally, the policy area of relating actions to environmental goals offers significant potential for creating innovative policies in alignment with environmental limitations.

The following subsections explore these six policy areas in detail and offer new recommendations to mitigate environmental impacts. The discussion critically examines existing policies on environmental impacts within the built environment. As these policies vary greatly both between and within countries, the scope of analysis is delimited to two developed nations, Germany and the United States. Germany is chosen due to the numerous policy efforts undertaken to achieve broad-reaching environmental goals, and because the original case study of induced impacts was conducted there (Anderson et al. 2015). The environmentally conscious U.S. state of California and New York City are also evaluated. This juxtaposition of a European nation and the U.S. offers critical insights into differences in the built environment, urban form, transportation, government structure, and policy-making. Future work should examine developing countries as well, as significant growth in construction and urban migration is taking place in these nations, especially China and India.

4.1 Methodology

In each policy area, the methodology will be to review existing policies (based on the traditional mono-scale approach) and reevaluate them in light of the findings on induced impacts from the Munich case study and the scientific literature. This process results in new policy recommendations based on a holistic multi-scale approach to environmental assessment. The systemic truncation of existing policies due to their mono-scale approaches would be resolved through these more comprehensive policies.

4.2 Government directives

Government policy-making typically takes place through laws, regulations, and taxes, implemented at the global, national, state, regional, city, and local levels by a variety of institutions. In the realm of the built environment, extensive policies have been undertaken to mitigate environmental impacts. In Germany, the most important current environmental policy is the *Energiewende* (Energy Transition), which seeks to meet established climate change goals, reduce energy use, phase out nuclear energy, and increase the market share of renewable energy.

One primary tool to achieve the Energy Transition's environmental goals is the federal *Energieeinsparverordung* (EnEV), or Energy Saving Ordinance. EnEV prescribes maximum permissible levels of yearly primary energy demand and yearly hot water demand for residential buildings (EnEV 2009: 76). However, EnEV focuses solely on building operational impacts and omits any requirements for electricity use. Furthermore, embodied impacts (e.g., building materials, the construction process, and the demolition process), as well as impacts from the building's interaction with the surrounding urban context (i.e., induced impacts), are absent from EnEV. As EnEV is the environmental standard for buildings, this omission is significant if actual environmental goals are to be met. No other federal-level ordinance addresses these impacts.

García-Casals (2006) showed that, in Spain, building energy regulations at both the EU and national levels had serious limitations and could not achieve significant reductions in building energy consumption. Furthermore, Szalay (2007) strongly criticized national building regulations in Europe for taking only operational energy into consideration while ignoring all other life-cycle phases, and she called for inclusion of additional phases within building regulations. Finally, Stephan et al. (2012) similarly challenged the limited analysis focus and supported the inclusion of indirect requirements in assessment. These observations motivate the first policy recommendation.

- Policy recommendation 1: Federal-level building standards must be expanded beyond operational impacts (i.e., heating and hot water) to include embodied and induced impacts in the built environment.

Within the framework of the Energy Transition, the German federal government is investing significant efforts into electric mobility (e-mobility). The federal government has set a goal of becoming a market leader in this field and has prepared a "National Development Plan for Electric Mobility." Its primary goal in this regard

is to reduce tailpipe CO_2 emissions from the operational phase of transportation (Bundesregierung Deutschland 2009: 53).

The crucial factor in the ecological balance of electric mobility is the source of (and the resulting emissions from) the electricity production used in powering vehicles. Again, a focus on the operational phase is observed. As with the environmental performance of buildings, little attention is given to the embodied impacts of electric vehicles. A limited focus only on tailpipe emissions (i.e., the transportation operational phase) has been shown to be misguided, and e-mobility can even lead to net emission *increases*. The source of the electricity (e.g., coal-fired power plants) and the tremendous material needs for batteries and other parts can quickly negate any reduction of tailpipe emissions (Helms et al. 2011: 54). In addition, the potential for related changes in urban form (e.g., shifting from multi-family houses with public transportation to suburban single-family houses with e-mobility) raises serious questions about whether e-mobility strategies will achieve any net emission reductions at all.

Stephan et al. (2013) included transportation impacts, including infrastructure, in the assessment of low-density neighborhoods in Australia. Heinonen et al. (2013) expanded the analysis of transportation impacts to include embodied emissions from vehicles. These authors' work illustrates the importance of extending the analysis boundary for transportation beyond tailpipe emissions.

- Policy recommendation 2: Transportation analysis must move beyond simplistic operational impact analysis to holistically analyze embodied impacts of the vehicles as well as potential changes in urban form.

4.3 Building rating systems

Along with governmental directives, the emergence of building rating systems has drastically altered the building sector in recent decades. These systems are often nationally focused (LEED in the United States, DGNB in Germany, Greenstar in Australia, BREEAM in the United Kingdom), but are also applicable across national borders (USGBC 2009a: 874; DGNB 2012: 32; GBCA 2009; BREEAM 2011: 451). These market-based systems offer third-party certification for environmentally friendly buildings; new rating systems also focus on infrastructure and city neighborhoods (USGBC 2009b: 660; University of Washington 2011; Kesselring, Winter 1994: 16). As certification is generally voluntary (although some governments require certification for publicly funded projects), the appeal of achieving certification is linked with the marketing of a project's positive environmental features.

While these rating systems have significantly advanced environmental design, two main problems must be addressed. First, although the rating systems claim to lower the environmental impacts of a project, research has found that they can actually *increase* net impacts (Humbert et al. 2007). Newsham et al. (2009) found that 28% to 35% of LEED buildings used more energy than conventional buildings. Scofield (2009) reanalyzed the same buildings considered by Newsham et al. (2009) using total energy and showed that LEED-certified office buildings do not offer any energy savings.

Second, these rating systems have strict assessment boundaries. Building systems focus only on the building, ignoring the urban environment, transportation, and induced impacts (USGBC 2009a). Similarly, infrastructure systems ignore interactions with individual buildings as they focus solely on a single infrastructure project (University of Washington 2011: 471). The following two recommendations apply to building rating systems.

- Policy recommendation 3: Rating systems must quantitatively assess environmental impacts of a project using a life-cycle approach rather than relying on assumed environmental benefits.

- Policy recommendation 4: Rating systems must move beyond scale-specific analysis to integrate induced impacts resulting from interactions between the building and urban scales.

Goldstein et al. (2013) similarly identified the gap between assessment of buildings on the neighborhood, city, and regional scales, calling for multi-scale assessment to determine true environmental impacts.

4.4 Urban-scale projects

The third action area of policy recommendations concerns large urban infrastructure projects. Even though these projects entail extensive planning and environmental reviews, induced impacts are typically overlooked. Two examples will be examined in detail: the Second Trunk Route for the suburban train in Munich and California's high-speed rail system.

The Second Trunk Route (German: *Stammstrecke*) is a proposed route for the suburban train running underground through Munich's city center. The route is planned to run parallel to the existing main route in order to relieve current overcrowding on this route and meet future projected increases in travel demand

(DB 2011). Although improving the service and capacity of the public transportation infrastructure can also reduce the overall environmental impact of the built environment, this is not the primary motivating factor for the project. However, the resulting changes in induced impacts could and should be quantified in order to determine the project's actual environmental footprint.

The California High-Speed Rail project is a proposed rail network from San Diego to Sacramento, connecting the state's major economic areas (CHSRA 2012: 22). This major infrastructure project is driven by the need to expand California's transportation infrastructure to serve the state's expanding population. Potential induced impacts from this transportation infrastructure project include modal shift and urban form changes. In addition to shifting travel away from automobiles and air travel, this project could also encourage public transportation use at the local level, in turn leading to changes in urban structure in the areas surrounding the rail stations as well as within the larger cities. These results would be the induced impacts associated with construction of the new transportation system.

When transportation system expansion options (such as airports, freeways, and traditional rail) are compared, high-speed rail is presented as the environmentally friendly alternative. Chester and Horvath (2012) found that high-speed rail, given its high ridership, does in fact provide significant savings over other infrastructure projects. Their extensive analysis accounted for both tailpipe emissions (i.e., transportation operations) and infrastructure (i.e., embodied impacts). In addition to assessments of this type, the resulting changes in the urban form of cities should be extensively reviewed via an induced impacts analysis so as to complete a comprehensive review of all infrastructure options. It is likely that such a review would show the drastic effects in reducing GHG emissions achieved through the secondary effects associated with high-speed rail (e.g., increased density around stations, more pedestrian-oriented cities, and lower automobile ownership rates). These two projects lead to the next recommendation.

- Policy recommendation 5: Large urban infrastructure projects should quantitatively assess induced impacts to reveal the actual environmental impact of such projects.

4.5 Urban form development

Urban form development is a critical factor determining the environmental performance of the built environment and is closely related to urban infrastructure projects. Identifying the induced impacts of urban form is a highly complex topic. Here it will be considered in relation to environmental planning in New York City, climate mitigation in California, and urban planning strategies.

At the metropolitan level, New York City is implementing *PlaNYC: A Stronger, More Resilient New York*, an environmental program intended to reduce GHG emissions by 80% as of 2050 through 257 separate initiatives. Since energy use by buildings accounts for almost three-quarters of emissions in the city, *PlaNYC* has a strong policy focus on the built environment. The three strategies to reduce building emissions are energy efficiency measures, reducing energy consumption, and reducing emissions from power supply sources (Shorris 2014). However, policymaking is clearly focused only on the building operational phase. No attention is paid to embodied impacts, induced impacts, or changes in overall urban form. At the same time, the city is dramatically increasing GHG emissions through its off-street parking requirements. These city regulations lead to higher automobile ownership rates, more driving, and a more suburbanized urban form (Weinberger et al. 2008). By increasing GHG emissions in these ways, New York City policymaking is negating the primary objective of *PlaNYC*. This dichotomy between the city's environmental goals and its actual planning requirements leads to the following recommendation.

- Policy recommendation 6: Cities and metropolitan areas must determine the environmental consequences of policies impacting the urban form (e.g., parking requirements) in order to meet stated environmental goals.

This recommendation is supported by Rickwood et al. (2008) in their detailed review of urban form and energy use.

In California, environmental policy is driven by the Global Warming Solutions Act of 2006 (AB 32), which aims to reduce GHG emissions from all sources in the state. Far more progressive than any federal policy in the United States, this state-level initiative is a cap-and-trade regulation focusing on six sectors to achieve the desired reductions: (1) transportation, fuels, and infrastructure, (2) energy generation, transmission, and efficiency, (3) waste, (4) water, (5) agriculture, and (6) natural and working lands (CARB 2013: 123). Of particular interest is the absence of attention to urban form. Although aspects of urban form are indirectly included in the outlined strategies, these references are likely insufficient to address

the major emissions resulting from California's highly suburbanized and automobile-dependent development. This omission fuels serious doubts as to whether the strategy's stated focus could possibly meet the intended GHG reduction goals. Thus the resulting policy recommendation is as follows:

- Policy recommendation 7: State-wide climate change mitigation policies must include urban form as a central strategy to reduce greenhouse gas emissions.

Finally, induced impacts should be integrated into urban planning. In her seminal work, *The Death and Life of Great American Cities*, Jacobs (1961: 458) outlined four fundamental requirements for a vibrant and functioning urban environment: mixed use, short blocks, buildings of various ages, and density. These criteria can be quantitatively assessed to reveal their importance in the environmental performance of a city. For example, maintaining buildings of various ages (by protecting rather than replacing older structures) has numerous positive environmental aspects. First, the embodied energy of the building has already been invested and only minimal maintenance is required. Second, preserving old buildings (e.g., in San Francisco and Munich) often results in an urban form that is denser than new construction. Even new construction within cities is burdened with excessive open-space requirements, resulting in lower density than in many historic downtown neighborhoods. Finally, these neighborhoods are often well served by public transportation and tend to be friendly to nonmotorized transportation modes. These findings motivate the next policy recommendation.

- Policy recommendation 8: Quantify fundamental aspects of urban design (e.g., mixed use, short blocks, building age, and density) via induced impacts.

4.6 Stakeholder actions

Numerous actors are involved in the development of the built environment. However, each actor has its own set of goals and interests, which may be in conflict with those of another actor. As shown in the induced impacts research, addressing environmental impacts in the built environment requires interdisciplinary work. For example, the success of Munich's Second Main Route in reducing environmental impacts depends on the role of additional stakeholders beyond the local transportation agency. The integration of this new route into the city and surrounding areas offers the potential to dramatically reshape mobility patterns. However, such strategies must be holistically integrated. Expanding ridership into the city via public

transportation and then integrating nonmotorized transportation within the city core is one strategy to reduce induced impacts within the city. This also requires that buildings constructed in the city center offer pedestrian amenities rather than automobile services such as on-site underground parking. Thus, transportation planners and building designers must work in accord to achieve a common goal.

- Policy recommendation 9: All stakeholders involved within the built environment must work together in an interdisciplinary manner in order to mitigate induced impacts.

This recommendation is supported by Stephan (2013), who called explicitly for an integrated stakeholder approach to the environmental management of the built environment.

4.7 Relating actions to environmental goals

As discussed at the start of this chapter, specific recommendations for greenhouse gas emissions have been clearly articulated by the international scientific community. Climate change mitigation goals have been defined both on a global level (i.e., temperature increase of no more than 2.0° C) and per capita (1.48 t CO_2e per person) (IPCC 2014a). However, environmental impacts in the built environment are typically measured in terms of reductions (e.g., x% CO_2 savings in construction materials). This mismatch in analytical metrics is problematic, as actions taken cannot be compared with required objectives. Furthermore, this approach may lead to the false belief that sufficient actions have been undertaken, without any actual understanding of the net balance of emissions. As the case study of Munich illustrated, the impacts from the built environment range from 2.24 to 3.32 tons of CO_2e per person per year. These emissions account only for the built environment (i.e., building embodied, building operational, transportation embodied, and transportation operational impacts). Further impacts from other sources (such as personal consumption and long-distance travel) must also be included in an exhaustive analysis (Treloar et al. 2000; Crawford, Pullen 2011; Heinonen et al. 2013). However, the results show that impacts for the built environment are already above prescribed emission limits. Consequently, the final recommendation is as follows:

- Policy recommendation 10: Assessment of impacts in the built environment should be quantified on a per-capita basis to enable comparison with international environmental objectives.

5 Discussion

This chapter reviews multi-scale environmental assessment in the built environment. The author has presented findings from his analysis of the Munich urban region in addition to the work of other researchers in this emerging field. The chapter contributes to existing knowledge by translating this scientific research into practical policy recommendations. This is an important step, as such research is often conducted outside the realm of practicing professionals and policymakers and therefore may have limited practical impact. The policy recommendations presented here enable the integration of induced impacts into practice, thereby furthering the achievement of environmental goals.

Of course, this work is still preliminary. The author only provides policy recommendations and does not explore their actual implementation and resulting effects. In addition, assessing the political feasibility of the policy recommendations is outside the scope of this chapter. Furthermore, the chapter focuses only on the built environment. Impacts from numerous other sources, such as personal consumption and long-distance travel, are not considered.

While the research has presented detailed results on induced impacts, additional research in the field of multi-scale analysis should be undertaken. As a next step, a life-cycle assessment of the policy recommendations should be carried out, so as to identify those policies with the greatest potential to reduce environmental impacts. In addition, initial political and administrative efforts to implement these policies are crucial. Only through the successful execution of such policies can real improvements in the environmental performance be realized.

6 Conclusions

The paper has reviewed the importance of quantifying induced impacts — that is, the environmental impacts resulting from the interactions between individual buildings and the larger urban context. Assessment of these impacts has been largely absent from analyses of the built environment; the author's research illustrates a framework to capture these impacts. Drawing also on prior research related to induced impacts, the chapter has explored six policy areas and offered ten specific policy recommendations to address these impacts in practice. These recommendations offer concrete, actionable steps that should be undertaken to ensure consideration of induced impacts within the built environment. The chapter thus offers valuable

practical insights for practitioners interested in meeting environmental goals within the built environment.

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Part II
Specific Target Groups

Sustainable Tourist Mobility: Implications for Urban Destination Management

Diem-Trinh Le-Klähn

Abstract

Worldwide concerns about climate change and sustainable development have spawned a great interest in mitigating the negative environmental impacts from tourism. Transportation is an essential element of the tourism system but is also the major contributor of emissions. Therefore, sustainable tourism must link to sustainable mobility. Based on a case study of tourist use of public transportation in Munich, this chapter discusses policy implications for transportation and tourism management. Marketing strategies for promoting public transportation in tourism, relevant not only to Munich but also to other cities with similar conditions, are presented.

1 Introduction: The importance of sustainable tourist mobility in urban areas

Throughout human history, people have been traveling for leisure, religious, and business purposes. Despite wars, terrorist attacks, natural disasters, and economic crises, international travel has continued to grow. In 2013, 1.087 billion international tourist arrivals were recorded worldwide, an increase of 5% over the previous year and of 24% when compared with 2008 (United Nations World Tourism Organization: UNWTO 2014b). Tourism provides various economic and social benefits to host communities, such as employment and business opportunities, economic diversification, and multiplier effects (e.g., Archer et al. 2005; Gunn, Var 2002; Lee, Brahmasrene 2013; Milman, Pizam 1988). However, it can also have negative impacts such as cultural erosion, crime, and damage to the environment (e.g.,

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Amelung, Nicholls 2014; Archer et al. 2005; Deery et al. 2012; Liu et al. 1987; Orams 2002; Scott et al. 2012). As tourism is one of the largest industry sectors in many economies, popular destinations around the world are concerned with reaping the economic benefits of tourism while also ensuring healthy development of the local community. Sustainable tourism has thus emerged as an important concept in several destination development plans (Gunn, Var 2002; Honey 2008).

Sustainable tourism "takes full account of its current and future economic, social, and environmental impacts, addressing the needs of visitors, the industry, the environment, and the host communities" (UNWTO 2014a). Although the term is ambiguous (Butler 1999), the ultimate aims of sustainable tourism are understood as mitigating the negative impacts of tourism while ensuring a positive experience for stakeholders (i.e., the tourists, the communities, and the involved industries). Sustainable tourism development involves multiple aspects, but is particularly associated with environmental issues (Mowforth, Munt 2009).

Many tourism activities contribute to changes in land use, affect the ecology, and increase air and noise pollution (e.g., Cole 2012; Hall, Lew 2009; Honey 2008; Mowforth, Munt 2009; Tyrväinen et al. 2014). Nonetheless, as most tourism-related emissions result from transportation (Dubois et al. 2011; Høyer 2000; Peeters, Dubois 2010), sustainability in tourism depends heavily on sustainable tourist mobility. Especially in urban areas, sustainable tourist mobility has become vital due to the high pressure of growing population, limited space, increasing traffic congestion, and air pollution. Simultaneously, it is important for destination management and tourism service suppliers to provide tourists with satisfactory experiences, including their experience of transportation infrastructure, and the accessibility of sites and attractions.

Using Munich as a case study, this chapter discusses the mobility of tourists at an urban destination. It provides an overview of tourism in Munich and highlights the importance of providing tourists with sustainable transportation choices. Next, a summary of the research method and findings is presented. The chapter concludes by considering policy implications in sustainable tourism and transportation.

2 Tourism in Munich

The German economy received €278.3 billion in total revenue from tourist expenditures in 2012 (Howath HTL 2014). As the second most visited city in Germany (after Berlin), Munich enjoyed revenues of €7.4 billion in 2012 (City of Munich 2013). Munich attracts a great number of tourists every year owing to its rich culture and

year-round surfeit of exciting events and festivals. The number of tourists visiting Munich has been increasing in recent years and has reached 6.3 million in 2013 (Table 1). The city's tourist profile indicates a relatively equal balance of domestic and international visitors – 54.65% to 45.35%, respectively, in 2013 (GNTB 2014).

Tab. 1 Tourist arrivals in Munich from 2010 to 2013 (City of Munich 2014)

	2010		2011		2012		2013	
	Count	%	Count	%	Count	%	Count	%
Domestic	3,131,210	56.20	3,376,697	56.93	3,375,014	55.03	3,444,616	54.65
International	2,440,068	43.80	2,554,355	43.07	2,757,772	44.97	2,858,338	45.35
Total	5,571,278	100.00	5,931,052	100.00	6,132,786	100.00	6,302,954	100.00

Since Germany has become an increasingly popular destination for travelers from across the world, Munich also anticipates significant tourism growth. As increasing number of tourists share space and facilities with local residents, it has become even more urgent for tourism and transportation planners to provide efficient transportation and access to tourist sites while still maintaining sustainable development for the city. To achieve sustainable tourist mobility policies and strategies, it is necessary to understand tourist travel behavior. Therefore, visitor surveys can provide policymakers with important and useful information.

3 The surveys

3.1 Research objectives and data collection

To understand tourist travel behaviors, transportation preferences, and use of public transportation in Munich, two visitor surveys were conducted in 2012 and 2013 as part of the author's doctoral research (Table 2) (Le 2014). The first survey had two major objectives: (1) to discover visitors' motivations for using or not using public transportation and (2) to measure visitor satisfaction with public transportation and identify the factors influencing satisfaction. The second survey examined visitors' mode choices and areas visited during their time in Munich, attempting to identify (1) the factors influencing these two decisions and (2) whether the two sets of decisions are related. Self-completed questionnaires were used in both surveys.

Tab. 2 Surveys on visitors' use of transportation modes in Munich

Survey	Year	Focus	Sample size	Survey sites
Survey 1	2012	Use of public transport	466	Selected tourist attractions
Survey 2	2013	Transportation mode choice	474	Central train station, central bus station, airport

3.2 Respondent profiles

The survey questionnaires were provided in multiple languages, and participants were recruited at random. Survey assistants approached potential respondents at the study sites and invited them to participate in the surveys. Those who agreed to participate were given questionnaires to complete. In both cases, the samples present similar profiles to that of the general tourist population in Munich, with some minor deviations (City of Munich 2014). Most respondents were from younger age groups (18 to 40 years old), well-educated, and in good physical condition. Most survey participants were repeat visitors to the city and were on vacation trips. However, the two samples differed considerably in terms of place of residence; international tourists dominated the first sample, whereas the second survey sample included approximately equal number of German and international. The most likely reason for this difference was the nature of the data collection sites, as the first survey was distributed at major tourist attractions whereas the second one was administered at transportation hubs. A closer look at the data showed that most international tourists were on vacation, whereas more of their domestic counterparts were visiting friends and relatives or were on business trips. Detailed demographic information on the respondents is provided in Table 3.

Tab. 3 Respondents' demographic characteristics

Category	Characteristics	Survey 1 (%), n = 466	Survey 2 (%), n = 474
Gender	Male	49.0	52.0
	Female	51.0	48.0
Residence	Germany	23.0	52.1
	International	77.0	47.9
Age group	<18	3.0	1.5
	18–29	35.4	41.4
	30–39	18.2	24.7
	40–54	18.2	22.4
	55–64	17.6	7.2
	65+	7.6	3.0

3.3 Summary of main findings

Findings from the two surveys have been previously published (see Le-Klähn et al. 2014; Le-Klähn et al. 2014a, 2014b). The main findings are summarized as follows:

- Most of the tourists in Munich (almost 80%) used public transportation at some point during their time in the region.
- Tourists' decision to use public transportation is influenced by several factors including socio-demographic characteristics, trip-related characteristics, destination features, and mode quality evaluation. Public transportation was more likely to be used by well-educated and overnight visitors, who also tend to be more price-conscious.
- Tourists are motivated to use public transportation for several reasons, including its drive-free benefits, traffic reduction, advantages of local public transportation, and car unavailability. On the other hand, public transportation use is discouraged by inconvenience and restrictions, lack of information, disadvantages of public transport, and personal preferences. Environmental concern is not a major element in tourist decisions on the transportation mode used.
- Most visitors were relatively satisfied with public transportation services in Munich. However, some areas were identified as needing improvement, such as prices, facilities at train stations and bus stops (e.g., seats in waiting areas, toilets, drinking water fountains), and system information.
- Tourists use public transportation most frequently for travels within the city and suburban areas. For trips to more remote attractions such as the Alps Mountains and lakes, a car is also commonly used.

Based on these findings, the following section discusses implications for sustainable tourist transportation policies in urban areas.

3.4 Implications for sustainable tourist mobility policies

The results of these surveys suggest important implications for transportation planners. First, public transport operators and transportation planners tend to focus on the sustainable aspects of alternative travel modes such as buses, subways, and cycling. However, findings from the surveys indicated that environmental concerns were not an important factor in tourists' decisions. Rather, convenience and price were identified as most important. Therefore, strategies to promote sustainable

transportation modes should focus on the convenience, comfort, and affordability of the modes, rather than on their eco-friendly characteristics.

Second, it is unlikely that a public transportation system could connect all tourist sites. Some sites of interest are located in remote areas inaccessible by public transportation. Cycling is another potential sustainable replacement. A combination of trains and a bike-sharing system should be considered in transportation and infrastructure planning. However, more research into cycling tourism is needed to better understand this option's potential.

Finally, integrated planning is very important in tourism and transportation planning. Transportation management involves multiple disciplines. Determining and implementing sustainable strategies requires the involvement of multiple stakeholders (Lumsdon, Owen 2004). The concerned parties are interdependent, and thus, cooperation among them is critical for successful sustainable development (Regnerus et al. 2007). Moreover, both stakeholders' and tourists' views should be considered when planning for sustainable tourism development. Thus, frequent market research to provide updated information on tourist behaviors and expectations is necessary.

To attract more visitors to use public transportation, marketing strategies should focus on the following aspects:

- *Targeting the right visitors.* Whereas public transportation users in rural areas are mostly middle-aged or the elderly (Dickinson, Dickinson 2006), city visitors who use public transportation are often younger. Day-trippers are less likely to use public transportation than those who stay longer. Public transportation is also more used by leisure tourists than by those who are visiting friends and relatives.
- *Offering attractive prices and packages*. Public transportation operators should consider fare promotions and special ticket schemes for visitors. Off-peak day tickets, special prices for the elderly and students, and group tickets are some potentially attractive options for tourist passengers. In addition to direct strategies to promote public transportation, sustainable tourist mobility could include other measures such as parking restrictions, car closures, and incentives for those who leave their cars behind.
- *Improving service quality.* Quality should be the chief priority for all products and services. Passengers using public transportation expect high service quality; however, most public transportation systems were built to cater to residents, and thus, the services should be modified and customized to better accommodate visitors' needs. For example, the focus of marketing strategies for tourist transportation should be on visitors' experience rather than on the mode selected.

Advantages of public transportation, such as a relaxed and carefree ride, scenic views, and freedom of movement, should be emphasized.

- *Making information about the city public transportation network widely available and accessible*. Lack of information is often a reason why tourists do not use public transportation. Hence, it is important to make brochures and leaflets on the city's public transportation network readily available at tourist information centers and lodging accommodations. In addition, real-time information should be accessible through mobile phone applications and the Internet. The information must be available in widely used languages such as English and Chinese in addition to the local language.

4 Conclusions

From a destination management perspective, three concerns are most important: (1) providing sufficient, effective, and accessible transportation for both local residents and tourists, (2) maintaining (environmental) sustainability, and (3) maintaining and promoting the destination's image. Public transportation, that offers advantages such as lower cost for passengers, less demand for precious space in congested cities, greater energy efficiency than cars (Filimonau et al. 2014; Peeters et al. 2007), and more social engagement and interaction opportunities (Stradling et al. 2007), is often considered a key to sustainable urban development. For similar reasons, public transportation has a great potential to support tourism. Furthermore, despite being restricted under some circumstances, cycling is an increasingly popular sustainable transportation mode as well as a tourism activity in itself. Therefore, public transportation and cycling should be highlighted in planning for sustainable tourist mobility. This chapter has summarized data on tourists' use of public transportation in Munich and some important implications of the findings for tourism transportation management policy in urban destinations. In sum, to attract tourist users, public transportation operators should offer attractive price packages, strive to deliver excellent service quality, and feature on-board benefits in their marketing strategies. Furthermore, information on public transportation should be made widely available and accessible to tourists. Finally, more attention should be given to the development of rail-bike connections to enhance visitors' mobility and accessibility at destinations.

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Corporate Mobility: When and Why Does it Become a Burden?

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Abstract

People's everyday lives and their working worlds in particular are deeply structured by mobility. People must commute, make business trips and often switch between several workplaces. Mobility is a basic requirement in today's modern and highly connected world.

Employees have to deal with this challenge and must plan and coordinate business trips. They have to be flexible and should be able to manage unforeseeable events. They have to keep in touch with their homes and their colleagues when being mobile, while remaining innovative and highly productive. Corporate mobility requires time and effort to cope with such mobility patterns. However, travel conditions often remain very unclear, and employees have to find individualized ways to maintain their mobility requirements. Studies and reports indicate that corporate mobility has an impact on work-life balance and causes stresses and strains.

First, this chapter points out the factors that contribute to alleviate the stresses and strains involved in commuting, business travel, and changing workplaces. Beyond the mobility-related conditions, working conditions as well as social and personal conditions play an important role in maintaining mobility requirements. Second, the chapter shows the impact of corporate mobility in relation to work-life balance conflicts. In summary, the chapter reflects the specific requirements for employees to remain mobile *to / from work* or *mobile at work* in a healthy and socially sustainable mode.

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1 Living and working in a mobile and connected world

People's everyday lives and, in particular, their working lives, are deeply structured by mobility. For their jobs, people have to commute, make business trips, and often switch between several workplaces. To be mobile is a basic requirement in today's modern and highly connected world (Boltanski, Chiapello 2003; Urry 2007).

People are mobile as long-distance commuters, shuttlers, or movers *for their work* (Limmer 2004; Schneider et al. 2002). They are *mobile to / from work*[1]. In addition, *during their work*, they have to be on the move for meetings with clients and business partners, for visits to international production locations and workplaces, and for finding new markets (*mobility at work).*

Corporate Mobility[2] is not a new phenomenon. In the building sector, for example, people always have to move from one workplace to another. But the intensity and the quantity of corporate mobility have increased: nearly "every fifth employee is occupationally mobile" (Ruppenthal, Lück 2009; translated by the author). Field managers, service technicians, and construction workers are more often on the move. Beyond that, research studies refer to the rise of commuting time and length (Haas, Hamann 2008; Haas 2012; Gräbe, Ott 2003; Lyons, Chatterjee 2007). For example, average commuting time increased by 8% in the period from 1999 to 2007 in Munich (Guth et al. 2010). In addition, business trips still occur frequently despite the advances in communication technologies. These technologies cannot substitute for face-to-face contact; instead, they reinforce it (Haynes 2010; Urry 2007). The extension of the value-added chain —that is, globalization and internationalization — cause an intense physical mobility of goods and people along with the virtual mobility of information.

In everyday life, people have to deal with these mobility requirements. Despite local congestions in metropolitan areas and long commuting times, employees have to commute to their workplaces every day. While being productive and innovative on a business trip, they have to manage unforeseeable events and keep in contact with their colleagues and family. They therefore need acquired competencies and skills to cope with these challenges; they learn while on the move. In addition, they

1 *Mobility to / from work* means: the journey to work, including long distance-commuting or weekly-commuting (shuttles); *mobility at work* means here: mobility on behalf of the company –, and ideally during the working timework hours, e.g., business travel or changing workplaces.

2 In this chapter the terms 'corporate' and 'work-related' mobility are used synonymously. They are used to illustrate, that the mobility requirements based on the company and generated out of the work. These terms exclude relocation, i.e., movements in order to get a job.

need a corporate framework which enables them to be successful in their job while at the same time being aware of their physical and psychological health. Work-related mobility has an impact on an individual's work life and private life. Work-life conflicts and related stresses and strains are two possible effects of a mobile life (Schneider et al. 2002; Stutzer, Frey 2008; Schier et al. 2011). However, mobility always enables people to live their desired life, to meet their job expectations, and to be physically mobile (Schneider et al. 2002; Lyons, Chatterjee 2008). Corporate mobility is an ambivalent and complex concept for employees; it's a challenge both for mobile employees and enterprises in a globalized world.

Companies are starting, quite hesitantly, to develop mobility management strategies. For this, they are adapting the mobility management strategies developed for cities and regions, whose objective is ecologically feasible and economical traffic management, starting with travelers' demands. Social aspects are included here, but are not systematically elaborated upon. Furthermore, the guidelines of corporate mobility are often very unclear. Thus, managing mobility involves the processes of individualization (Vogl, Kratzer 2015). Employees have to find individualized solutions on their own while being required carry out work responsibilities successfully.

This chapter wants to open up the possibility of integrating corporate mobility management, which includes aspects of physical and mental wellbeing and respects a balanced relation between work and private life. Therefore, the chapter discusses stresses and strains due to work-related mobility for employees. First of all, the chapter begins with a description of the specific socially sustainable approach of this research (2), before it introduces mobility management as a tool for transportation planning and decision-making (2). It then presents results of a current research project with data from enterprises in the Metropolitan area of Munich (3). On one hand, factors related to stresses and strains caused by corporate mobility are identified (4.1); on the other hand, the impact of corporate mobility on work-life conflicts is discussed (4.2). In a final step, this chapter discusses the results by reflecting on the specific requirements for employees (5), and provides an outlook for a reshaped mobility management approach (6).

2 Sustainable mobility for mobile individuals

This chapter focuses on the perspective of employees, who have to be mobile due to work-related requirements. What does it mean for those people to be mobile in a sustainable way? What do they expect from their mobile life and what crucial points must be dealt with?

To respond to these questions, the chapter refers to the mobil.LAB-group definition of "Sustainable mobility," which relays together the Brundtland-definition on Mobility:

> "Sustainable mobility ensures the individual fulfillment of basic needs and activities located in different places without harming the environment, economy, or society, whether now or in the future. (…) Instead, it should be safe for all users and therefore minimize any type of negative effects on individuals, communities, the private sector, and the environment." (mobil.LAB 2014)

This last sentence is important when looking at the work-related mobility of employees. From an individual viewpoint, people expect to be mobile in a healthy and social embedded way. This means safe transportation modes, accessibility, and modes of choice — being able to choose one's way of being (im-) mobile. Mobility helps to enable individuals to participate in all aspects of society; it goes beyond just moving. With regard to the work context, mobility becomes a requirement which people have to cope with apart from their private life. Thus, work-related mobility has its impact on work-life balance as well as on physical and mental wellbeing. There are long-term implications on health to be considered. There is evidence which suggests that workers underestimate the effect of changes in commuting time on well-being in the short term but not in the long term (Stutzer, Frey 2008).

"Sustainable mobility" in this context means making people mobile in a healthy way, along with their whole working life. It also means maintaining a personal work-life balance and maintaining vitality, employability, and motivation.

3 Existing concepts of mobility management

"Transportation Demand Management" or "Mobility Management" is a concept in transportation planning and "decision making" that aims to solve the problem of increasing traffic in a demand-oriented way. The central point of the management perspective is the *demand* for the mobility of actors and participants in the traffic field. When the traffic system reaches its capacity limit, environmental and ecological harm is the consequence. Neither goods nor people can be transported well in matters of mobility costs and travel time, occupational safety, and ecological aspects. The concept intends to change individual's mobility behavior in an ecological and social way, while also considering their mobility demands.

More than 40 million employees are mobile everyday due to their work, and the variety of ways to commute to and from work create potential for appropriate

traffic planning by communes and companies (Scharnweber 2012). Companies generate traffic and become aware of this traffic and transportation challenge. Transportation of people and goods is, increasingly, an issue of cost. At the same time, unintended side effects like traffic jams and parking spaces must be taken into account. Companies are one of the players in the urban und transportation planning field, along with communes, cities, regions, and people. Therefore, they have started to adapt the mobility management approach for their own needs. However, not every company has a mobility management strategy.

Corporate mobility management focuses on the economic and ecological impacts of corporate transport, considering the "social welfare" of employees. Corporate mobility management mainly focuses on movement, for example manages the way from one working place to another, controls the fleet, and regulates the choice of transport modes. Business trips and trips to other working places are regulated under traffic-related aspects. Conditions of work, such as workload and/or personal issues, are not systematically included in this concept.

Mobility management is a serious and essential concept to make mobility and transport more sustainable in cities and regions. To realize, apart from the economic and ecological factors, the *social* aspect of *mobility to / from* and *at work,* the complexity of working life, and mobility of mobile individuals has to be discussed within the perspective of the individuals employed.

4 When does corporate mobility become a burden?

For the working population, work-related mobility is part of daily life. It is a necessity and a corporate imperative (Kesselring, Vogl 2010). To cope with work-related mobility requirements is a preconditioned task, which can lead to an imbalance between work and private life. Corporate Mobility is a complex phenomenon, which comprises the way to work, business trips, and the changing workplaces while being employed in one enterprise.

The main hypothesis is this: when work-related mobility becomes a burden, the causes are not limited to the conditions of the mobility itself, or to be more precise the conditions of movement, such as the duration or the frequency of the trips. Work conditions and social/personal conditions also play an important role[3]. This study concentrates on workload, recognition, autonomy, and work-related

3 Considerations and discussion with Gerlinde Vogl and Sarah Nies have helped to form the basis of this hypothesis.

availability as factors in the working field. Concerning the private sphere, it focuses on the situation of household and family management, as well as on "self-efficacy perception"[4]. All these factors can affect the wellbeing of one person. But in what way do they interact with mobility and work-related mobility requirements?

In the following section, the results of a standardized questionnaire performed in four enterprises in Munich are presented. The questionnaire asks for work-related mobility requirements as well as for details about working conditions and private situations. The outcomes are shown in regression models of different mobility forms: commuting, business travel, and changing work places. The case of Munich represents Metropolitan Regions with high traffic volume and a monocentric infrastructure[5].

4.1 Stresses and strains of corporate mobility requirements

The journey to and from work: commuting

In general, employees have an obligation to come to work. Seventy-seven percent of 715 persons who answered the questionnaire stated that they commute daily. Sixty-five percent of these daily commuters are car drivers. The respondents are divided in two groups: daily commuters who commute daily or at least three times per week, and weekly commuters (who commute weekly or less).

The majority of respondents are daily commuters with a travel time of above one hour. It is imperative to note that they do not have the option of working from home. More than 40% of this group feel commuting time is "lost time," except 14% who report that they relax or recover from work on their way home or to work.

Figure 1 shows the different impact on stresses and strains due to the journey *to and from work* of daily commuters. Travel time aggravates stresses and strains: the longer the travel time is, the more stress commuters feel. "Self-efficacy perception" and the "accessibility of the workplace" limit this effect and impart a protective potential for the commuter. Because of the small number of cases of weekly commuters, there is no valid regression-model and figure available.

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4 In this research project "self-efficacy perception" of individuals is one important mobility competence. The certainty and confidence one has in one's own ability to handle all mobility challenges is crucial in coping with mobility requirements.

5 The database arises from the research project: "Mobilität ‚rund um die Arbeit'- Katalysator sozialer Ungleichheit?", founded by the Hans-Böckler-Stiftung (project term: 10/2012 – 5/2015) . The database includes 719 respondents from four enterprises in Munich, most are male and have a fulltime job. For more information please see Vogl et al. 2014.

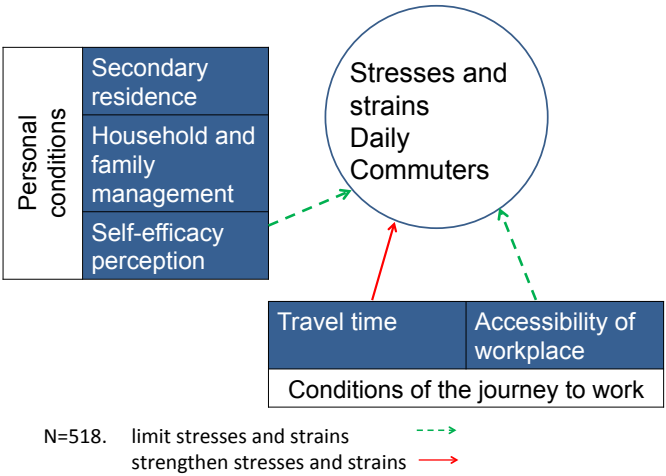

Fig. 1 Parameters of stresses and strains according to the journey *to / from work* (adapted from Vogl et al. 2014)

Business travel

Business travel is a form of corporate mobility for highly qualified employees. Within this sample, nearly 60% of business travelers had a graduate or university degree. These jobs are well paid and all of respondents have permanent employment.

About 60% of all respondents make business trips. The majority of them travel on behalf of their enterprise up to 10 times per year (64%), 23% travel between 11 and 49 times per year and only 10% travel more than 50 times over the course of one year.

Business trips are seen as enrichment but they can also produce stresses and strains. Trips are stressful for more than one-third of business travelers, and they are exhausting for 23%. Thus, every fifth respondent wants to decrease the number of business trips taken. However, on the other hand, nearly 30% enjoy being on the move and 58% say that being away on business makes work varied and enriches life.

If we look at the regression model in figure 2, we find a negative correlation between "self-efficacy perception" and the "autonomy of trip scheduling" on the one hand, and increasing stresses and strains of business trips on the other. To be in a position to manage the length and the frequency of a trip has more impact on subjective wellbeing than the length and frequency of the journey itself.

The conditions of work have a strong correlation with the increasing stresses and strains caused by business trips. The greater the "workload", or the greater the

work-related availability, the greater the stresses and strains individuals feel when taking business trips. Apart from the conditions of the business travel itself, both working and personal conditions have a strong impact – in a reinforcing or limiting way – on the increase in stresses and strains caused by business trips.

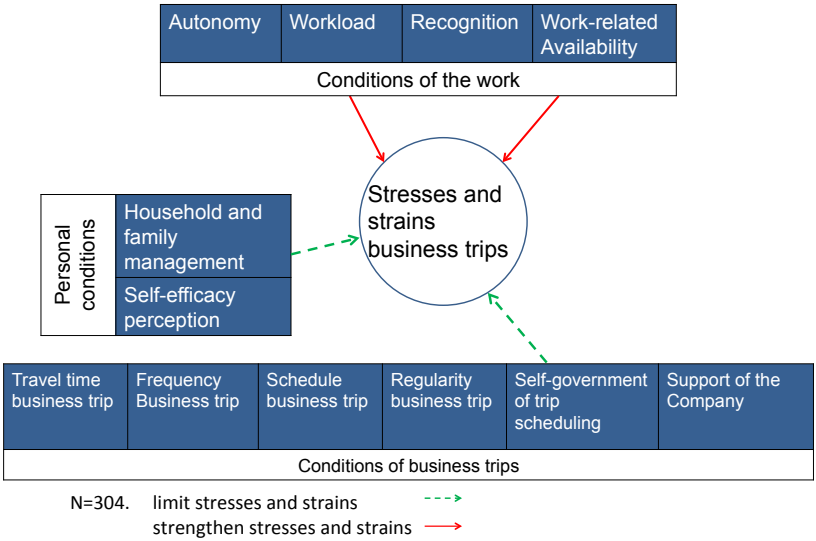

Fig. 2 Parameters of increasing stresses and strains according to business trips (adapted from Vogl et al. 2014)

Changing Workplaces

Nearly 40% of all respondents have a job which requires changing workplaces. These employees, particularly those[6] in the energy and building sectors, are employed by one company and perform their work at several different workplaces. Although they usually do not work at the head office, for most of the year, their workday starts and ends at their current workplace.

The majority of respondents of this group "changing workplaces" (55%) must change their workplace more than 20 times per year. At least 24% work in up to five workplaces over the course of one year. The remaining group of respondents (21%) changes workplace between six and 20 times per year. These respondents often stay just for one day (40%) or up to one week (33%) at the same workplace.

Many of the respondents are partly or permanently overnighters (52%) and often, are not able to plan their assignments more than one day in advance (nearly 30%). In all other cases (70%), upcoming workplaces could be arranged one week or more in advance.

The model in figure 3 shows that three of four factors related to the conditions of the changing workplaces have an impact on the increasing stresses and strains of the employees. Overnight stays and the length of assignments reinforce the negative effect; the ability to schedule limits these negative effects on employee wellbeing. The better their assignments can be planned, the lower the stress levels these employees feel.

Work conditions and personal conditions have a protective effect on the health of employees. For example the parameters "recognition" and "self-efficacy perception" reduce the feeling of stresses and strains.

6 This group covers some workers and many employees. For the sake of simplicity, the chapter use the term "employee" only.

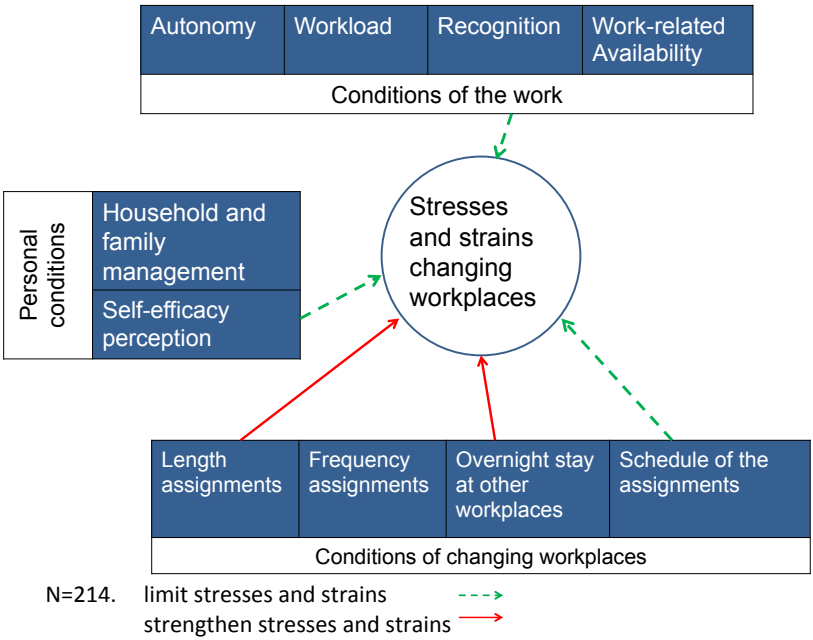

Fig. 3 Parameters for increasing stresses and strains according to changing workplaces (adapted from Vogl et al. 2014)

4.2 Corporate mobility: impacts on work-life balance

In the section above, the key driving factors for increasing stresses and strains according to corporate mobility were discussed. In this section, work-life conflicts are analyzed in relation to different forms of work-related mobility. In the first part (4.1), corporate mobility is considered as the dependent variable; in the following section, it is considered to represent one parameter of the model for work-life conflicts.

Corporate mobility starts with the journey to work (almost) every morning and ends with arriving at home, except for employees who stay overnight at their current workplace or employees who are away on business. During this daily travel time, employees can do a lot of things: sleep, read, prepare some work, make telephone calls, look out the window, drive the car, listen to music, etc. Commuting time here can be leisure time, or even more work time, or can perhaps be seen as a necessary evil. Within the sample, only 14% feel the travel time is recreational.

In contrast, 40% state the commuting time as "lost time," and 72% of them are aware of the high costs of commuting. This indicates that the journey to or from work can induce a negative impact on work-life balance. It costs time and money. Consequently, it prevents employees from performing leisure activities or spending time with their family or friends.

Mobility at work, such as business travel and changing workplaces during working hours, does not result in the loss of private time. Therefore, the impact on work-life balance should not be as grave. However, on the other hand, these forms of mobility deeply affect private life. For example, when one stays overnight at one's current workplace or at the destination of the business trip, one cannot meet family or friends. Instead, one must reside in other surroundings and deal with this challenge. As a result, this way to be mobile at work can still create work-life conflicts.

The results of the survey are shown in Figure 4. The regression model is based on the hypothesis that conditions of work, conditions of corporate mobility, and personal conditions influence private life and can have negative or positive effects on work-life balance.

In this model, all working condition parameters have an impact on work-life conflicts. "Autonomy" and "recognition" limit work-life conflicts, whereas "workload" and "work-related accessibility" reinforce these conflicts. The negative effects are a slightly stronger than the positive effects of the working conditions. "Self-efficiency perception" as a personal condition also limits the conflicts.

With regard to the conditions of corporate mobility, the "commuting time" or travel time of the journey to or from work has a strong impact on work-life conflicts. The longer the time spent on commuting, the higher the chances of work-life conflicts. This statement applies to the group of daily commuters who have, on average, a shorter travel time than weekly commuters. For long distance commuters, the regression model is not significant.

However, even for weekly commuters, the structuring power of the mobility regime (Kesselring, Vogl 2010; Kesselring 2015) due to the life arrangement of employees is obvious. During the week, employees live at their work destination, and at the weekend they stay at home with their families. On weekends they can spend time with their children or other relatives close by, but they must also fit all their needs into a specific timeframe. For example, married male commuters often perform some skilled manual work while the woman takes care of the household. This life arrangement limits and restricts the time spent at home[7]. All weekly com-

7 By the way, weekly commuting reinforces traditional role models between men and women. The men are the main earners in the household while the women (almost)

muters in the sample have a 4-day working week[8]. Thus, they spend three days at home and this proportion between private and working life enables them to keep their work-life balance. Another reason for being able to achieve a work-life balance may be that the decision to take up weekly commuting was decided upon before taking up employment. In this situation, employees can anticipate the specific work life and mobility situation.

Surprisingly, within the sample, business travel has no impact on work-life conflicts. The business travelers of the sample have a moderate travel frequency and they often make one-day trips. One reason for this could be that they can manage their one-day trips during the time at which they might otherwise be working. The

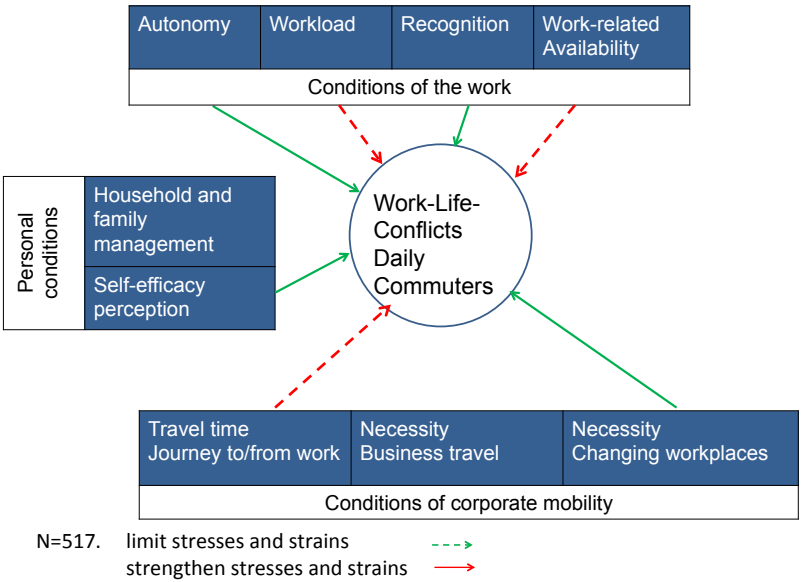

Fig. 4 Parameters for work-life conflicts of daily commuters (adapted from Vogl et al. 2014)

are immobile while working in a part-time-job on site and managing the family and household (Schneider et al. 2008).

8 Beyond the questionnaire, employees are interviewed for the research project: „Mobilität ‚rund um die Arbeit'– Katalysator sozialer Ungleichheit?" also found through Hans-Böckler-Stiftung.

frequency of such trips is not high enough to impact on work-life balance. Nevertheless, there is a correlation between frequency and work-life conflicts. Other research studies show the impact of travelling more than 50 times per year on work-life balance (Easynet Global Services 2009). Just a small group in this sample found themselves in such circumstances (10%).

5 Corporate mobility is more than movement

The increasing stresses and strains of corporate mobility depend on various factors. Each form of corporate mobility, e.g., the journey to or from work, business travel, or changing workplaces, has a set of specific requirements to cope with. This specific setting of work, personal conditions, and mobility conditions creates mobility for employees. Employees do not simply move from one point to another; their mobility is embedded in a social framework.

5.1 The journey to and from work: commuting

The "commute time" and the "availability of the workplace" are stable factors in the model above. Commute time has increased in recent years and strengthened the stresses and strains experienced by employees; however, availability has limited this burden. Availability is one component of mobility management strategies designed to influence the mobility behavior of the working population. Availability can be seen as the mode of transport used by employees. This can include company cars to begin carpooling with other employees located at the same accommodation, or a job ticket integrating transport modes, like cycling from the station to the workplace, and so on.

However, this availability does not stop with the classical "measures" of corporate transportation planning. Workplace availability is also related to the duration and location of working time: Has an employee arrived at midnight to his working place, or does he work for just a few hours at his place of work and has a long commuting time? For weekly commuters, for example, a good deal of time between time at home and time at the work place could comprise a 4-day-working-week. The working time per day is exceeded here, but it nonetheless allows for spending more time at home, making longer commute times worthwhile.

Over the course of the skills shortages which have already been significant in some industries (Bundesagentur für Arbeit 2014), companies must offer good

conditions for their employees that include a sustainable way to be mobile. In the present situation, it is mainly the working population that takes responsibility for commuting. They must manage the way to work and back on their own, regardless of the accessibility of the workplace and the availability of transport modes. They must cope with traffic jams and crowds during rush hour. A corporate mobility management could enable a balance between work and private lives, by focusing on questions of transport mode, parking place, and vehicle fleet, and, beyond that, by taking work conditions into account.

5.2 Business travel

Mobility at work generates interdependencies between working conditions and mobility requirements. Business travel causes stresses and strains when "workload" and "work-related availability" are subjectively experienced as very high. When this occurs, mobility becomes an additional stress factor. However, there is an accumulation effect here. When one is away on business, one has to handle a lot of things: one must perform a job at one's destination, while daily office work continues. In addition, mobile employees have to plan their business trip and move from one site to another. The amount of work increases and, as a result, the work load expands, the coordinative tasks faced by mobile employees increase and the vicious cycle of business travel, workload, and stresses and strains increases in severity.

A limiting factor is the "autonomy of the trip-schedule." With respect to the challenges of business travel, it seems crucial to schedule the trip itself and coordinate and communicate in an independent way. Mobile employees could take "phases of recreation" during their business trip when needed. If they were to do so, they would need travel guidelines enabling successful work at their destination and back at home. These guidelines would need to regulate availability and working time. Business travelers often work on the move as well as at their destination. Normally, travel time is not working time[9], but when one travels during one's regulated working hours, it is accepted as working time. However, travel time often goes beyond one's allotted working time and, in fact, workload must still be met in such cases. Therefore, employees tend to work harder than working standards or labor laws allow for. These employees have a tendency toward the so-called "interested

9 The Labor Court of Germany has defined travel time as resting time, not as working time (Judgement of 11.07.2006 BAG: Bundesarbeitsgericht) relating to § 5 ArbZG (ArbeitsZeitGesetz). Available at: http://www.arbeitsrecht.de/newsletter/archiv/2007/die-dienstreise-in-der-aktuellen-rechtsprechung-17-2007.php

self-endangerment" (Peters 2011; translated by the author). This term refers going beyond one's physical and mental limits to be successful within one's job.

Thus, corporate mobility management has to open up to questions relating to working conditions, in the case in which they limit social costs and enrich the wellbeing of business travelers.

5.3 Changing workplaces

The sample consists of the building and energy sector. In contrast to business travelers who often work on the move or in hotels, employees with changing workplaces work exclusively on site. They work in small groups in a self-contained way, away from the direct control of the head office. While being on the road, employees are not able to work; therefore, the company does not earn money.

In this case, mobility management strategies should enable a realistic schedule of assignments to decrease time pressure. This factor will limit the stresses and strains which are reinforced through the length of time spent commuting, and the fact that employees are required to stay overnight at their current workplace.

Another protective parameter for employees is recognition. This can include acknowledgement for doing a good job, payment, or other incentives that make work easier (such as a company car). These soft factors (appreciation or acknowledgment) play an important role in maintaining mobility requirements[10], not least because the missing spatial integration of the company headquarters can produce a lack of affiliation with the company.

10 Voswinkel (2012) shows the relevance of "recognition" in the working field that can describe the working relationship between employer and employee in a precise way. Roller and Vogl (2013) reflect on the role of "recognition" when business travel changes from being an incentive (as a specific form of recognition) to a basic requirement (that contains the loss of "recognition" of the mobility activities).

6 The outlook for corporate mobility management: toward a sustainable direction from the perspective of employees

From an individual's perspective, it is crucial to take into account the whole life situation of employees, and the life circumstances faced during their working life, by developing sustainable mobility strategies (Vogl, Kratzer 2015). Working conditions in combination with an employee's place of residence structure the way individuals are mobile *to / from* or *at work* (Haas, Osland 2014). Furthermore, as seen above, there are factors that strengthen and others that limit the stresses and strains of corporate mobility. Corporate mobility can also become a burden when personal conditions change, e.g., when founding a family or if an employee takes care of relatives. Before such an incident, mobility requirements might have been seen as positive and enriching. Mobility needs change during the life course.

Moreover, corporate mobility is more than movement: it is "a way of being in the world" (Cresswell 2006: 3). The forms of corporate mobility have a structuring power to the whole life of employees. They alter the way they work, the mode through which they spend time with their families, the kind of role-models they are at home, the manner in which they handle their social and work-related ties, and so on. Thus corporate mobility is both structured by corporate/work-related requirements and private needs, and also has a structuring power on the way individuals live their lives.

On the basis of the results of this study, strategies for a mobility management approach that limits the social costs of employees and protects their wellbeing should take into account the work-related circumstances and personal conditions of individuals in relation to their needs and requirements. It would be appreciated if companies could integrate the sector of occupational safety and health, as this is the sector where work is regulated with the corporate mobility management sector.

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Social Sustainability and Mobility: The Case of Low-Income Groups

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Abstract

Within this book on sustainable mobility, this chapter focuses on social sustainability. Mobility is essential for participation in society; mobility-related discrimination prevents people not only from being mobile but also from taking part in societal processes. Mobility is very much related to settlement structure and therefore to people's choice of residential location. Using the example of low-income groups in Munich, this chapter presents the little knowledge available and formulates questions for further research. The goal is to shed light on the neglected issue of mobility-related discrimination in urban areas and to discuss the connections among residential location, income, and mobility.

1 Introduction

As a key prerequisite for participation in society, mobility carries high social value. Conversely, mobility-related discrimination can prevent people from taking part in societal processes. Barriers to mobility can arise from various sources, both systemic and individual. Previous research has frequently focused on the lack of transport supply. Consequently, as the issue of mobility-related discrimination has gained traction in recent years, most of the attention has been devoted to rural areas, and the specific challenges faced by urban residents have not been addressed. This imbalance in research focus should be corrected, especially since the global population is being increasingly concentrated in urban areas. Even though an urban environment can provide a good transportation infrastructure to support an inclusive society, mobility-related discrimination can still be a problem.

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The first part of this chapter addresses the links between sustainability, mobility, and mobility-related discrimination, with emphasis on the influence of settlement structure, residential location, and accessibility. These relationships will be illustrated by examining low-income groups, the people often most affected by mobility-related discrimination. A spatial link will be drawn to the region of Munich where low-income groups have very limited housing options because of the highly competitive and expensive housing market. I will present the relatively limited knowledge available and point out research gaps. The goal of the chapter is to shed light on the too frequently neglected issue of mobility-related discrimination in urban areas and to highlight the connections between residential location, income, and mobility.

2 Conceptual background: social sustainability and mobility

In this section, the connection between social sustainability and mobility will be highlighted, with a special focus on the importance of participation and accessibility. I will describe barriers to mobility that can lead to mobility-related discrimination. In addition, I draw connections to issues of settlement structure and residential location.

2.1 Bringing it together: sustainability and mobility

When we talk about sustainability, we often refer to the United Nations report *Our Common Future* (1987), which is seen as defining the main concepts of sustainability and as a starting point for current discussions. In this report, Gro Harlem Brundtland referred indirectly to what are commonly known as three main pillars of sustainability: economy, ecology, and social aspects.

This chapter focuses on the third of those pillars, the social dimension of sustainability. Social sustainability means the organization of society in such a way as to ensure social stability and enable all people to fulfill their basic needs. This can happen only through a fair distribution of opportunities and wealth, which entails fighting poverty. Externalities impeding such a fair distribution or negative side effects should be kept as small as possible. Clear, unresolved social imbalances can lead to societal tensions, even violence. Also, sustainability always refers to both the present and the future; present actions must not curtail upcoming generations'

opportunities. The literature therefore often refers to intergenerational fairness as an essential part of social sustainability.

Two major prerequisites of social sustainability, to be discussed in detail below, are participation and accessibility. Only when individuals can access various activities are they able to participate fully in social life, resulting in an equitable society. Multiple studies show that people in more equitable societies are not only more satisfied with their life but also more productive, leading to a more effective economy. According to the British Social Exclusion Unit (SEU 2003), equity benefits not only each individual but also the community, businesses, and the state. A region, for instance, may be less attractive for business or residential development because it is not accessible to the people. As a result, companies in that region may struggle to attract customers or hire suitable employees. In addition, social inequity forces the state to counteract negative effects such as high unemployment or crime (Lucas, Jones 2012).

This book aims to approach sustainability, and mobility in particular, from multiple perspectives. Sustainable mobility is obviously a broad field, with no common definition or checklist of criteria. As the internal mobil.LAB concept paper (mobil.LAB 2014) states:

> "Sustainable mobility requires affordable access to multiple options, freedom of choice in terms of mode and access to life opportunities. … [It] does not and should not require a reduction of mobility. It is oriented to reduce individuals' derived demand for mobility and increase the intrinsic demand for mobility. Instead it should be safe for all users and therefore minimize any type of negative effects on individuals, communities, the private sector and the environment."

This description is not intended to be exhaustive, but it does emphasize the relevance of mobility for individuals in society. In short, the crucial point of sustainable mobility is to provide mobility (i.e., choices) for everyone. Therefore, it can be seen as highly socially significant.

In contrast to this emphasis, discussions of sustainability in the field of transport and mobility often focus on ecological factors such as carbon dioxide and alternative fuels. Of course, such ecological aspects are related to the economic and social spheres, but the approach is very different. The social dimensions of the field are often neglected or overlooked, even though social and ecological disadvantages often occur simultaneously. Fortunately, consciousness has grown in the last few years, and some research has taken place on social sustainability in transport and mobility.

2.2 Mobility as key for participation and barriers to self-determined mobility

So why should we provide mobility for everyone? Mobility ensures people's ability to participate in social, economic, cultural, and other processes, since the activities of most people's daily lives are spread across different locations. Work, education, and other activities are essential parts of our life (SEU 2003) that cannot be accessed without mobility. Pickup and Giuliano (2005: 39) call transport a "tool for living and working". Therefore, mobility, as one key prerequisite for social participation, is also one of the main ways to prevent and address social exclusion.

Nowadays, society has great expectations with regard to mobility. Cars are getting bigger and faster, vacations are spent as far away from home as possible, employers expect workers to tolerate greater commuting distances, and employees are willing to go on business trips every other week (see Roller's contribution to this volume). Furthermore, society has become organized around the car, providing increased opportunity for most people but leaving behind those who do not have access to a car. In recent years, the average time that people spend on the road has not risen significantly, even though the average distance per trip has risen (Läpple 2005). Conversely, limited mobility can affect people's chances of participating in society and thus their self-reliance and life satisfaction. Not everyone can fulfill society's mobility demands in order to participate in activities to the same extent. We need to take a closer look at whether everyone in society is able to keep up with emerging transportation patterns and at the extent to which they create new means of exclusion.

In this context, it is important to recognize the difference between transport and mobility. Whereas mobility can be seen as people's ability to move in physical space (i.e., their potential for movement), transport and traffic refer to realized mobility. Additionally, mobility addresses the range of possibilities available to an individual. This differentiation enables us to distinguish between the overall goals of reducing traffic, with its negative externalities, and promoting mobility for all people (Ahrend et al. 2013), as this chapter seeks to do.

When people's limited ability to meet their mobility needs affects their social life, Runge (2005) refers to the situation as *Mobilitätsarmut*. The term is often translated as "transport poverty," but it really covers more than this, since it concerns people's ability to move, not just their actual trips. Accordingly, I will instead refer to *mobility-related discrimination*, which can, of course, differ significantly in its manifestations.

The issue of transport poverty began to receive scientific attention in the late 1990s, initially in Great Britain, where the government founded the Social Exclusion

Unit to combat social exclusion in various fields. This unit's far-reaching findings in the area of transport encompassed the influence of accessibility on participation in the labor market and in the educational system and on access to health care, to name only a few key activities (SEU 2003). Consequently, mainly means of accessibility planning were developed to improve these issues. The primary approaches usually focus on transport supply and land use.

There are various reasons why people's mobility may be restricted. The literature categorizes them into spatial reasons (which include the availability and accessibility of transport and the location of activities), temporal reasons, financial circumstances, and individual aspects. This last category includes not only individual concerns for safety and security while traveling, but also the physical ability to use a given mode of transport and access to relevant information (SEU 2003; Runge 2005). Financial issues are crucial because the less money people have, the less they can spend on transportation (I will look at the situation of low-income groups in more detail in section 3.2). Different kinds of barriers can interact and reinforce each other. Therefore, when we analyze the causes of mobility-related discrimination, individual factors must be considered along with structural conditions of the local area and economic influences on the local, national, and even global levels (Lucas 2012).

Runge (2005), in her literature review on mobility-related discrimination, identifies some goals that society should aim for. She states that everyone should have sufficient mobility to be equally able to participate in key activities, which presumes safe and healthy transport. The transport system should be designed in a way that minimizes negative externalities on society and social inequities. Finally, low thresholds should be provided for all people to participate in decision-making processes regarding the provision of transport services and land use planning.

The barriers mentioned above affect different groups of people to different extents. A particular transport supply may meet one person's mobility needs but not another's. Generally speaking, groups of higher social status often benefit from new projects, whereas less affluent people tend to be affected by negative externalities. Planning for a new public transport route must carefully consider the most important areas to serve. Furthermore, providing transport for some people can curtail the mobility options of others; highways can divide neighborhoods or congestion may block streets. Which transport modes receive priority is a highly political issue and a matter of policy decision-making. The extent to which people's mobility is restricted by policies or planning decisions is highly individualized, making the topic of mobility-related discrimination very hard to clearly capture and operationalize.

2.3 The matter of location: accessibility and residential location

As already mentioned, mobility is closely related to accessibility, which is therefore an important parameter to look at when we consider mobility-related discrimination. Geurs and van Wee (2004: 128) define 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)".

Hence mobility requires accessibility in the first place. Accessibility depends on multiple factors, which can be divided into land-use, transport, temporal, and individual components (Geurs, van Wee 2004). This breakdown reminds us not only that transport and spatial structure are highly interrelated but that individual factors must be taken into account. An open slot for one's child in the nearest kindergarten, operating hours of shops and offices, and the ability to interpret public transport timetables might not initially be recognized as accessibility issues. Consequently, it is not possible to define a certain level of adequate accessibility for all residents of a neighborhood; different conditions can affect people in various ways. These various accessibility factors influence people's choices and possibilities and therefore their mobility behavior.

Most prior research has focused on concerns regarding transport supply, which is most frequently deficient in rural areas where public transport services are comparatively weak and populations are heavily dependent on car travel. In rural regions, activity locations are usually far apart, resulting in great travel distances that cannot easily be covered by walking or cycling. If a household does not have a car, few transport alternatives are available and people's activities are highly restricted. Due to these considerations, research on transport poverty or mobility-related discrimination in Germany has concentrated primarily on rural areas (Barlösius 2009; Wehmeier, Koch 2010; BMVBS 2012). But is mobility-related discrimination really only a problem for people living in rural areas?

The lowest degree of mobility-related discrimination could be found in an environment with good public transport supply, high density, and short travel distances in combination with an ample choice of activities. These features are most likely to be found in urban areas. Indeed, an urban environment tends to provide a solid transportation infrastructure, enabling its residents to participate in society more broadly. High population density and a mixture of land uses reduce the need for long trips. But even so, not everyone can profit from available services to the same extent. Additionally, in urban areas other barriers can arise, such as high traffic

volumes, permanent competition between different transport modes on streets, or a high cost of living, which leaves no money available to pay for transport. We know only little about these interrelationships, since the topic of mobility-related discrimination in urban areas has been neglected in academia thus far. I will introduce some basic findings for the Munich region as an urban case study in the next section of this chapter.

As we can see, mobility behavior and settlement structure are very much interrelated (Kagermeier 1997), and residential location plays a significant role in this context (Bauer et al. 2005; Fuchte 2006; Jarass 2012). There is an ongoing debate on the causal direction of the relationship between residential location and transport behavior. It is uncontroversial that the accessibility of residences influences people's mobility. People living in mainly rural areas use their car more often than most people in cities. On the other hand, city dwellers' modal share of public transport is usually higher, obviously due to the greater supply. But some recent studies have gone beyond the simple observation that residential location influences transport behavior; the reverse can also be true. Preferences for particular transport modes also influence choices of residential location (Cao, Mokhtarian 2008). A passionate cyclist will most likely look for a residence from which he or she can reach destinations by bike, whereas others will focus on the residence's accessibility by public transport. Of course, selections of one's residential location have various motivations, and enthusiasm for one or another transport mode is often not the main reason; financial or organizational reasons play an important role, too. Especially when the housing market is rather supply-dominated, as in Munich, choices are highly restricted by availability and real estate prices, so that location and accessibility-related criteria might fade into the background as one decides where to live.

Not only the starting point of trips — mostly the residence — is important for overall accessibility but so is the location of destinations. Mixed-use, dense areas usually offer a broader array of activities, since demand is greater and competing options can co-exist. This leads to much shorter travel distances within the city than in rural areas, thereby increasing the share of walking and cycling. Additionally, when activities are located close to each other, it is easier to combine trips, and one can complete more tasks within a given time frame or on a limited financial budget. All these correlations show the strong impact of settlement structure on people's mobility.

In order to derive reasonable possibilities for participation, it is insufficient only to improve transport infrastructure or to foster access to different modes of transport for as many people as possible. Accessibility is not simply an issue of

transport planning. We must aim for a new way of thinking about accessibility in all fields of policy and decision-making.

3 A case study of the Munich region: what do we know about residential and mobility choices of low-income groups?

We have discussed the conceptual background of social sustainability and mobility. The interrelationships clearly show the importance of an integrated view of mobility and its high relevance for combatting and preventing social exclusion. Against the background of housing shortages in metropolitan areas, changing gender roles, and family arrangements, individuals must weigh their priorities between residential comfort and cost on one hand and mobility costs and additional time and social expenditures on the other. Positive effects on one aspect often come with negative impacts in another regard. The following paragraphs summarize some findings on residential location choice and transport behavior, with a particular focus on the situation of low-income groups in the Munich region.

3.1 The case study area

The mobil.LAB conducts its research in the metropolitan region of Munich, which has been economically successful over the last years and thus has experienced significant population growth. People moving into the region are confronted by a very tight housing market and high costs. Real estate prices in Munich are among the highest in Germany (City of Munich 2014). Since demand tends to exceed supply, the suppliers' side controls the market, resulting in rising prices and strong competition that present stiff challenges to households with limited financial resources.

Although poverty rates in Munich have been low and fairly stable within the last years, there have been some alarming developments, indicating that only some residents have profited from the region's economic growth, whereas others have been left behind. In the last few years, the income gap between the poor and the rich has widened. In 2006, the quintile with the highest incomes earned around 36% of the total monthly income of all residents. Five years later it had 46% of the total monthly income, which corresponds to six times the income of the quintile with the lowest income (City of Munich 2012b). The region's economic success has kept unemployment rates low, so labor market policies can be of little help in combatting

poverty. Besides, unemployment is only one factor that can put families in precarious situations. The main challenges in the Munich region are high rents and the high cost of living, which are pushed upward by the rising demands of the well-off.

The Munich region has a very well-developed public transport infrastructure. The city itself has a dense network of U-Bahn, S-Bahn, tramways, and buses. However, the supply wanes as one moves away from the city center. The public transport network is radially aligned toward the city center, with few tangential links outside the city, so residents of suburban areas generally depend on cars. Also, due to population growth, the public transport infrastructure is approaching its maximum capacity. Within the city center, attempts have been made to reduce car traffic, such as by introducing a low emission zone or through high parking fees. Conditions for cycling are good in most parts of the city, leading to a high share of cyclists across all walks of life.

3.2 Focus on low-income groups

People with limited income are one of the groups at greatest risk of mobility-related discrimination (Church et al. 2000; Lucas 2012). The literature on social dimensions of mobility often refers to social exclusion or socially disadvantaged people. Research on social exclusion has been conducted mostly by social scientists, whose studies do not focus specifically on mobility, so we have relatively little detailed knowledge of the mobility needs of the disadvantaged. Many studies show that social discrimination reaches far beyond the multidimensional concept of poverty, which is not related only to income (see generally Böhnke 2001). I will attempt to take a closer look at the situation of the poor, differentiated by their economic status, since they often face multiple kinds of social discrimination and are likely to experience some mobility limitations, even if not all of them are directly affected by mobility-related discrimination.

High real estate prices and a competitive housing market limit choices for people of small financial means. Since housing is an essential need, low-income people must often make compromises on residential quality and location, which can also affect their access to transport infrastructure and destinations. Furthermore, they are also the people most affected by high transport costs, which can restrict their use of individual and public transport options. Moreover, high-income groups tend to articulate their political values and interests more effectively and are typically better networked, with the result that spatial planning is often more attentive to their needs.

Residential location choices of low-income groups

The residential location choices of low- and medium-income groups are more likely to be determined by external constraints, whereas people who have more money at their disposal have more options. The higher real estate prices are, the more obvious this correlation is.

We know that low-income groups often prefer inner-city residential locations (Glaeser et al. 2008; Seils, Meyer 2012). Low- and medium-income groups often have to be more flexible concerning their job opportunities. Fixed-term contracts or irregular working hours make long-term planning difficult. Choosing a residential location based on one's workplace location can therefore be risky. If one must seek a new job, the chances of finding one within an urban environment are better than in the periphery. In households with low incomes, often both partners must work, and rarely can they work at the same geographic location. This factor makes the need for flexible mobility even greater, since reaching two different job locations must be feasible. The same situation applies for people who hold more than one job – which is increasingly often the case in the low-income sector, because one job does not provide enough money to live on. In contrast, the traditional one-earner family model is predominant in suburban areas. These families usually organize their lives from a long-term perspective, where they do not have to react as flexibly and where one person can concentrate on taking care of the household instead of doing housework on top of a full-time job.

The location of real estate has great influence on housing prices, which also depend, among other things, on accessibility. Prices per square meter often rise in cities and highly accessible areas and are usually lower in rural areas. But small apartments can often be found more easily in inner-city locations, whereas houses or apartments outside the city tend to be more spacious. This means that even though real estate prices per square meter are higher in the city, apartments could still be less expensive there due to the smaller amount of space. Moreover, the price differences are not only between the city and the periphery; even within the city, prices can vary considerably. Further reasons to pursue living in the city are the better supply of public transport and easier access to support services.

The housing market in Munich, as described above, makes it hard, in particular, for low- and medium-income groups to find affordable accommodations meeting their preferences within the city. For many people at risk of poverty, living within the city is increasingly difficult. One major reason that former city residents indicate for leaving is increased household size, which brings with it a need for more space. Not indicated as often, but also among the top reasons and closely connected, is the high cost of living in their previous residence (City of Munich 2012a). On average, households leaving the city of Munich double their residential size in square

meters while saving up to one-fourth of their rent cost per square meter. Thus, it is reasonable for low-income households to consider whether living outside the city would be better financially. On the other hand, people moving into the city typically give up one-fourth of their former apartment size and pay up to 40% more per square meter (City of Munich 2012a). Given this comparison, moving into the city is increasingly an option only for the well-off.

Consequently, two contrary spatial effects can be observed in the Munich region. On one hand, low-income households tend to prefer an urban environment, which offers more flexible access to job opportunities, small residential units, good public transport supply, and short distances to urban amenities; on the other hand, strong price pressure and a highly competitive housing market are forcing many low-income households to leave the city.

In addition, within the city there are signs of a slow spatial manifestation of income-related residential patterns. The smallest percentages of households benefiting from social transfer payments are found in the city center and in districts that have seen substantial renovation activity. The distinction between districts has been reinforced in recent years, so that in already poorer neighborhoods the population living on subsidies has increased, whereas their share in the city center has decreased (City of Munich 2012b). These are also the districts that have seen the greatest number of conversions from rental properties to condominiums (City of Munich 2014). It is apparent that the districts in greatest demand have the best supply of public transport and the greatest choice of activities in the immediate vicinity. In these neighborhoods, low-income groups have virtually no hope of finding affordable housing, unless they have access to housing cooperatives or subsidized forms of accommodation such as public housing or student residences.

The lower a household's income in the city of Munich, the higher the portion of income devoted to rent; for the lowest-income group, rent often exceeds 40%, sometimes even 50% of total income. And these percentages do not include utility costs (City of Munich 2012b). This pattern is further reinforced by the shrinking public housing stock, since many social contracts dating back to the 1970s are now expiring.

Residential location choice in Munich is therefore often not really a choice at all anymore for many families, who are simply taking whatever they can afford. As the availability and affordability of housing decline, low-income groups have to compromise especially on accessibility-related decision criteria, such as access to public transport, when searching for a residential location. In this way, the local housing market can have a major impact on people's mobility options. Relocation to the outskirts, where rents are usually lower, often leads to rising transport costs. If they succeed in finding a place in the city, households are often so burdened

financially that they must skimp on other expenses, including transport. At worst, people can become severely restricted with regard to mobility despite the relatively good transport supply in urban areas. So far, we have limited knowledge and even less empirical evidence of these correlations.

Transport behavior of low-income groups

Let us take a closer look at how low-income groups travel and any evidence of income-related patterns with regard to the use of transport modes. *Mobilität in Deutschland* (MiD) is an extensive survey on transport behavior in Germany. The last such survey, conducted in 2008, was expanded for the city of Munich, allowing local evaluations of the dataset. The data can be analyzed for households of different economic statuses depending on equalized (i.e., taking household size into account) income.

When we compare the modal splits of survey participants of different economic statuses (Figure 1), it becomes obvious that low- and high-income groups differ the most in their share of car use and walking. Low-income groups do the most walking by far and have slightly higher shares of cycling and public transport use, whereas car use rises with increasing income. The generally high shares of public transport use, walking, and cycling are due to the urban environment.

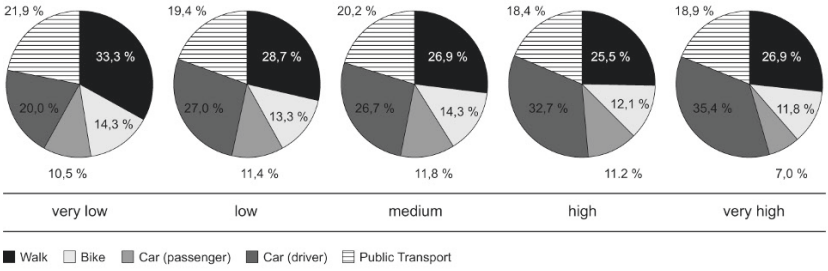

Fig. 1 Modal splits of transport by household economic status (source: author's analysis based on MiD data for Munich 2008)

In Munich, medium-income households are the group most likely to have one or more cars, whereas both high- and low-income households are more likely not to have a car, but for different reasons. Low-income households who go without a car

do so mainly for financial reasons, whereas many high-income households choose a lifestyle that does not require a car.

The survey did not ask people their reasons for using or not using public transport, but some information about the participants' means of paying for public transport was requested. These data reveal that the lower a participant's income, the less often annual tickets are used, even though they are cheaper in the long run than monthly or weekly tickets. Presumably, low-income users are less able to make a single, large lump-sum payment for an annual ticket. The survey was conducted before the IsarCard S, a subsidized monthly ticket for the poor, was introduced. Evaluations of consumer spending regularly show that households with low incomes spend only a small share of their income (6–8%) on transport, whereas households with high incomes spend more than twice that percentage, or 16–18% (Statistisches Bundesamt 2014). This is not only a higher share, but a far higher total amount.

The number of trips differs only slightly by economic status: low-income participants averaged 3.3 trips per day, whereas high-income participants took 3.8 trips. The distance covered per trip varies more widely: the average trip length by low-income participants is 7.2 kilometers, barely half of the 13.2 kilometers per trip among high-income participants (including a correction for overestimation). This shows that activity spaces (Hägerstrand 1970) shrink for those with less income, making a smaller number of destinations accessible. Finally, when we look at the general and broad classifications of trip purposes (Figure 2), we can also see some differences; for example, low-income people take fewer business trips and more accompanying trips and trips for education. Leisure trips are the largest category for all groups, but respondents with high economic status have the highest percentage of them.

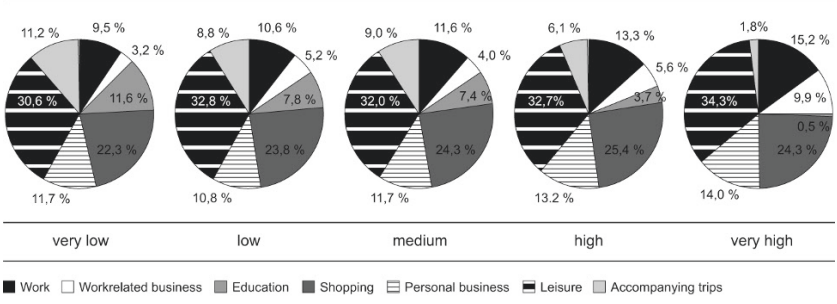

Fig. 2 Main trip purposes by household economic status (source: author's analysis based on MiD data for Munich 2008)

Overall, the results confirm findings of other surveys, but they can only indicate income-related differences. We do not know much about the underlying context, such as how many low-income people actually suffer from mobility-related discrimination or if their limitations are caused purely by their financial limitations or by other barriers as well. People's mobility depends not only on their financial capabilities but also on many other factors, such as their cultural background. For example, in New York, unlike in Munich, cycling is essentially a mode of travel for the upper class (McKenzie 2014). More research is needed to address factors affecting mobility choices in greater detail.

4 Conclusion

This chapter provides an overview of the interrelationships between sustainability, mobility, and mobility-related discrimination and highlights the importance of mobility in the context of social sustainability and participation. Further linkages to settlement structure and accessibility are described. The relationship between mobility and participation shows not only the high relevance of the topic to current discussions on transport and social policy-making but also the need for further research, especially aiming at a better understanding of mobility-related discrimination in urban areas. In particular, qualitative research approaches are needed to complement existing quantitative surveys.

Low-income groups tend to spend a disproportionately high portion of their income on rent and a lower-than-average share on transport. These patterns undoubtedly have unfavorable effects on their mobility that merit further research. The focus on low-income groups in this chapter makes the issues easier to conceptualize, but it is also a simplification that does not match the complexity of the topic.

Until now, approaches to combat mobility-related discrimination have typically been limited to single, freestanding actions (Daubitz 2016). Future measures should be part of an overall conceptual approach that coordinates, at a minimum, social and transport policies. Only an integrated approach can address the various causes, effects, and manifestations of mobility-related discrimination. To develop appropriate strategies, we need further knowledge about connections between residential location, actual mobility, and mobility needs of different target groups. The evidence presented here indicates that residential and transport patterns are intimately related with income, but these concerns are seldom the subject of current research and planning practices.

The overall goal of spatial planning should not be the reduction of mobility; however, we need a new way of planning that takes complex interdependencies into account. The need for long trips should be reduced through an adequate, decentralized supply of services, which also strengthens local economies. Alternative modes of transport should be promoted by providing proper walking and cycling facilities. We must also aim for improved integration of transport and land use planning, accompanied by consideration of disadvantaged groups. When planning new transport infrastructure, it is important to weigh different stakeholders' needs equally, especially in the evaluation of positive and negative externalities. Nowadays, the well-off tend to profit from new infrastructure, whereas the poor often have to cope with the negative impacts. The largely unexamined relationships between sustainability, mobility, and mobility-related discrimination offer significant avenues for further research and practical implementation.

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‘Knowledge-Workers’: A Conceptual Framework on Commuting Patterns

Juanjuan Zhao, Michael Bentlage and Alain Thierstein

Abstract

Knowledge has become the most significant factor in the knowledge Age, and knowledge workers, acting as key “knowledge agents,” drive regional development. Despite much research on the intra-regional migrations of these workers, few studies till date have systematically focused on intra-regional relocation and commuting. We will attempt to explore the commuting patterns of “knowledge workers” in the Munich metropolitan region.

We present a comprehensive framework of analysis and discuss the preferences and choices of knowledge workers regarding residential location, workplace location, and commuting behavior. We first analyze the evolution of spatial structure in terms of employment distribution. Second, the concepts of job-housing balance and commuting intensity are applied to track the dynamics of commuting patterns of the overall population. Finally, we apply spatial analysis in ArcGIS and regression analysis in the software package SPSS to investigate whether the magnitude of commuting flows from one place to another matches car-based travel time between these two places, the population at the origin, and existing jobs at the destination.

We reach three conclusions: First, the Munich metropolitan region is in an early transition phase from a monocentric to a polycentric structure. The relative importance of the city of Munich as a center of employment has weakened, and new employment centers are simultaneously emerging in secondary cities. Second, the overall spatial extent of people’s commute has enlarged in the last decade. Commutes are not limited by the borders of the municipality, but extend to other counties. Last, apart from these three factors, the specific composition of the labor force, the types of employment opportunities, and mobility behavior need to be considered to better explain the magnitude of the commuting flow.

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1 Introduction

The Information Age is another name for the third wave (after the agricultural and industrial waves) in human socioeconomic development history (Toffler 1990). Knowledge has become the main capital for creating or improving products and services (Simmie 2002; Schamp 2003; Savage 1997). Presently, an increasing number of employees are applying knowledge in economic sectors, and this will continue in the future. Attracting and retaining these workers within a region is essential to sustain regional competitive advantages.

As society modernizes, social differentiation simultaneously enlarge. This will lead to the specialization of land use and population segments (Næss 2006). Florida (2002) argued that the location choices of creative knowledge workers are distinct from those of other workers due to their specific lifestyles, demands, and values. They have different preferences when choosing a residence. Moreover, knowledge-intensive jobs are concentrated in metropolitan cores rather than being universally distributed over space. This prompts us to expect that knowledge workers will have distinct commuting patterns when compared with the general population regarding time, distance, and direction.

Urban spatial structure, in terms of the distribution of land use, particularly impacts travel distance and behavior (Næss 2006). Commuting, as the regular trip between one's place of residence and workplace, amounts to a large proportion of a person's total distance traveled. This share ranged from 13% in the greater area of Munich to 14% in Germany in 2008 (Pitterle et al. 2010). Commuting distance is a good indicator of the effectiveness of employment and housing distribution (Sohn 2005). It is closely related to sustainable mobility mainly in its economic and environmental aspects. Investigating the dynamics of the commuting patterns of this fast-growing labor force enables us to judge whether the mobility situation in metropolitan regions is sustainable.

Furthermore, spatial structure, in terms of the flows between different locations, can be identified through individual commuting patterns (Parr 2014). Understanding the commuting patterns of knowledge workers enables us to delineate the spatial range of knowledge-intensive labor markets and provides suggestions for knowledge-intensive firms on how to attract competent employees.

The remainder of the paper is organized as follows. Section two elaborates the conceptual background and three hypotheses. The discussion of methodology in section three includes the research area, data information, and methods of analysis. Section four presents the results. Section five draws conclusions and also introduces specific research questions for the future.

2 Conceptual background

This section provides the theoretical and empirical background on commuting patterns. The first part introduces the general framework of analysis. The second part reviews definitions of knowledge workers. The third and fourth parts present theories of residence and workplace location, particularly those of knowledge workers. The last part focuses on the commuting trip and factors relevant to it.

2.1 Interrelation between commuting, decision makers, and spatial context

The general framework of analysis is shown in Figure 1. "Activity space and mobility behavior" is the starting point. It contains our research subject, "commuting," which is the result of interaction between one's location of residence and workplace. Two important factors greatly influence commuting: the socio-demographic conditions of the "decision maker," the person choosing the residence and workplace, and the "spatial context" of the Munich metropolitan region (Scheiner 2006).

Major activities performed in a place include living, working or studying, and entertainment. These functions are located in different places and correspond to different activity spaces. Mobility refers to travel between these different locations. In our research, we specifically focus on commuting, namely mobility between one's place of residence and workplace. On the one hand, commuting behavior is influenced by the location of residence and workplace. On the other hand, commuting distance or time is also an important factor in the choice of residential and workplace location. These choices are greatly influenced by individual socio-demographic characteristics.

From a micro perspective, the decision-making process for commuting, living, and working comprises different parameters of individuals (see figure 1). First, each person is a member of a household. Age, gender, marital status, and the existence of children characterize his or her role within the household. Second, a person is working in a firm or as an entrepreneur with business partners. Occupation, job position, and wage together characterize the role of this person in business activities. Apart from these two important roles, a person is also a consumer of leisure activities with different preferences, such as an orientation toward sport or culture. Last, a person's personal values, which are independent from other roles, might also have an impact on choices of residential and workplace location and commuting behavior.

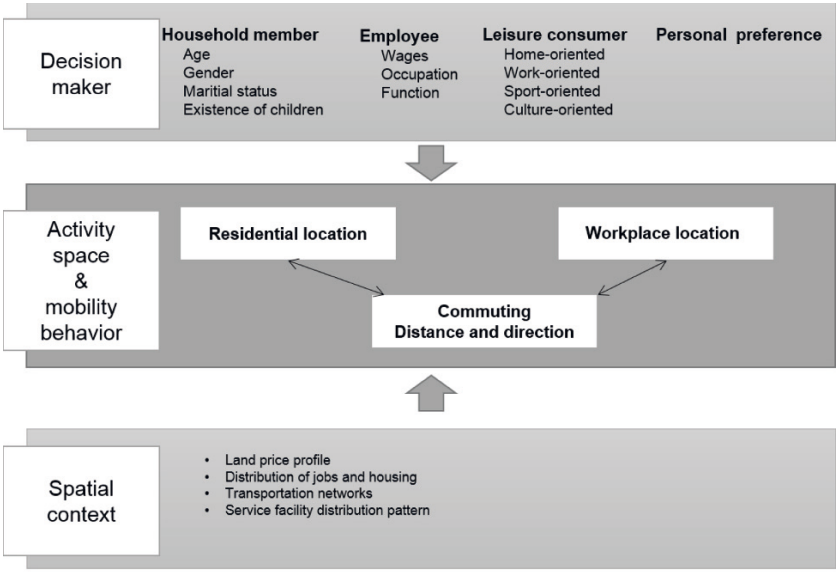

Fig. 1 Framework of analysis in this research. Source: authors' illustration

From a macro perspective, spatial context also influences the behavior of the decision maker. The length of a commute is influenced, to some extent, by the spatial separation of a home and workplace and the prevailing urban structure (Horner 2004; Laan et al. 1998). Here, urban spatial structure refers to the distribution of locational data such as total employment, total working population, transport infrastructure, and service facilities, as well as land prices. Spatial structure provides important information on supply, such as where job opportunities and housing are concentrated, or which city centers attract people to live and work.

2.2 Knowledge workers

The production of knowledge is driven by firms, institutions, and knowledge workers. Knowledge workers steer and drive regional development, since they bring and apply knowledge in the region. Thus, focusing on regional competitive advantages requires a perspective that follows the "knowledge agents" (Vissers, Dankbaar 2013:

716) in addition to following knowledge. Along with the production of knowledge, these agents aim to optimize their career opportunities, housing conditions, and mobility behaviors within a region. In order to assess their use of space in a metropolitan region we have to define which individuals represent knowledge agents. There are four major definitions of "knowledge workers." The *traditional classification of the labor force into white, blue, and pink-collar workers* holds that white-collar workers are those conducting professional or managerial work, whereas pink-collar workers conduct customer-related jobs. *Human capital theory* (HCT) focuses on traditional indicators of skill, measured by formal education (Glaeser et al. 2004; Becker 2009). The third approach is the *creative-class approach* (Florida 2002). It centers on the actual profession as a proxy for the skills of employees. The fourth approach, applied by Brinkley et al. (2009), includes the specific tasks performed in the job to determine whether workers are performing knowledge-intensive work, knowledge-based work, or work that is less related to knowledge.

Many empirical studies focus only on a small sample of knowledge workers. These studies select employees within the high-tech and financial service sectors (Frenkel et al. 2013) or specifically focus on finance, R&D and higher education, law, and other business services (Hafner et al. 2008). Research by Miguelez and Moreno (2014) exclusively focused on inventors. Their empirical findings will be stated in the next section.

2.3 Choice of residential location

The classic residential location theory of *access–space trade-off* states that trade-offs are made between housing costs and transport costs during residential location choice (Alonso 1964; Muth 1969; Evans 1973; Romanos, Romanos 1976; Thrall 1987). Regarding the choice of residential location is multifaceted, and much evidence challenges this simplified hypothesis, for instance, the phenomena of gentrification in the inner city (Hamnett, Williams 1980; Huu Phe, Wakely 2000). The second residential location theory of a *status–quality trade-off* (Phe, Wakely 2000) proposes an alternative approach. Trade-offs are made between the status of residence and the quality of housing. The term "quality" refers to the condition of housing, including its size, typology, and age. "Status" refers not only to proximity to work but to other important poles such as educational or cultural centers.

Studies on the prominent factors in the residential location choices of knowledge workers are inconclusive. On the one hand, the desire for "vibrant," "bohemian" neighborhoods forms a focal point of the amenity preferences in Florida's thesis of the "creative class." Such workers value an urban image of an active street scene of

coffee shops and bars in a historic or "bohemian" urban area (Florida 2002, 2005), and a tolerance of immigration and integration (Haisch, Klöpper 2015). Van Oort et al. (2003) showed that urban amenities (urban services such as theaters or cafes and green spaces such as parks or natural areas) are a key factor for information and communications technology workers in the Randstad region. On the other hand, classical factors, such as housing costs, size, and accessibility to work remain important considerations for these workers (Frenkel et al. 2013). Lawton et al. (2013) confirmed that classical factors are still prominent in Dublin. Furthermore, Frenkel et al. (2013) concluded that the municipal socioeconomic level, affordability of housing, and commuting time are the most important factors for knowledge workers' residential choice in the Tel Aviv metropolitan region, which is consistent with findings in the Munich region by Hafner et al. (2008).

2.4 Choice of workplace location

Job search is sensitive to geographical distance (Kim et al. 2005). Job seekers often begin from their place of residence to reduce both screening and searching costs as well as commuting costs. Jobs located farther from the residence imply either higher commuting costs or the additional costs of moving to a new residence with greater proximity, which renders the choice of these opportunities less attractive.

Meanwhile, the skills of knowledge workers are often specific: it is difficult to match such skills and the payment of the labor in the local labor market (Simpson 1992). Hence, highly skilled persons may search for jobs over a wider area from their place of residence, despite their higher valuation of commuting time, to maximize the return on their human capital investment (Simpson 1980).

2.5 Commuting time and distance

Empirical studies done in US metropolitan areas have shown that urban commuting time has remained stable or increased only slightly in the past three decades despite continuous population growth and increases in commuting distance and congestion (Gordon et al. 1991; Levinson, Kumar 1994; Crane, Chatman 2003; Kim 2008). A rational individual may periodically relocate their workplace and residence in order to optimize commuting time (van Ommeren, Rietveld, Nijkamp 2000). This corresponds to *Marchetti's constant*, which shows that in most cases, people spend a constant time commuting each day. With the advancement of transport

infrastructure, long distances become an important share of commutes and commuting space is expanding (Siedentop 2007; Guth et al. 2011).

As mentioned in section 2.2, knowledge workers bring knowledge with them. With the help of telecommunication technologies, they may apply their mobile knowledge to perform certain job tasks from home, with the exception of some key tasks that demand face-to-face communication. A lower frequency of travel to a workplace will reduce the weight of commuting time in the choice of residence (Giuliano 1998). Moreover, commuting time is no longer "dead" time due to the ability of such workers to productively employ this time. Lastly, since knowledge workers with higher job positions can enjoy transport welfare such as public transit tickets or company cars, these transport benefits may increase the acceptance of long commutes, leading to a longer commuting trip. In contrast, some factors tend to decrease with the length of the commuting trip. Time nowadays is becoming more valuable than ever, especially for knowledge workers. People who are more productive have a higher opportunity cost per unit of time and are unwilling to commute long distances. Furthermore, knowledge workers regard their jobs as careers or even as pleasure (Jemielniak 2012). They tend to work relatively long hours. This will encourage them to save time on the commuting trip.

3 Research hypotheses

The spatial structure of the Munich metropolitan region provides the decision context for the location of individuals' residences and workplaces. Our first hypothesis focuses on the evolution of the spatial structure of the Munich metropolitan region. The second hypothesis refers to the dynamics of commuting patterns from 1998 to 2013. The third hypothesis investigates the interrelationship between the number of commuters traveling from one place to another, travel time, and the number of jobs in the destination.

Hypothesis 1: *The Munich metropolitan region is in an early transition phase from a monocentric to a more polycentric structure. The relative importance of the city of Munich as a center of employment has weakened, and new employment centers are simultaneously emerging in secondary cities.*

Hypothesis 2: *With the improvement of transport infrastructures on the one hand and the development of information and communications technology on the other hand, the Munich metropolitan region is upscaling. The overall spatial extent of people's commute has enlarged in the last decade.*

Hypothesis 3: *Compared to the amount of population or jobs at the origin and destination and car-based commuting time, other factors have a greater influence on the number of commuters between two places. These factors include the specific types of employment provided at the place of work, the number of competent employees and local employment opportunities at the place of residence, and the chosen travel modes.*

4 Methodology

This section firstly introduces the basic characteristics of the Munich metropolitan region and data sources in the analysis. The second part will introduce methods of analysis that will help to test our hypotheses.

4.1 Research area and data

The Munich metropolitan region covers an area of 25,000 km^2 and has a population of 5.6 million (EMM 2014). The city of Munich, as the metropolitan core, is a hub of knowledge containing multiple highly ranked universities and a large number of firms that operate in knowledge-intensive sectors (Goebel et al. 2007; Lüthi 2011). Of the region's total employees, 20.1% are highly qualified, which is the highest rate among major German cities (IW Consult 2006). The research area in our analysis is larger than the administrative region of the *European metropolitan region of Munich* (EMM), in order to preserve the complete labor catchment area (Hafner et al. 2008).

We use commuting data regarding commuting balance from the Bavarian State Office for Statistics from the years 1998 and 2013. Commuting matrix data is only available for the year 2009. These data include origin-destination commutes between 1331 municipalities within the governmental districts of Oberbayern, Niederbayern, and Schwaben. A county is a higher-level administrative unit, containing several municipalities within it. There are a total of 67 counties in the research area.

4.2 Methods of analysis

In order to test our three hypotheses, several analyses with different indicators are applied. Firstly, we analyze spatial structure in terms of the distribution of employment centers. Secondly, in order to assess commuting distance, we apply two indicators: job–housing ratio and commuting intensity across county boundaries. Last, the spatial patterns of commuting flows help us to investigate major factors that influence the number of commuters from one place to another.

Employment center: ratio of in- and out-commuting share and minimum employment

A municipality is not a closed system. It is a place of both employment and residence provision. The ratio between total in-commuters from other municipalities and the total employment in a municipality is the in-commuting share. It is used as an indicator for the employment function. The ratio between out-commuters and the total employed residents in the municipality is the out-commuting share. It is an indicator for the residential function. In order to determine whether the employment function dominates the residential function in an area, leading it to be regarded as an employment center, we apply the indicator that is the ratio between the in-commuting share and the out-commuting share (Formula 1),

$$R = \frac{Si}{So} \cdot = \frac{I/T}{O/W} \cdot \tag{1}$$

where R is the ratio of the in- and out-commuting shares, S_i is the in-commuting share and S_o is the out-commuting share to an area, I represents the number of in-commuters and O represents out-commuters. T is the number of jobs and W is the total number of employed people who live in the same region. If R is smaller than 1, the residential function is more prominent than the employment function; if R equals 1, the employment function has the same importance as the residential function; if R is greater than 1, the employment function is more dominant than the residential function in the region. Furthermore, we count 5000 employment opportunities as a minimum threshold for evaluating the role of employment center.

Commuting time and distance

We apply two indicators to approximate commuting time and distance: job–housing ratio and commuting intensity.

Commuting time: Job–housing ratio

The job–housing ratio is calculated according to Formula 2. It describes the relative locations of jobs with respect to housing in a given area (Giuliano, Small 1993). A job–housing ratio close to one implies that there is an almost identical number of jobs and employed residents. It is associated with short commutes for both residents and employees (Boussauw et al. 2012),

$$B = \frac{T}{W}, \tag{2}$$

where B is the job–housing ratio, T is the number of jobs that have compulsory social insurance, and W is the total number of employed people who live in the same county. Here we consider a ratio between 0.8 and 1.2 as balanced. A ratio below 0.8 indicates that there are more employed residents than job opportunities in a region; a ratio above 1.2 indicates that there are more job opportunities than employed residents in a region. Both cases correspond to a relatively longer average commuting time within a given area. We should note that a job–housing ratio close to one is only associated with, instead of indicating, a short commuting time. In other words, job–housing ratio is only an approximate indicator for commuting time since information is lacking about whether the employed residents are actually those people performing the local jobs or not.

Spatial extent of commuting and intensity of commuting across county borders

The overall commuting dynamics of the labor market at the county level are calculated with Formula 3, according to Guth et al. (2011). The variable In represents the commuting intensity. The meanings of I, O, W, and T are the same as in Formulas 1 and 2. The greater the commuting intensity, the greater the ratio of in- or out-commuters compared to total workplaces and employed residents.

$$In = \frac{I+O}{W+T}. \tag{3}$$

This commuting intensity considers commuting in both directions, including the in-commute and out-commute at the same time. It is an effective indicator of

the intensity of commuting across county borders. Moreover, it also mitigates the scale-related bias by normalization with total workplaces and employed residents.

Spatial patterns of commuting

To identify the important factors that influence the number of commuters between two places, we take the city of Munich as a case study. The city of Munich is the metropolitan core, providing a large number of job opportunities for the whole region while at the same time residents in the city of Munich also commute to other regions to work. Based on the transport network used in the accessibility atlas (Büttner et al. 2011), "*Service area analysis*" in ArcGIS calculates car-based travel time to the city of Munich. The travel time is an optimal travel time, since the free-flow speed is set in the transport network. Moreover, we apply regression analysis to examine the correlations between the dependent variable, namely in-commuting flow, and independent variables, including travel time by car and population of origin places. For out-commuting flow, the independent variables are travel time by car and employment in destinations.

5 Findings

Our analyses are threefold. The first analysis determines whether the regional spatial structure is evolving into a more polycentric form. The next shows the spatial extent of individuals' commuting trips. The third part analyzes the major factors that influence the number of commuters travel from one place to another.

5.1 The spatial distribution of employment centers

In 1998, the ratios of in- and out-commuting in the cities of Munich and Ingolstadt were greater than two, which means they had a dominant employment function in comparison to their residential function. They were highly ranked as employment centers. In contrast, in 2013, the ratios in the cities of Munich and Ingolstadt had decreased. The difference between the employment function and residential function in these two cities was reduced. Moreover, among the 1331 municipalities in the study area, there were 191 municipalities with a ratio greater than one in 1998, increasing to 219 in 2013. Emerging municipalities with an important employment function are mainly located in the east of the region. Lastly, compared with em-

ployment centers in 1998, many new employment centers have emerged in 2013, as shown in Figure 2. We can perceive that the distribution of employment function is increasing, instead of being concentrated only in the metropolitan cores, namely the city of Munich, or major cities, for example, the city of Ingolstadt.

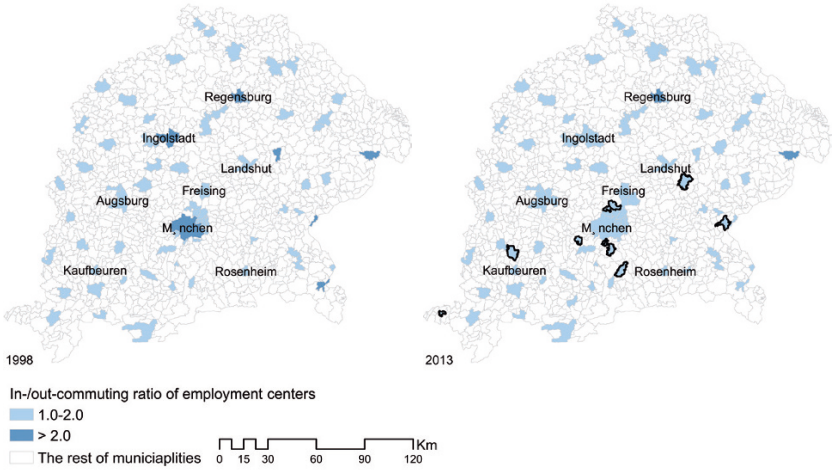

Fig. 2 Employment centers in the Munich metropolitan region (left: 1998, right: 2013). Source: authors' illustration

Several reasons underline the decrease of the employment function in major cities: the first is the dispersal of employment out from the city of Munich, similar to that existing in the Tel Aviv region. Due to lower rents, many high-tech firms, especially once they are established, locate themselves in the outlying part of the Tel Aviv metropolitan region rather than other major cities (Frenkel 2012). Another important reason might be that major cities are also important residential centers where the out-commuting ratio is also quite high, hence a lowering of the in- and out-commuting ratio. In other words, the attractiveness of residing in central high-density areas is increasing and many employed people who live in central areas work in other regions. This is also justified by the out-commuting flow in Figure 5.

5.3 Spatial extent of commuting

We firstly show the spatial as well as temporal change in job–housing ratio. We then show the change of commuting intensity across the county border.

Job–housing ratio

Among the 67 counties in the region, 29 of them had a balanced job–housing ratio in 1998, while only 25 counties had a balanced ratio in 2013. Five additional counties had a ratio below 0.8 in 2013. In other words, the number of jobs was less than the number of employed residents, resulting in a longer commuting time on average. These counties lie on the fringe of the region. This implies that there is still a huge spatial disparity in the region. Jobs are mostly concentrated in the metropolitan core, namely the city of Munich, and other major cities.

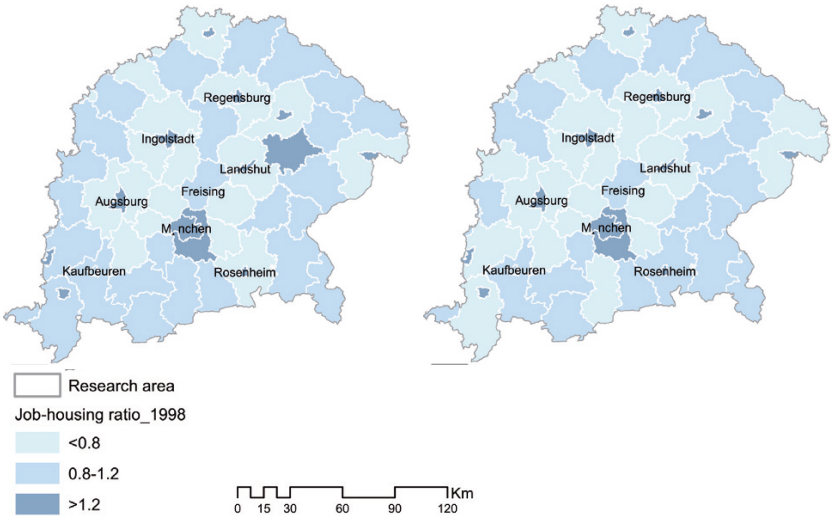

Fig. 3 Job–housing ratio within each county in the Munich metropolitan region (left: 1998, right: 2013). Source: authors' illustration

Job–housing ratios in the major cities of the study region were greater than 1.2, while closely neighboring counties had a ratio below 0.8 in both 1998 and 2013 (Figure 3). This is perhaps due to the fact that there is a high density of workplaces

concentrated in major cities (marked with the dark color in Figure 3) and a high density of employed residents in the neighboring counties (marked with the light color in Figure 3). People residing in central cities are willing to commute to another county for their job, and simultaneously, people residing in neighboring counties also commute to major cities to work. The exchange of employees between major cities and their neighboring counties is intensive and the self-containment level or the job–housing ratio reduces. Consequently, the average commuting times in central areas and their neighboring counties were longer than the rest of the region in both 1998 and 2013.

Commuting intensity

The commuting intensities in 75% of the counties in 1998 and in 84% in 2013 were greater than 0.25. This implies that out of every four workers, there was at least one working in a county other the county containing his place of residence. We notice an apparent increase of commuting intensity from 1998 to 2013 at the level of the cross-county border (Figure 4). The maximal commuting intensity has also increased from 0.69 to 0.72. Counties with a commuting intensity higher than 0.50 mainly neighbor major cities.

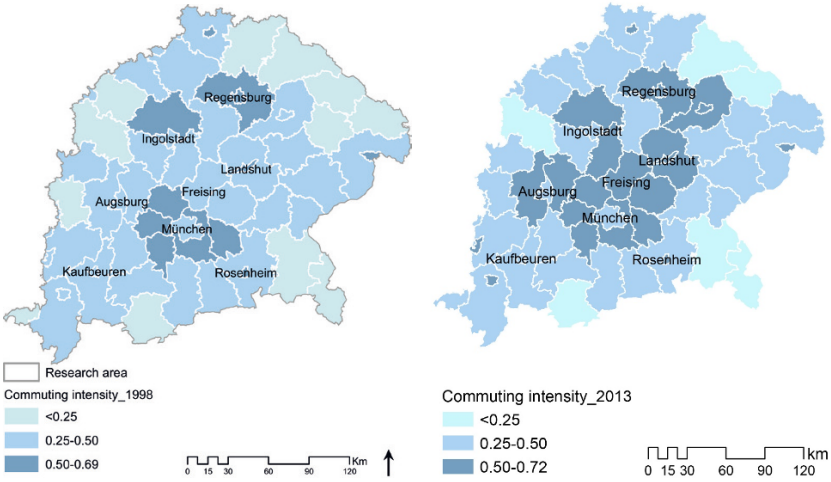

Fig. 4 Intensity of commuting across county borders in the Munich metropolitan region (left: 1998, right: 2013). Source: authors' illustration

The increase of commuting intensity in the past decade might be due to a spatial mismatch between jobs and workers. Compared to 1998, less people in 2013 were constrained by the borders of administrative municipalities. They might accept a workplace in a county other than their county of residence. This supports the statement that a county is not a closed system and mainly interacts intensively with neighboring ones in the area of employment.

Knowledge workers may be a group that contributes to the interactions between counties. On the one hand, those workers with a high position in their jobs always receive a relatively higher wage, allowing for a greater commuting distance and cost; on the other hand, their specific knowledge and skills also limit the location of their workplaces to major cities. Therefore, for knowledge workers that do not live in the counties where jobs are located, commuting across county borders has become the solution to connect their separately located residences and workplaces, guaranteeing a suitable job and satisfactory housing at the same time.

5.4 Commuting to and from the city of Munich

Large and small commuting flows are processed separately: commuting flows above 500 commuters are shown by lines of different widths; commuting flows below this threshold are represented by points.

The connections of road networks in the radial direction are better than those of the tangential direction in the Munich metropolitan region. For this reason, Figure 5 displays a concentric form for car-based accessibility, which decreases with distance to the city of Munich. Isochrones with an interval of 15 minutes are displayed.

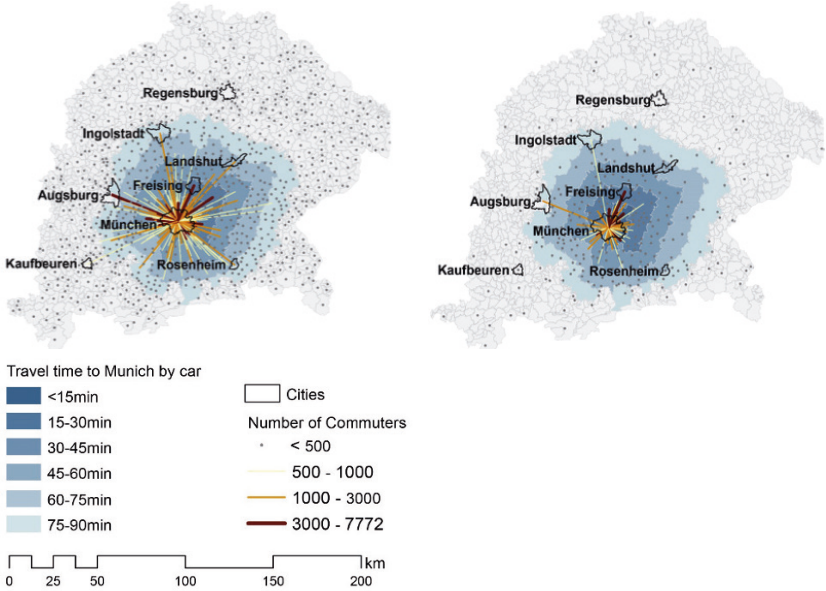

Fig. 5 Distribution of in-commuters (left) and out-commuters (right) to and from the city of Munich in 2009. Source: authors' illustration

The results of regression analysis are shown in Tables 1 and 2. As expected, positive or negative coefficients are generally consistent with the gravity model. The numbers of in- or out-commuters are positively correlated with population at the origin and jobs at the destination and are negatively correlated with travel time. A large number of jobs or population and small travel time together contribute to a large commuting flow. As shown in Figure 5, large in-commuting flows of more than 500 commuters are mainly concentrated in easily accessible areas from which it takes less than an hour to reach the city of Munich. More than 3000 persons from the city of Augsburg and the city of Freising commute to the city of Munich to work. The largest out-commuting flow is to the neighboring municipality Unterföhring. Unterföhring is an important media center in Germany. Moreover, the insurance company Allianz SE alone provides 6000 workplaces there. The city of Freising is the second-largest out-commuting destination. It provides many job opportunities, owing to the many prominent firms, such as Deutsche Post AG and Texas Instruments, providing job opportunities there. The city of Freising is

accessible from the city of Munich in only 45 minutes via private car and in less than 30 minutes via rail.

Tab. 1 Regression analysis of in-commuting flows

Number of in-commuters	Unstandardized Coefficients	Significance	Adjusted R Square
			0.441
Population of origin	0.032	0.000	
Travel time by car	−0.676	0.000	

Tab. 2 Regression analysis of out-commuting flows

Number of out-commuters	Unstandardized Coefficients	Significance	Adjusted R Square
			0.296
Jobs of destination	0.033	0.006	
Travel time by car	−1.170	0.000	

However, the very low values of R squares, in the models of both in-commuting and out-commuting flows, imply that the independent variables are far from adequate to account for the number of commuters. Furthermore, the distribution of the residuals is not a normalized distribution, i.e., extremely large or small residual values exist. This also suggests that the regression model needs further reconstruction. Focus on the aforementioned factors alone cannot explain the intensity of commuting flow between two places. Many other specific factors should be further investigated. Hence, we will examine the residuals and select extreme cases with the largest/smallest residuals to discover additional important factors.

In the model of in-commuting flow, the actual number of in-commuters from the city of Dachau to the city of Munich is more than double the predicted value. This is because there is a rail connection between these two cities and commuting via rail is faster than using a private car. The actual number of in-commuters from the city of Ingolstadt to the city of Munich is much lower than the predicted value. This is perhaps due to there being adequate employment opportunities in the city of Ingolstadt and local residents tend to find jobs within their city instead of choosing a long commute to the city of Munich. In the model of out-commuting flow, we found out that the actual numbers of commuters from the city of Munich to the municipality of Unterföhring and the city of Freising are much greater than

those predicted. This is because the job types provided in these two cities match well with the competencies of the residents in the city of Munich. Advanced service jobs in these two places attract many qualified persons from the city of Munich to work there.

Consistent with our expectations, commuting is a very complex issue and we should be quite tentative when modeling the number of commuters. Apart from the population at the origin, the number of jobs at the destination, and commuting time, there are many other key factors determining the number of commuters. The following factors account even better for the number of commuters between the two places, namely, the specific job types provided at the place of work, competent employees and local employment opportunities at the place of residence, and commuting time related to specific travel modes.

5 Discussion and conclusion

Polycentricity may have different forms or features: one important feature is a reduced disparity between central cities and secondary cities in a region. In other words, there is a redistribution of employment functions among each of several spatial entities. These functions are no longer only concentrated in major cities; rather, they are being gradually shifted to other municipalities. In our analysis, the relative importance of the city of Munich and the city of Ingolstadt is being reduced, on the one hand, and several other municipalities are simultaneously gaining in importance of employment function on the other. Hence, in this sense we have verified our first hypothesis that the Munich metropolitan region is becoming a more polycentric spatial structure in terms of employment distribution. Nevertheless, the comparative advantage of the city of Munich is still great. This suggests that the region is only at the very beginning of the transition phase from a monocentric to a polycentric structure.

The number of counties with an unbalanced job–housing ratio has increased, correlating to a greater commuting distance and time. Moreover, the cross-border commuting intensity of counties neighboring major cities has also increased, implying a greater commuting distance, compared to intra-county commuting. With this finding, we confirm our second hypothesis. The overall spatial extent of people's commute has enlarged over the last decade, which is the result of many factors, such as the development of transport infrastructures and telecommunication technologies. People nowadays commute across county borders to work, instead of being limited by the borders of municipality. Five percent of total in-commuters to

the city of Munich travel more than an hour and a half to their workplaces. This increase might be attributable to the growth in knowledge workers, as they may have a higher tolerance level of commuting distance and time than the general population, as mentioned in section 2.1. Nevertheless, we must bear in mind that cross-county commuting accounts for cases where the places of work and residence are not in the same county; this division with the static administrative border may also include many short-distance cross-border commuting trips.

Our third hypothesis is also verified. The amount of jobs and population at the origin and destinations are only capable of explaining the number of commuters to a small extent. Many other significant factors are more determinant, the composition of the labor force and local employment opportunities at the origin or place of residence and the specific job types offered at the destination, namely places of work. These factors are more essential for a regional structural match between a job seeker and a workplace. Furthermore, the variety of mobility behavior should also be included in the analysis since workers use various travel modes such as public transport for commuting trips, instead of depending merely on private cars. Due to data availability, we are not able to quantify the intensity of influence of these additional factors listed above.

6 Next steps in research

Actual commuting patterns capture people's personal choices concerning their arrangements for their journeys to work, which differs from the minimum level of commuting mandated by urban structure (Horner 2004). Available mobility, demographics, and personal choices all contribute to the difference between observed commuting and minimum commuting. This may require that we focus explicitly on the choices of individuals (Kwan, Weber 2003) rather than treating geographic space as areas. Commuting distances differ among groups with different income levels (Hu, Wang 2015) and educational levels (BFS 2014). This encourages us to expect a different pattern for knowledge workers. Further disaggregation of commuting flows with the proposed three criteria would permit us to analyze the residential preferences and choices of knowledge workers. Here we formulate three hypotheses and briefly explain the underlying rationales.

Hypothesis 1: *Knowledge workers trade easily accessible location for the properties of the dwelling and neighborhood environment in their choice of residential choice.*

Knowledge workers tend to engage in many learning activities to maintain their sustainable competiveness in their careers. They value each unit of time and try to maximize its utility. Hence, they opt for residences in easily accessible places in order to access as many opportunities to promote themselves as possible. The relative location of the residence is an important consideration for knowledge workers in their decisions concerning residential location, despite the importance of the dwelling itself and the neighborhood environment.

Hypothesis 2: *Job location has an impact on knowledge workers' residential trade-offs. A central job location will reduce the weight of a central residential location upon the residential choice.*

Given that both residence and workplace are essential reference points for engaging in all kinds of activities, knowledge workers try to locate at least one of these two reference points in a central location. In other words, knowledge workers prefer to at least live or work in central locations.

Knowledge workers have a certain tolerance level for commuting; additionally, it is quite costly and challenging to find a satisfactory workplace and residence in a central area. Thus, the location of workplace and residence actually function complementarily to each other. That is to say, a central workplace may reduce the desire for a centrally located residence, or alternatively, knowledge workers tend to have a strong desire for a central residential location, especially when their workplace is outside easily accessible areas.

Hypothesis 3: *The mobility preferences of knowledge workers influence their residential choices. They choose residential locations that support their mobility preferences.*

Knowledge workers have a certain way of living or lifestyle that is assumed to have a great impact on their residential choice today. Mobility preferences, as one important dimension of lifestyle, may precondition residential choices.

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Part III
Options of Change

Sharp Increases in Mobility Costs: A Trigger for Sustainable Mobility

Benjamin Büttner

Abstract

The growing Munich region is facing increasing pressures on its housing market and its citizens' everyday mobility. Rising land and rent prices are resulting in greater development of residential sites in peripheral locations and dispersed transport links on the regional level. This situation highlights an urgent need for coordinated control by decision makers on different scales of the Munich region. Along with the potential of rising mobility costs, the Munich region faces a significant risk of housing misallocation in relatively hard-to-reach locations on the regional level. The potential negative impact of these developments is exacerbated by shortages in fossil fuel supplies, political instability in oil-producing countries, and energy price increases (in the context of the energy turnaround). These scenarios were observed during the recent energy crisis and will inevitably lead to increases in mobility costs (Wegener 2009; Büttner, Wulfhorst 2013).

In the context of rising energy prices, assessing the vulnerability of regions in terms of not only their exposure (e.g., their level of fossil fuel consumption) but also their sensitivity (average income) and resilience (accessibility of jobs by public transport) allows for a better identification of long-term sustainable planning opportunities. Such vulnerability assessments, which allow for methods of sustainably improving mobility to directly address mobility cost increases, can better prepare municipalities and their respective decision makers. For example, reshaping land-use with an emphasis on multi-functionality and density, enabling non-motorized transport, and enhancing community solutions (e.g., carpooling and community buses) all offer ways to increase the sustainability of vulnerable municipalities.

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Public decision makers and actors at the local and regional levels must make sustainable provisions for the future, taking increasing mobility costs into account in their decision-making processes on real estate and transport development. To do this, they need appropriate and accessible tools that can help them assess the possible effects of changes in mobility costs within their area of responsibility.

1 Background and problem statement

Even though the share of transport costs in the typical household budget has been rising dramatically, mobility costs are often underestimated or completely ignored in household relocation decisions (see Figure 1). Similarly, conventional housing affordability models also ignore transport costs (Mattingly, Morrissey 2014), whereas residential costs — e.g., the monthly mortgage — remain the main financial concern for households deciding where to relocate (Haller et al. 2012). The Munich region is a prominent example of how migration and especially the growth of labor can create a disconnect between residential location decisions and mobility costs.

Fig. 1 Monetary factors in household relocation (MORECO 2014)

While population and employment levels are declining in many parts of Germany, the Munich region presents a conflicting case. Population forecasts project that the city of Munich will grow by 14.9% between 2011 and 2030 (an annual population growth of 0.73%). This growth will result in a total urban population of 1.65 million inhabitants. Both positive birth-to-death ratios and migration from other parts of Germany and Europe are contributing to this development (City of Munich 2015).

Households migrating into the Munich region are confronted with a highly competitive housing market, with the current housing shortage resulting in sharp increases in residential costs. Munich has the most expensive housing market as a result of these increases in costs. Residences in the city are particularly high-priced, so new arrivals usually end up living in the outer suburbs or even in more remote and correspondingly more affordable locations (City of Munich 2012). As a natural response to such a competitive housing market, remote municipalities are pushing for an allocation of new inhabitants that are in desperate search for affordable housing (MIMMO e.V. 2014).

Unfortunately, this relocation pattern is not sustainable. The remote locations often lack convenient access to a wide range of desired urban amenities and activities, and as a result, their residents must travel long distances to commute to work and for leisure, as well as to fulfill their basic needs. Sparsely distributed populations do not favor public or non-motorized transport; rather, this increasingly dispersed urban structure favors car use (Cervero, Guerra 2011; Scheiner 2006). For example, according to the Institute of Media Research and Urbanism (IMU), amidst this population growth in the less dense outskirts of Munich, the portion of trips traveled by non-motorized transport decreased from 12% to 6%, whereas public transport's share of trips dropped from 31% to 15% (IMU 2002).

This dispersed urban structure and the growing distances to daily mobility destinations exacerbate another problem: increased transport costs. Political instability in oil-producing countries, volatility in supply, increasing consumer demand, and peak oil have driven sharp and unpredictable increases in mobility costs (Wegener 2009). Between 2002 and 2012, gasoline prices in Germany nearly doubled from US$1.03 to $1.96 per liter (see Figure 2). Coupled with only minor increases in real income during the same period (Brenke 2009), the combination of longer travel distances and higher gas costs has forced households to spend a greater share of their budget on transport (Büttner et al. 2013). It is important to study sustainable transportation alternatives and strategies so that households can better adapt to increased mobility costs.

Fig. 2 The price of fuel in Germany from 2002 to 2012 (U.S. Energy Information Administration 2015)

2 Methodological approaches

In line with the complexities of individuals' mobility behavior, a set of diverse approaches has been applied to examining the impact of increased transport costs on the mobility decisions of various user groups and stakeholders. To cope with the consequences of rising costs for people's mobility, the Scan-Explore-Prepare methodology was developed (see Figure 3). Its three steps can be described as follows:

Scan: An oil vulnerability assessment aims to scan and subsequently highlight which regions in Munich are at greatest risk due to increasing fuel costs (see Büttner et al. 2013).

Explore: An exploration of individual households is undertaken to develop a range of different storylines that portray real-life reactions to mobility cost shocks. These storylines form the basis for a common language between planners, decision makers, and households.

Prepare: Local stakeholders and decision makers are then given sustainable accessibility recommendations so that they can be better prepared to make key decisions at the regional level.

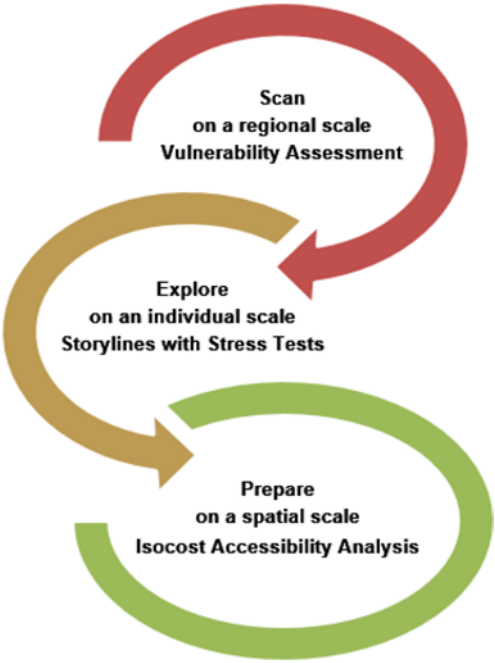

Fig. 3 The Scan-Explore-Prepare methodology

2.1 Scan: Adapting the vulnerability assessment

As a first step, the resilience of the Munich study region was analyzed by means of an oil vulnerability assessment (see section 3 below), which identified those municipalities in the Munich area most threatened by increasing mobility costs. This vulnerability concept, which has previously been used to test susceptibility to famine and food security, hazards, and climate change (Adger 2006), is adapted here to examine regional vulnerability to drastic increases in mobility costs.

To adapt the vulnerability assessment to the issue of increasing fuel prices, appropriate indicators must be identified and data must be collected. Based on Kasperson et al. (2006), the three vulnerability indicators of exposure, sensitivity, and resilience are used. At the municipal level, these indicators can be described as follows:

- Who will be exposed by an increase in fuel prices?
  Answer: Those who have a high fossil fuel consumption
  Indicator: Municipal average of vehicle kilometers traveled per capita
- Who will be sensitive to rising fuel prices?
  Answer: Those who have relatively low income
  Indicator: Municipal average net income
- Who will be resilient in the case of increasing fuel prices?
  Answer: Those who have alternatives to private cars
  Indicator: Accessibility of jobs by public transport
- Who will be vulnerable to an increase in fuel prices?
  Answer: Those who are highly exposed and highly sensitive with low resilience

Therefore, the vulnerability index was calculated as the sum of the listed indicators.

In general, this methodology can be transferred to other regions or thematic questions. However, for effective benchmarking, the framework and indicators must be adapted to such issues as data availability and index choice, as the current index demonstrates only one municipality's vulnerability relative to another's. To ensure a certain level of comparability, identical or at least similar and comparable data must be chosen. Another possibility is to combine indicators and weight them according to their perceived magnitude.

2.2 Explore: Developing individual storylines with shock scenarios

Following a determination of the characteristics of the Munich region, an exploration of individual households was undertaken (see section 4). The underlying premise was to analyze households' mobility behavior so as to develop a range of different storylines that portray real-life reactions to mobility price shocks (see Büttner, Wulfhorst 2012 for all storylines).

As a first step, synthetic households and their respective mobility behaviors were derived by analyzing a range of regional databases. Local communities also reviewed the qualities of the hypothetical households generated, including their individual mobility patterns, and confirmed their relevance and reasonableness.

After the data were prepared, stress tests were established in line with studies predicting a rise in the crude oil price to US$200 per barrel (e.g., ifmo 2010). The first stress test aimed to demonstrate the effects of such an increase, which would cause the price of fuel at German gas stations to rise to 2.11 €/L — a 35% increase.

The second stress test considered the scenario involving a tripling of fuel prices, forcing German households to spend 4.65 €/L for fuel.

By applying these stress-tests, the second approach aims to investigate the initial vulnerability assessment through exploring how changes in mobility constraints could impact daily activity schedules, mobility behavior, and selections of residential and activity locations. In line with a simplified economic approach, the research did not focus on the economic theory and variables related to gradual oil price increases; instead, it focused on how households would react to sudden drastic oil price shocks. It was assumed that a rise in oil prices would be directly translated into higher pump prices, thus directly affecting consumers each time they refueled.

2.3 Prepare: Including monetary budgets in accessibility analyses

In most cases, vulnerable households can change their mobility behavior only when they are offered more viable transport options or alternatives. Therefore, helping governments to recognize the interdependencies between land use and transport can enable vulnerable communities to prepare for and adapt to increases in mobility costs. Policies, intervention strategies, and recommendations should also be discussed in order to foster sustainable spatial development (Hull et al. 2012). This point is reinforced by Geurs et al. (2012), who state the importance of testing the current accessibility analysis in practice. For the implementation of accessibility planning, a strong collaboration between researchers and planning practitioners is needed.

With the help of the TUM Accessibility Atlas, different catchment areas and their respective potentials were calculated (see Büttner et al. 2011). Following this, the accessibility of the investigated areas was calculated based on each transport network. Using the Accessibility Atlas, mobility costs were implemented for both private motorized transport (PrT) and public transport (PuT). For a single journey (one-way), a budget of 2.50 € per trip was assumed. In 2010, private transport expenditures in Germany averaged 305 €; this value corresponds to 14% of total private consumption expenditures (Federal Statistical Office 2013).

3 Analysis within the study region

To tackle the issue of increasing mobility costs, the spatial scale of the analysis had to be adapted to the respective aims. We chose to delineate the region by the extent of its public transport network, which includes the city of Munich and eight neighboring districts. This area is served by most of the public transport services in the near vicinity of Munich (e.g., underground trains, suburban trains, trams, and inner-city and regional buses), all of which are managed by the regional public transport authority (the MVV).

3.1 Scan on a regional level by vulnerability assessment

As a first step, understanding the Munich region as a whole was of high importance. Therefore, as explained above, a vulnerability assessment based on Kasperson et al. (2006) was adapted to measure the entire region with regard to three indicators: exposure (fossil fuel consumption), sensitivity (income), and resilience (accessibility to jobs by public transport). Following the assessment, three municipalities representing different settlement structures (urban, sub-urban, and rural) were selected in order to better understand and characterize localized differences in vulnerability (see Büttner et al. 2013).

Exposure assessment

To measure exposure, two sources of data were used. The first, GENESIS online, is a national database of regional statistics that provides population data. The second source is the regional transport model, developed jointly by the city of Munich, the MVV, and the Munich public transport operating agency (MVG). This model allows for the calculation of vehicle kilometers traveled (VKTs) by the inhabitants of each municipality within the coverage area of the MVV network. This key indicator for measuring exposure was chosen because VKTs are directly related to fuel consumption.

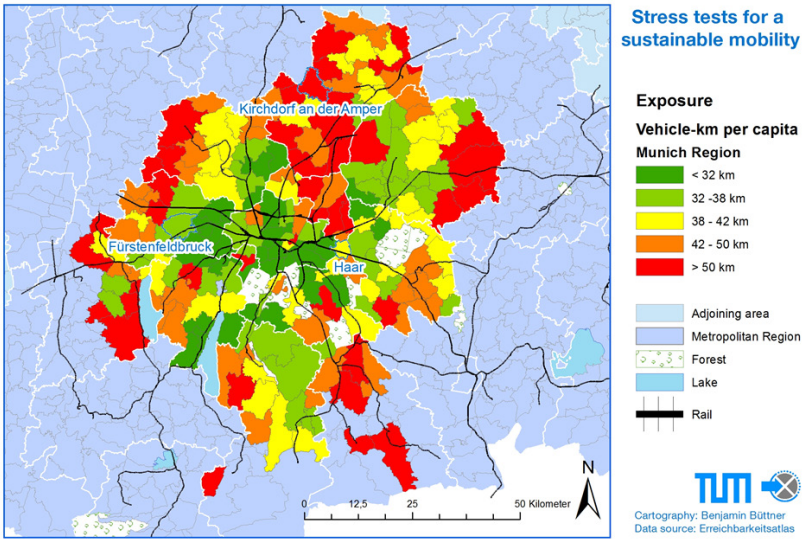

Fig. 4 Municipal average of vehicle kilometers traveled per inhabitant in the Munich region

The red municipalities in Figure 4 show a very high exposure due to their high level of VKTs per inhabitant. On average, the inhabitants of these municipalities drive their car more than 50 kilometers each day on regular trips. Locations with higher exposure tend to be located on the periphery of Munich, with a cluster in the far north. The more exposed municipalities are generally located in rural regions, characterized by almost no public transport services. Individuals living within the red municipalities are very car-dependent.

Sensitivity assessment

The measurement of sensitivity relies on two indicators: unemployment rate and average monthly income. Both datasets, available on the municipal level, are drawn from the GENESIS online database provided by the Bavarian Department of Data and Statistics (2010).

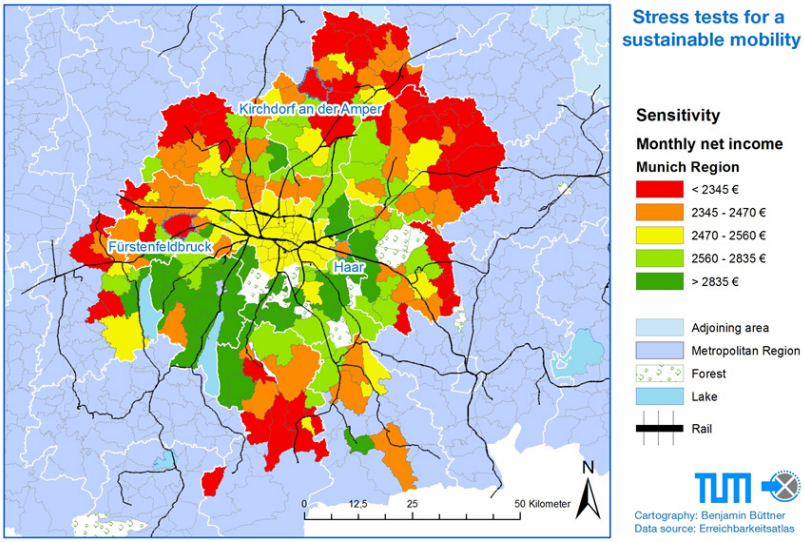

Fig. 5 Monthly income in the Munich metropolitan region

The average monthly net income for employees is illustrated in Figure 5. Sensitive municipalities are located mainly on the outskirts of the Munich region. Many of these municipalities have both net monthly income of less than 2,345 € and high VKT levels, meaning that they would suffer severe consequences from an increase in mobility costs. On the other hand, the southwest municipalities have less sensitivity despite their large amounts of VKT, due to their relatively high net monthly income of more than 2,835 €.

Resilience assessment

The level of resilience is measured in terms of accessibility of jobs by means of public transportation. Accessibility can be defined as the ease of reaching various life opportunities from a given location using a particular transportation system (Morris et al. 1978). In this case, jobs are selected as the most relevant opportunities because of their high importance in generating traffic.

Access to jobs by public transport during the morning peak period serves as a key indicator of resilience. Figure 6 displays the total number of accessible jobs within one hour for every municipality.

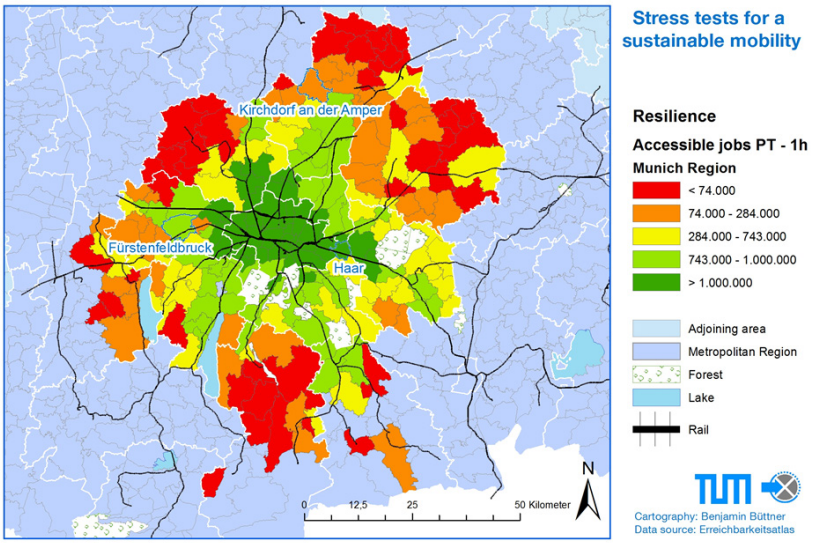

Fig. 6 Accessibility to the number of jobs by public transport in the Munich region

From the green municipalities, more than one million jobs are accessible by public transport within one hour. Red municipalities lack adequate public transport and, in most cases, are not located in close proximity to jobs. Moreover, in less accessible municipalities, it is often impossible to shift from car to public transit for one's daily trips between home and work. Public transport is even less available for other trip purposes (e.g., leisure, shopping), and thus, people are less resilient with regard to these types of trips (see Büttner et al. 2012).

The inhabitants of these municipalities without convenient access to public transit also have limited ability to shift to non-fuel-powered modes of transport. Thus, these inhabitants are not resilient in the face of rising fuel prices.

Vulnerability assessment

A vulnerability index can be calculated based upon the indicators of exposure, sensitivity, and resilience as described in section 2. Due to the different methods of valuing the three indicators, the order of magnitude varies considerably: exposure ranges from 10 to 100 VKTs per day, sensitivity ranges from below 2,345 € to more than 2,835 € of net income, and resilience has a maximum of over a million jobs accessible by public transport. In order to make the three indicators qualitatively comparable to each other, a rank ranging from 1 to 100 was applied to each indicator.

The following assumptions were adopted when assigning the ranks: the more one drives (highly exposed), the more vulnerable he or she is; the less one earns (highly sensitive), the more vulnerable; and the better public transport accessibility one has (highly resilient), the less vulnerable. The scales were all constructed so that a score of 100 signifies the greatest vulnerability.

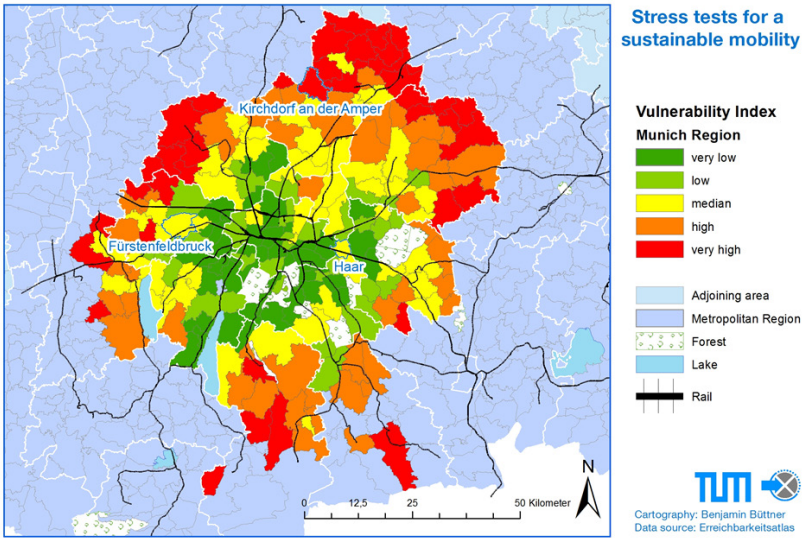

Fig. 7 Vulnerability assessment concerning fuel price spikes in the Munich region

The green municipalities in Figure 7 show low vulnerability to rising fuel prices. These municipalities are able to cope with sharp increases in fuel costs. In con-

trast, the highly vulnerable red municipalities will suffer heavily due to high car dependency and low average income. Most of these vulnerable municipalities are located between the railway axes or in the outskirts of Munich. Therefore, to ensure resilient and sustainable regional development, transit-oriented development close to highly accessible public transport stations should be further fostered. At the same time, to maintain the quality of life within these vulnerable municipalities, it is urgently necessary to provide mobility alternatives (e.g., public transport) as well as convenient facilities to meet people's daily needs (e.g., supermarkets, jobs, and schools).

By adapting the vulnerability assessment methodology, regions (municipalities or zones) can be tested for their future viability in the case of sharp increases in mobility costs. Although dependent on data availability, it is highly important for proper analysis to select reasonable indicators. For benchmarking and comparing different case studies, the same regional scales as well as the same indicators need to be chosen.

Despite this, it is not advisable to transfer these municipal-based impacts to an individual basis. Therefore, an analysis of households has been performed within the same study region to point out the individual effects and differences people are facing to not only households but also decision makers in the region. As a result of drastic shock scenarios, individual strategies are formulated for maintaining social and economic participation.

4 Explore on an individual household level by storylines with stress tests

Having scanned the Munich region for municipalities in danger of increasing oil prices, subsequent analysis focuses on the effects felt by households due to sudden fuel price increases. This chapter aims to provide a common language for planners, decision makers, and households so that they can better understand the actual situation of households trying to maintain their mobility levels and their social and economic participation under financial strains.

This chapter is dedicated to just one household — "Household Y" — which represents a typical four-person family (see Table 1) unable to change their mobility behaviors suddenly. Within the MORECO project report (see Büttner, Wulfhorst 2013), other representative households (e.g., an elderly couple, a single mother, students, etc.) are included in different structural settings (urban, suburban, and rural).

4.1 Current mobility behavior

Tab. 1 Members of Household Y

Person	Age	Work / Education
Father	40	Full-time
Mother	39	Part-time
Son	9	Elementary school
Daughter	5	Kindergarten

Tab. 2 Household Y's Residence

Address	Floor Space (m^2)	Living Costs (€/month)	Income (€/month)	Number of Rooms	Number of Cars
Industriestraße 61, Aubing	120	1,400	3,750	4	2

Tab. 3 Household Y's Activities

Person	Frequent Activities				Infrequent Activities (Monthly)	
	Work Days		Leisure (Weekly)			
Father	Full-time	Ottostraße 13 (City center)	Soccer	Connolly-straße 32 (Olympic Park)	Barber	Innere Wiener Straße 48 (Au-Haid-hausen)
Mother	Part-time	Kapuziner-platz 1 (Isar-vorstadt)	Meeting friends/ dinner	Hohen-zollern-straße 25 (Schwabing)	-	
Son	School	Flurstraße 8 (Au-Haid-hausen)	Music academy	Flurstraße 8 (Au-Haid-hausen)	Doctor	Karl-Theodor-Straße 97 (Schwabing)
Daughter	Kinder-garten	Flurstraße 8 (Au-Haidhausen)			Doctor	Karl-Theodor-Straße 97 (Schwabing)
Together			Shopping/ bowling/ movie theater	Thomas-Dehler-Straße 12 (Neuper-lach)	Vis-iting family/ hiking	Beccostraße 12 (Pöcking)

Since the father has accepted a new job in Karlsfeld, and considering the commuting time from their existing residence in the center of Munich, the family has decided to move to a closer residence in Aubing. From here, Karlsfeld can be reached by car within 14 minutes via the A99 highway. The drive from the new residence to the mother's work takes 24 minutes, which is acceptable as well. Additionally, the new location is accessible by the suburban train, which provides direct service to the city center. The station is within one kilometer of the new house. Moving to the outskirts, in order to be closer to the father's new job, has also enabled the family to live in a green area where rent prices are lower than in the city center (see Table 2).

Since they want neither to lose contact with friends nor to dramatically change their habits, they continue to practice exactly the same activities as before (see Table 3). Leisure activities and meeting friends in Munich remain part of their weekly schedule. Overall, Aubing has high public transport accessibility, but the move will still influence the family's monthly transportation expenditures significantly.

4.2 Shock scenario: US$200/barrel (increase to 2.11 €/L)

An increase in fuel prices to 2.11 €/L (US$200/barrel) would not have a dramatic impact on the family's household budget. Only 78 € less would be available per month, compared with the pre-shock scenario (see Table 5). This slight increase would most likely cause no change in the family's mobility behavior. Nevertheless, some suggestions can be made concerning potential behavior changes so as to reduce total transport costs to the same level as before the price shock.

The mother could use Park and Ride (P+R) four times a week to go to work, instead of relying solely on her car. Only when she meets her friends in the city center would she need to use the car. Another simple alternative to save 30 € per month would be to change the weekly route to the music academy. In the pre-shock scenario, the mother drove her child to school via highway A99 (35 km); however, using a more direct route (22 km) would also save money.

But these changes in mobility behavior have significant time drawbacks, in that modifying mobility patterns as suggested would cause the household to spend an extra 477 minutes traveling per month.

4.3 Shock scenario: Tripling of oil price (increase to 4.65 €/L)

A spike in fuel prices to 4.65 €/L (a tripling of current prices) would have a drastic impact on the household budget. Each month, the family would spend an extra

429 € compared with the current situation. Such an increase would mean that 78% of the families' income is spent on mobility and living costs, compared with only 66% before the shock.

Assuming that the family wants to maintain the same budget as before the price shock, they will likely aim to travel in more cost-efficient ways. The mother will experience a longer travel time of 20 minutes each way on her commute to and from work. She will continue using the car for a series of connected trips on some days (combining leisure activities with work) as this requires a greater level of travel flexibility. The son will also go to music school by public transport, spending an extra 10 minutes per trip (each way). The husband will suffer the most from this new situation, as he will be forced to spend an extra 49 minutes traveling to work.

The husband's extra travel time is one major drawback of the chosen residential location, as the public transport connection to his workplace in Karlsfeld is very inconvenient compared with the car. For all remaining car trips, the shortest route will be chosen in order to minimize fuel consumption. Due to these changes in everyday mobility, the family's small second car will not be necessary any longer and can be sold. This saves 350 € of fixed car ownership costs per month.

Table 4 and 5 summarize the differences between the status quo and the two shock scenarios. Further strategies for adopting more efficient mobility patterns in response to oil price spikes can be found in the MOR€CO project report (see Büttner, Wulfhorst 2013).

Tab. 4 Shock scenario expenditure summary for Household Y in Aubing

Type of Expenditure		Mobility Scenario Costs				
		1.55 €/L	2.11 €/L	2.11 €/L (incl. P+R change)	4.65 €/L	4.65 €/L (incl. PuT + Selling Car)
Living costs per month (€)	Net rent	1,100	1,100	1,100	1,100	1,100
	Additional living costs	300	300	300	300	300
	Total	1,400	1,400	1,400	1,400	1,400
Mobility costs per month (€)	Car ownership	800	800	800	800	450
	Car use	348	426	284	777	180
	Public transport	25	25	0	25	136
	Commuting allowance savings	91	91	91	91	91
	Total	1,082	1,159	1,059	1,511	674
Travel time (minutes/month)		2,572	2,572	3,049	2,572	5,569

Tab. 5 Shock scenario budget summary for Household Y in Aubing

Income and Expenditures	Mobility Scenario Total Costs				
	1.55 €/L	2.11 €/L	2.11 €/L (incl. P+R change)	4.65 €/L	4.65 €/L (incl. PuT + Selling Car)
Net income (€)	3,750	3,750	3,750	3,750	3,750
Mobility and living costs (€)	2,482	2,559	2,459	2,911	2,074
Ratio	66%	68%	66%	78%	55%
Disposable income (€)	1,268	1,191	1,291	839	1,676

4.4 Intermediate conclusions

A fuel price based on US$200 per barrel has a relatively minor impact on household activities and only a limited effect on short-term mobility behaviors. The tripling of gas prices, however, greatly affects the household budget, especially for the most vulnerable households — which are usually lower- or middle-class families living in suburban areas.

Nevertheless, potential alternatives, such as using public transportation, carpooling, or changing activities or residential locations, can prevent this shock from highly impacting household budgets. Activities like working and shopping can be linked efficiently, and unnecessary trips can be avoided. Despite not always being possible, trip chains can offer enormous potential in terms of more sustainable travel behavior while also saving time and money. Choosing a more sustainable mode of transportation, if available, can also save money while reducing a household's vulnerability to mobility price shocks.

Daily private vehicle commutes can also be made more sustainable through ride sharing, which provides cost savings over operating one's own motor vehicle daily but with faster travel times when compared with public transport. P+R is another alternative as it combines the advantages of two modes. It offers flexibility and comfort in sparsely settled regions without any public transport services while still avoiding congestion in densely populated urban centers. In some instances, telecommuting can also allow households to save on mobility costs.

In most cases, households can change their mobility behavior only if they are offered other transport alternatives (which could range from public transit services to demand management incentives). Recommendations to stakeholders and decision makers should be based on detailed regional-level analyses that consider projected future residential and mobility costs. Regional decision makers, when discussing policies and strategies, should consult maps, like those presented in this paper, that

display residents' degree of access to daily activities. Such an approach can help to foster sustainable spatial development.

5 Preparing decision makers by isocost accessibility analyses

Having first investigated oil vulnerability for the Munich region and subsequently the reality of oil price shocks for households, local stakeholders and decision makers can now be prepared on the regional scale by means of isocost accessibility analyses. These analyses aim to show how different oil price shocks affect the accessibility of a range of activities (e.g., employment, health, and education). Analyses that consider public transport as well as walking accessibility are also offered.

This section examines the effects of severe oil price shocks on communities reflecting three different types of spatial development within the same region: the peripheral city of Fürstenfeldbruck (suburban), the town of Kirchdorf an der Amper (rural), and the inner-city suburb of Haar (urban). A detailed presentation on these municipalities and others is included in initial analyses and can be found in the report "MOR€CO: Investigation of future living and mobility costs for households in the Munich region" (see Büttner, Wulfhorst 2012).

5.1 Current situation and outcomes

Fürstenfeldbruck

Figure 8 details pedestrian access from the Fürstenfeldbruck suburban train station. The periphery of the station is distinguished by the lack of nearby activities accessible to pedestrians. Sparsely located shopping opportunities can be reached by a five-minute walk from the station; however, the main activity focal point is located more than 15 minutes away. Important educational institutions are located northeast of the suburban train station, but pedestrians need between 10 to 15 minutes to reach these areas even though they are only at a distance of 500 meters due to the lack of direct routes and the rail tracks serving as a barrier.

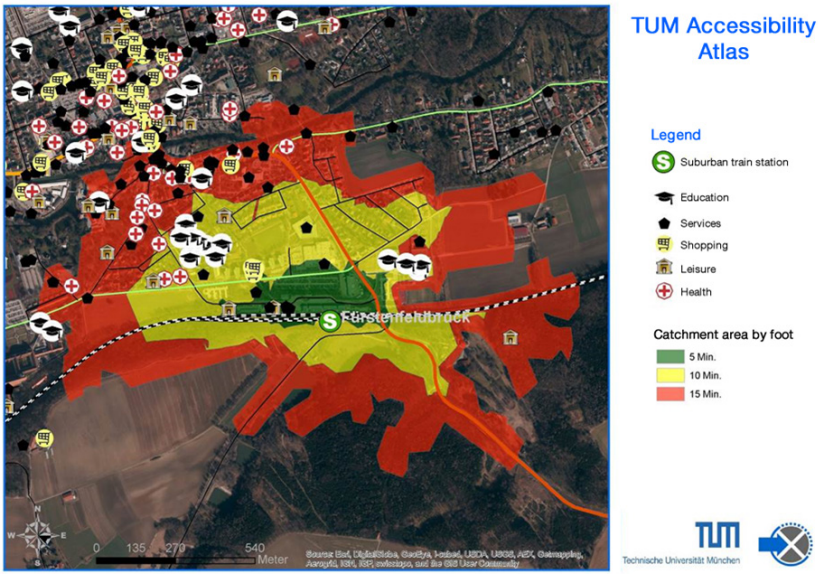

Fig. 8 Pedestrian accessibility from the Fürstenfeldbruck train station

In the case of accessibility by private motorized and public transport, isocost analyses (shown in their entirety in the full MOR€CO II report; see Büttner et al. 2014) demonstrate that private motorised transport can cover three times more area than public transport, assuming a travel budget of 2.50 € while conservatively taking into account solely operational costs (i.e., fuel costs at 1.55 €/L and a single-ticket train fare). For this scenario, twice the amount of population, jobs, and shopping opportunities can be accessed by car when compared with public transport, with the western areas of Munich also within reach.

Figure 9 highlights the car-based accessibility scenarios that involve fuel prices reaching US$200/barrel as well as the drastic tripling of prices. With a moderate fuel price increase to 2.11 €/L (US$200/barrel), less than half the previous number of jobs and residents would now be accessible by private car on a budget of 2.50 €/day, and the economic opportunities within. As a result, the potential of the city of Munich would no longer be accessible.

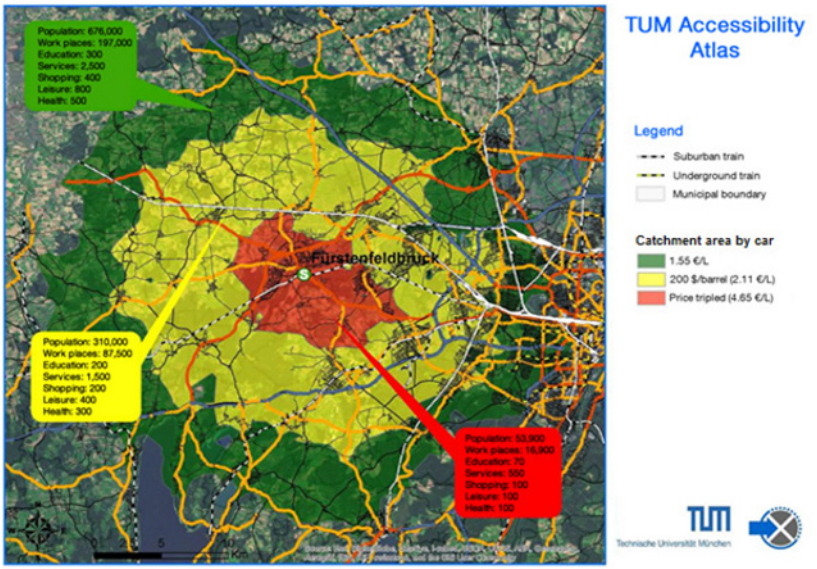

Fig. 9 Access to opportunities by private car for different fuel price shock scenarios in Fürstenfeldbruck

In the case of a tripling of fuel prices, the close surrounding areas of Munich would not be accessible (see Figure 9) and therefore, only approximately 8% of the originally accessible population and job potential remain available. This shock scenario results in an expected increase in the price of a one-way train ticket from 2.50 € to 3.50 €. Consequently, public transportation is still not preferable to private motorized transport given this price increase, assuming that the public transport tariff structure does not change. With a budget of 2.50 € (enough for short trips), only public transport from within Fürstenfeldbruck is accessible. With a budget of 3.50 €, more than double the workplaces, service providers, and educational and recreational facilities are accessible.

Kirchdorf an der Amper

The rural town of Kirchdorf an der Amper, approximately 50 km north of Munich, has no S-Bahn (rapid transit) connections within its periphery. Accordingly, the City Hall bus station is the most important public transport stop. Figure 10 highlights pedestrian-accessible service areas within this small municipality, whereby it can

be seen that all activities are accessible on foot within 15 minutes and that most are accessible within 10 minutes.

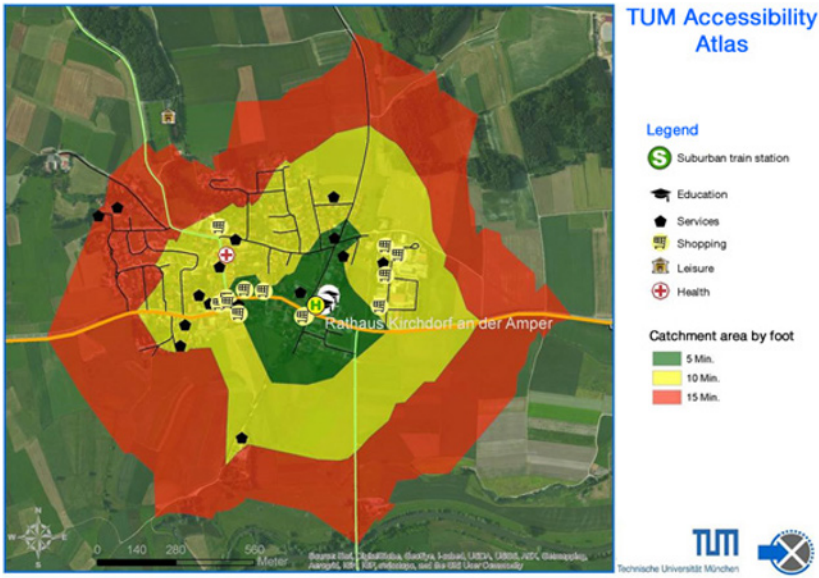

Fig. 10 Pedestrian access from the Kirchdorf an der Amper S-Bahn station

A relatively larger area is accessible by using regional buses. Both Freising and Munich Airport can be reached with only a single-trip ticket of 2.50 €, but the frequency of these services is rather small and irregular. Accordingly, the realistic availability of public transport is highly dependent on the time of day and the day of the week. By car, the municipalities of Neufahrn, Hallbergmoos, and Eching, south of Kirchdorf an der Amper and north of Munich, are also accessible.

Figure 11 shows how a drastic fuel price increase in Kirchdorf an der Amper would affect the accessibility of activities. For the US$200 per barrel scenario, more than half of the previously reachable population, jobs, services, and shopping would become inaccessible. In this region, the Munich Airport specifically plays a supporting role with its variety of activities, which would no longer be accessible even with such a moderate increase. The accessibility within the airport region is at significant risk with an increase in mobility costs.

Should fuel costs triple, the cost of public transport is not affected as greatly as that of PrT. Accordingly, with a travel budget of 3.50 € by public transport, more than double the population, jobs, services, shopping, and leisure and health facilities are accessible (see the full MOR€CO II report for details).

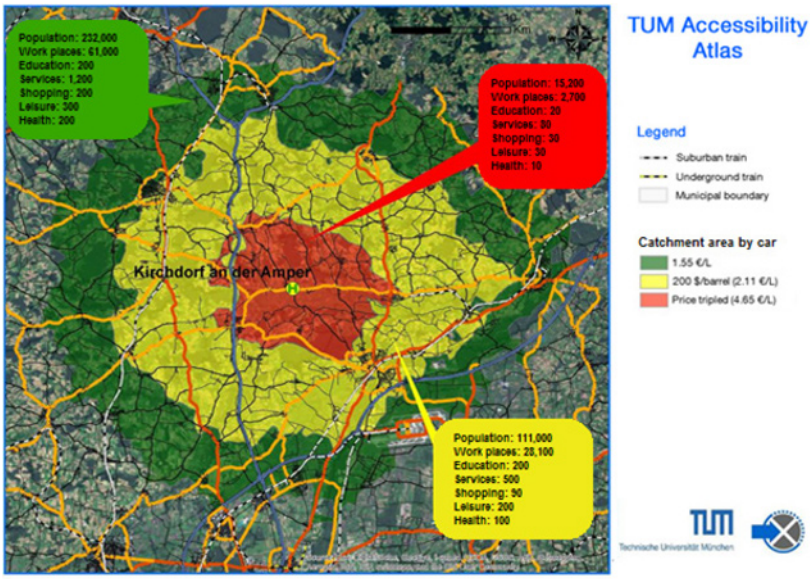

Fig. 11 Access to locations by private car for different fuel price shock scenarios in Kirchdorf an der Amper

The development of attractive and reliable public transport connections between land use priorities and major workplaces, such as Munich Airport, is necessary to make this region more resilient in response to increasing mobility costs.

Haar

The suburban municipality of Haar is distinguished by a high density of activities. The S-Bahn station is located northeast of the municipal center, and accordingly, some activities to the west cannot be reached by pedestrians within 15 minutes. In the immediate vicinity of the station, an urban upgrade involving a high utilization

mix would bring about positive outcomes, especially north of the S-Bahn station where there are only a few restaurant options.

With such a large amount of activity potentially reachable by public transport, Haar benefits from its close proximity to the border of the city's inner and outer PuT tariff zones. With a single-trip ticket, a rider can access both tariff zones, whereas fuel consumption in dense urban settings is particularly high due to the stop-and-go traffic at intersections. Accordingly, the potential of all achievable activities reachable by PrT is already only half that of public transport (see Figure 12). This is particularly clear with regard to population and jobs.

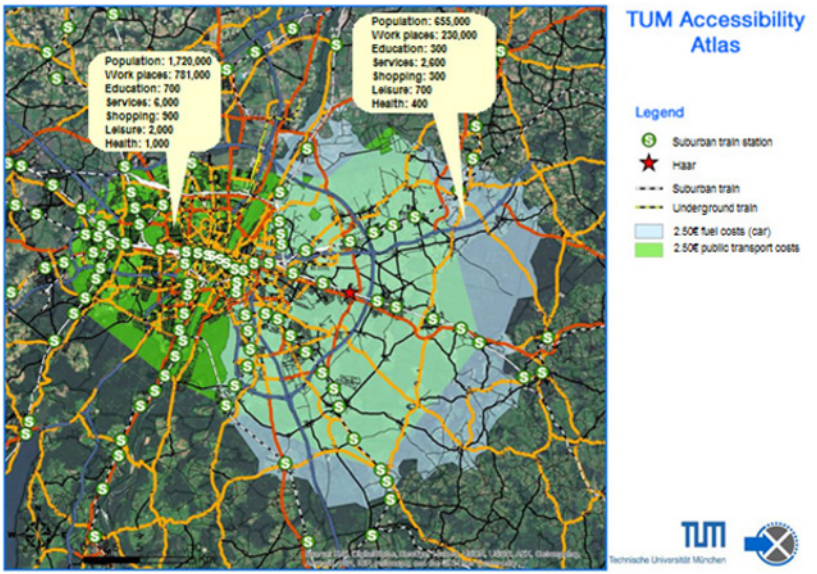

Fig. 12 Private car and public transport accessibility in Haar

With the urban density of Munich acting as a mobility barrier, it is already almost impossible, with no fuel price spike and a budget of 2.50 €, to reach popular landmarks within the city (e.g., the Isar River) by car. Should fuel prices rise to 2.11 €/L, car trips would no longer reach activity concentrations on the city's outskirts; instead, they would be limited to Munich's closer suburban areas.

Haar benefits greatly from its very good public transport connections, specifically its two S-Bahn lines. Owing to its dense and mixed land-use structure, coupled with very good access to public transport, Haar is relatively resistant to mobility cost increases.

In the scenario of a tripling of fuel prices, public transport would be able to access almost six times as much population as private transport, seven times as many workplaces, nine times as much shopping, 10 times as many education and health facilities, and 20 times more recreational facilities.

6 Suggestions for local and regional development strategies

After the accessibility analysis was completed, the findings were presented at a stakeholder workshop setting (see Büttner et al. 2014), and the following recommendations were formulated for responding to increasing mobility costs in the Munich region. For each strategy, the different spatial scales and the main actors responsible are given.

6.1 Local level: municipalities

Promoting local areas

Local vulnerability to mobility cost increases can be reduced through targeted internal development and sustainable densification. Mixing of land uses (e.g., jobs and workplace activities) is an important strategy, which will contribute to sustainable mobility behavior. Local supply (both at home and around the workplace) of everyday goods also plays a major role. This supply can be both pedestrian- and bicycle-based so as to strengthen local mobility in the process. In the case of Household Y, proper spatial development within the family's neighborhood might have allowed both parents to walk or cycle to work, decoupling the family's mobility needs from the private car.

Convenient recreational open spaces as well as local activities can also support independence from mobility costs while increasing a neighborhood's attractiveness. Accordingly, decentralized, small-scale supply structures should be encouraged, rather than economically driven concentration processes (i.e., economies of scale).

Support for citizen engagement, self-supply, and mobile supply

In rural municipalities, public participation can, to some extent, maintain a temporary supply. For example, the citizens of Oberbiberg (a suburb south of Munich) have organized their own citizen bus. As public transport in the Oberbiberg municipality is inadequate, 35 volunteers drive this citizen bus to the Deisenhofen suburban train station. In addition, municipalities can create online forums to facilitate carpooling. As seen in the storyline analysis of Household Y, carpooling or increasing car occupancy can reduce mobility costs.

Similar citizen engagement can be applied to village shops that frequently offer and even bundle a range of services, such as post offices, cafés, and pharmacies. Such arrangements develop community character through the creation of important social meeting places. In relatively dispersed locations, it is also helpful, for economic reasons, for part of the supply to be maintained by mobile services (mobile markets, pharmacies, banks, etc.).

6.2 Regional level: District and public transport authorities

Inter-municipal cooperation/balance management

In peripheral and vulnerable regions that cannot provide the required supply on their own, inter-municipal cooperation with neighboring municipalities is a possibility. For example, several municipalities could jointly operate a local school, possibly preventing the need for motorized transport. If the distances between participating communities are too great for pedestrians or cyclists, an adequate public transport system (possibly a citizen bus) linking the communities could be operated. Household Y's children were required to switch to public transport for educational activities so as to maintain the same mobility budget; with no public transport available, this would not have been possible.

Public transport expansion, but only in line with spatial development policy

The expansion of public transport is necessary especially in a still-growing region. Such expansion should be undertaken only in conjunction with sophisticated spatial development. For this reason, information concerning the future development of settlement structures (i.e., the location not only of jobs and services but also of leisure) and their demands should be integrated. In addition, dense nodes can be connected in a polycentric network so as to enable an efficient public transport

system. A sustainable public transport network should be linked not only radially to the regional centers but also tangentially between smaller nodes.

For sustainable development, especially in rural areas, it is necessary to focus on sub-spaces, clusters, and centers of different hierarchies. In particular, workplace nodes should focus on integrated, high-quality public transport from accessible locations. For this purpose, spatial planning instruments should be consistently employed to avoid further errors and oversights. This requires joint responsibility on the municipal level and thus a corresponding reform of business-related taxes.

Accessible places

The designation of green fields as areas for new business development often occurs without a prior assessment of traffic impacts. These peripheral and non-integrated sites are not sustainable in relation to rising mobility costs. In the future, public transport access for business areas will also be an important factor (as already seen in the case of one company in the Munich region that contributed financially toward establishing a bus line).

Promotion of "sharing economy" → Inter-modality → Establish networks / nodes

As seen in the case of Household Y, mobility chains that link different modes of transport can offer significant value. For example, bicycle stations can be implemented at public transport nodes, such as train stations. In this way, people can use bicycles to travel to the suburban train station and then again for their remaining distance to the workplace in order to solve the "last-mile problem." In addition, innovative mobility models such as car sharing and carpooling can make individual mobility behavior more flexible.

Promote e-mobility, particularly in rural areas

With increasing mobility costs, electric mobility can also gain attractiveness if the price of energy (see energy turnaround) does not increase to a similar extent. E-mobility especially offers opportunities for dispersed rural municipalities where an efficient public transport system cannot be operated effectively and the distances for non-motorized mobility are too great.

6.3 Upper levels: State of Bavaria, Federal, EU

Many of the measures discussed above could be achieved only by the assistance of higher levels of government — i.e., the State of Bavaria, the federal government, and/or the European Union. Consequently, a sub-regional, cross-sectoral funding policy to implement such measures is needed.

These responsibilities are often not clearly defined. To take a parallel example, who is responsible for the widespread rollout of high-speed Internet access using broadband cable? If such a service were available, peripheral regions could be better served through e-shopping, e-learning, e-banking, and so on. However, nationwide broadband coverage is not attractive to the private sector and hardly affordable with public funds.

7 Discussion and further research

The volatility of oil prices poses a significant challenge to planners. The inability to predict sharp increases in travel costs and the prevalence of poor choices in both housing and transport development can present a significant danger to households in relatively hard-to-reach locations within the Munich region. To mitigate the effects of unwise housing and transport policies, governments and individuals in vulnerable regions must equip themselves to manage this threat.

Vulnerability assessments like the one presented in this study have proved to offer a very capable platform for identifying areas most vulnerable to severe oil price shocks. Whether this methodology can be transferred to other European regions is, however, still being questioned in terms of data availability. Recognizing the vulnerability of municipalities in terms of their exposure, sensitivity, and resilience has allowed for a more complete identification of long-term planning opportunities that can better prepare municipalities and their decision makers.

In terms of preparing municipalities for the possibility of increasing mobility costs, a range of recommendations, strategies, and policies can be developed that address this risk through sustainable methods of improving mobility, e.g., reshaping land use with an emphasis on multi-functionality and density and enabling non-motorized transport offer opportunities to increase vulnerable municipalities' sustainability and hence their citizens' quality of life.

At the same time, however, it is crucial for decision makers and practitioners to buy into the strategies and policies provided by researchers. Academics can facilitate this process by raising awareness of mobility issues through the use of bold, readily

understandable maps and comprehensible storylines. The findings should then be presented, explained, and discussed with responsible practitioners (see Büttner et al. 2014). In this way, the usual gap between research-based findings and practical implementation can be substantially decreased (te Brömmelstroet et al. 2014).

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Handling Non-Motorized Trips in Travel Demand Models

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Abstract

Non-motorized modes of transport as agents of sustainable mobility have received increased attention, and the need to account for them in travel-demand models has long been recognized. Non-motorized trips are generally short trips, and in macroscopic models, many of them end up in the same traffic-analysis zone. Intrazonal trips are, however, rarely modeled very precisely, mainly due to the spatial aggregation problem of macroscopic models, which renders it difficult to estimate intrazonal impedances for demand calculation. Two possible ways to mitigate the intrazonal problem for non-motorized modeling include (1) enhancing the modeling of intrazonal trips, a process which requires the estimation of intrazonal impedances as a first step and (2) avoiding intrazonal trips, which requires a reduction in zone sizes. After providing a background to the modeling of non-motorized trips, the chapter describes ongoing research efforts aimed at enhancing the treatment of non-motorized trips in regional travel-demand models. The outcome of the research is expected to improve the capabilities of planning agencies in incorporating non-motorized travel in their travel-demand models.

1 Introduction

In the quest for sustainable mobility solutions, non-motorized modes of transport have received increased attention due to the potential environmental, social, and health benefits associated with pedestrian and bicycle travel. By serving as a cheaper alternative to automobile travel, walking and cycling can alleviate stress on

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fuel resources, reduce congestion, and improve environmental quality. Likewise, walking and cycling can contribute to the improved health of a society, serve as an avenue for recreation, and promote livable communities by providing increased opportunities for interaction among individuals. Consequently, the desire to promote non-motorized transport has increased, and according to Bhat et al. (2005), the subject of non-motorized transport has been studied not only in the field of transport but also in the field of public health. While transport agencies see walking and cycling as means to alleviate traffic congestion and reduce vehicular emissions, health agencies consider these modes as means to boost the levels of physical activity among individuals (Bhat et al. 2005; Guo et al. 2007).

Improved conditions for bicyclists and pedestrians have been considered means to increase walking and cycling and, as stated in Litman et al. (2015), virtually all communities that have increased non-motorized transport have achieved this by improving their walking and cycling environments. However, Porter et al. (1999) caution against adopting the attitude of "if you build it, they will come," and emphasize the need for reasonable estimates of usage and corresponding benefits. Evaluation of usage and benefits arising from improvements in non-motorized transportation options compared with alternative transport projects is also required for an efficient allocation of the finite resources available for transport improvements. The built environment is considered to influence non-motorized travel (Cervero, Duncan 2003; Rodríguez, Joo 2004; Guo et al. 2007; Cervero et al. 2009), and a number of urban-planning philosophies such as new urbanism, transit-oriented development, and traditional town planning have sought to reduce motorized trips while increasing non-motorized trips (Cervero, Kockelman 1997). However, Guo et al. (2007) state that not all strategies aimed at increasing non-motorized travel result in decreased motorized travel. According to Guo et al. (2007), a complementary effect can emerge where levels of motorized travel stay the same; a synergistic effect can also appear where motorized travel increases along with an increase in non-motorized travel.

As important as it is to identify actions that can encourage the use of non-motorized transport modes, the ability to assess the impacts of these actions are even more crucial. Such assessments require a good understanding of non-motorized travel behavior and the development of methods capable of estimating non-motorized travel demand along with motorized travel demand in a single framework. In this regard, the need to account for walking and cycling in travel-demand models has long been recognized, and many planning agencies have attempted or desired to incorporate non-motorized travel in their models.

Conventional models, which forecast travel demand in four steps, have traditionally focused on motorized transport. Although these could incorporate

non-motorized transport in several ways, the coarse nature of these models poses a difficulty in the representation of non-motorized travel. To ensure that these models are compatible with the scale of non-motorized travel, and in effect reduce the number of intrazonal trips, recent practices tend to use more-refined zone systems. Since non-motorized trips are relatively short trips, many of these trips terminate in the same zone in which they originated. Non-motorized trips can therefore not be treated without recourse to intrazonal travel. Intrazonal trips, however, are rarely modeled very precisely, mainly due to the representation of each zone by a single centroid which makes it difficult to estimate intrazonal impedances for demand calculation. Two possible ways to deal with the intrazonal problem in these macroscopic models include (a) enhancing the modeling of intrazonal trips, which requires the estimation of intrazonal impedances as a first step, and (b) avoiding intrazonal trips, which requires a reduction in zone sizes.

This chapter is motivated by the recognition of the role of non-motorized travel in the quest for sustainable mobility, the usefulness of regional models in forecasting travel demand, and the desire to enhance their capability in handling non-motorized trips. The next section offers background information regarding the modeling of non-motorized trips. This is followed by a description of the relationship between non-motorized trips and intrazonal travel. The chapter then examines the treatment of intrazonal trips by discussing the methods available for estimating intrazonal impedances, followed by a discussion of the different systems of analysis zones for non-motorized travel. Afterwards, an overview of ongoing research is presented, and the chapter concludes with a summary of the implications for practice.

2 Modeling Non-Motorized Trips

Planning for non-motorized travel requires tools that are capable of estimating bicycle and pedestrian travel under different conditions and a number of methods have been used over the years. Porter et al. (1999) have classified these methods as follows:

- Aggregate-level methods, which predict total trips by mode for an area served by a facility, based on characteristics of the area served, such as population and land use;
- Attitudinal surveys, which are used to estimate the potential impacts of non-motorized improvements and determine relative preferences for such improvements;

- Discrete choice models, which predict decisions made by individuals as functions of variables describing facility improvement or facility change; and
- Regional travel models, which use data on existing and future population, employment, and transportation network characteristics, together with data on existing travel patterns and models of human behavior, to predict future travel patterns.

2.1 Regional Modeling of Non-Motorized Trips

In relation to the regional planning of non-motorized travel, although Liu et al. (2012) have identified the activity-based modeling approach as more promising, the standard practice comprises a four-step trip-based model, according to Kuzmyak et al. (2014).

Four-step trip-based models have originally been oriented toward motorized travel, but their relevance for non-motorized travel has been highlighted in a number of studies. After a comprehensive review of the state of practice for forecasting non-motorized travel, Schwartz et al. (1999) identify a number of areas in which additional research and methodological development could be particularly useful. They made three major recommendations: (1) the need for a manual covering bicycle and pedestrian sketch-planning in the short term, (2) further research on factors influencing non-motorized travel behavior, and (3) integration of bicyclist and pedestrian considerations into mainstream transportation models and planning.

In arguing for the need to focus on improving regional models to include bicycle and pedestrian travel, Porter et al. (1999) argue that regional travel models have the unique advantage of offering an integrated framework for predicting travel decisions, considering all trips and modal options, as well as personal and household characteristics within the spatial structure of the surrounding area. Furthermore, while considerable initial investment may be required to collect data on bicycle and pedestrian facilities and to establish behavioral relationships for the model, once this is done proposed changes can be evaluated with little additional effort.

According to Eash (1999), modeling non-motorized travel as part of regional transport is necessary if agencies are to evaluate how regional development scenarios affect growth in vehicle travel. Porter et al. (1999) also contend that the inclusion of non-motorized modes in travel models will improve capabilities for forecasting both motorized and non-motorized travel and will help place bicycles and pedestrians on a level playing field with motorized modes in transportation planning. As stated in Kuzmyak et al. (2014), assuming that choices are captured correctly, the four-step model allows for multiple forces to interact in producing the final outcome while providing multiple places for testing planning interventions or other assumptions.

The treatment of non-motorized travel in regional models has been identified as both a modeling deficiency and an advanced modeling practice (Transportation Research Board 2007). However, in reviewing the current practice of incorporating non-motorized travel in regional travel-demand models in the United States, Liu et al. (2012) conclude that considerable progress has been made.

The non-motorized travel component can be structured in several ways in the regional modeling framework, and Liu et al. (2012) underscore the need to consider these structural choices when trying to improve non-motorized travel modeling. In standard four-step trip-based models, Singleton and Clifton (2013) state that non-motorized trips can be generated on their own, separated from motorized trips before or after trip distribution, distinguished from trips of other modes during mode choice, or further segmented into walk and bicycle trips. Liu et al. (2012) categorize them into pre-trip distribution, pre-mode choice, and mode-choice structures. They also point out the possibility of carrying the treatment of non-motorized travel through a route choice-trip assignment stage. The different structural options are summarized in Figure 1.

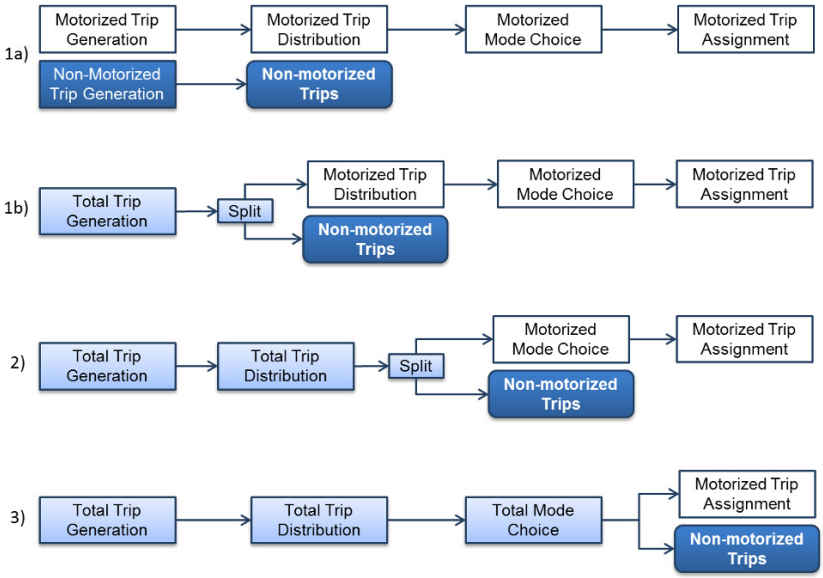

Fig. 1 Non-Motorized Trips in Four-Step Models (Singleton, Clifton 2013)

Options 1a and 1b are both pre-trip distribution structures. Whereas Option 1a involves separately generating trips for motorized and non-motorized trips, option 1b generates trips together but then separates non-motorized trips from motorized trips before trip distribution. Option 2, which is the pre-mode choice structure, generates and distributes trips together but then separates non-motorized trips from motorized trips before mode choice. For Option 3, which represents the mode-choice structure, trips are generated and distributed together and non-motorized modes are also considered as modal options in the mode-choice step.

According to Liu et al. (2012), while Options 1a and 1b have the potential to incorporate a variety of policy-related variables, they lack the capacity to evaluate non-motorized patterns since they cannot incorporate variables that require knowledge of both origins and destinations, such as distance or travel time. The pre-mode choice structure, on the other hand, can incorporate variables at the origin-destination level, which increases its potential for planning applications. However, since the split occurs before the mode-choice step, this structure is unable to evaluate trade-offs among different modes. The mode-choice structure handles this limitation and permits the incorporation of trade-offs into the model, but according to Liu et al. (2012), most models using this structure appear in practice to have a limited set of variables relevant to non-motorized travel, and this limits the structure's potential for use in planning applications.

Despite the several ways in which non-motorized travel can be incorporated into regional models, these methods have difficulties representing non-motorized travel demand. This has mainly been attributed to the coarse sizes of traffic analysis zones (TAZs) as well as the insufficiency of the variables considered. These models use TAZs as their geospatial structure and according to Kuzmyak et al. (2014), this level of aggregation is incompatible with the scale of non-motorized travel since they lack the fine granularity necessary to capture the essence of non-motorized travel-choice factors. This assertion has been put forward by a number of authors (Eash 1999; Porter et al. 1999; Liu et al. 2012; Singleton, Clifton 2013; Kuzmyak et al. 2014), and to enhance the capability of the four-step model in estimating non-motorized travel demand, these authors have recommended the use of more-refined zone systems as well as the revision of variables considered in these models.

2.2 Relationship between Intrazonal Travel and Non-Motorized Trips

The coarse nature of analysis zones has been identified as one of the main challenges in treating non-motorized trips in the four-step model, since it causes a majority of

these trips to terminate in the same zones in which they originate. In summarizing criticisms of the four-step model, Schiller et al. (2010) cite its inability to predict non-motorized travel behavior as a limitation, and attribute this difficulty to the fact that non-motorized trips are mostly short intrazonal trips that the models do not handle well.

The close relationship between non-motorized trips and intrazonal travel has been described by many researchers in different ways. Eash (1999) asserts that most walking and cycling trips take place inside the large analysis zones of travel-demand models. Bhatta and Larsen (2011) also concluded that intrazonal trips were more likely to be made by non-motorized modes compared with motorized modes. Since walking and biking trips tend to be relatively short compared with motorized trips, Liu et al. (2012) point out that non-motorized trips frequently fall into the rather uninformative intrazonal trip category. Non-motorized trips can therefore not be treated without recourse to intrazonal travel.

Intrazonal trips are rarely modeled very precisely, mainly due to the representation of zones by single centroids as this poses a difficulty in the estimation of intrazonal impedances for demand calculation. Furthermore, as intrazonal trips are not assigned to the transport network, intrazonal traffic does not react to volume-delay functions. In addition, vehicle miles traveled can also not be correctly estimated.

Two possible ways to deal with the intrazonal problem in macroscopic models include (1) enhancing the modeling of intrazonal trips, which requires the estimation of intrazonal impedances as a first step, and (2) avoiding intrazonal trips, which requires a reduction in zone sizes. Ideally, a combination of both would be most effective, and would help ensure a thorough treatment of non-motorized trips at different spatial scales.

3 Mitigating the Intrazonal Problem for Non-Motorized Modeling

3.1 Estimating Intrazonal Impedances

Travel impedances, which measure the separation between origins and destinations, play a central role in travel-demand modeling. They are relevant for the distribution of trips and the choice of modes as well as the choice of routes and, in some cases, the generation of trips where accessibility is considered. In macroscopic travel-demand models, these impedances are measured along the paths joining the centroids of pairs of zones.

Modeling intrazonal trips requires the estimation of intrazonal impedances but since each zone is represented by a single centroid, there are no paths over which these impedances can be measured; this complicates the estimation of intrazonal trips. According to Kordi et al. (2012), a common approach to avoid the intrazonal impedance problem is to simply exclude intrazonal trips from the analysis. However, removing intrazonal trips means omitting a high number of non-motorized trips. Many studies have underscored the need to account for intrazonal trips. According to The Louis Berger Group Inc. (2004), the estimation of intrazonal trips is important since many of the travel interactions needed to evaluate the effect of land-use changes on emissions occur in intrazonal trips. Greenwald (2006) has argued that the exclusion of intrazonal trips leads to inefficient allocation of trips to other zones whiles Bhatta and Larsen (2011) have asserted that omitting intrazonal trips results in biased samples and thereby affects model results.

4 Existing Methods for Estimating Intrazonal Impedances

Various approximate methods exist for estimating intrazonal impedances. Prominent among them is the nearest-neighbor technique. The United States Bureau of Public Roads (1965) points out that this method estimates intrazonal driving time as one-half the average time required to drive from the centroid of one zone to the centroids of adjoining zones. Bhatta and Larsen (2011) describe this method as very useful since it forms the basis of most methods used to estimate intrazonal travel times.

According to Batty (1976), the most consistent way of defining intrazonal distances is from trip and distance data disaggregated within each individual zone. Batty concludes that it can thus be seen as a problem of finding the average trip length. If a zone i is divided into x origin subzones and y destination subzones, then the intrazonal travel distance can be represented mathematically as

$$d_{ii} = \frac{\sum_x \sum_y T_{xy} \cdot d_{xy}}{\sum_x \sum_y T_{xy}}; x, y \in i \tag{1}$$

where

d_{ii} = intrazonal distance of zone i;
T_{xy} = trips between subzone x and subzone y; and
d_{xy} = travel distance between subzone x and subzone y.

He contends that the lack of data for the process makes the method difficult to use in practice but Ghareib (1996) demonstrates the practicability of the method. Kordi et al. (2012) used a similar approach for estimating the average trip lengths of intrazonal flows by scattering origins and destinations of the flows within their zones.

According to Bhatta and Larsen (2011), an intrazonal trip's length depends on the zone size, with the average length of these trips normally estimated as a function of the zone's area. A number of area-related functions exist for estimating intrazonal impedances (Batty 1976; Martin, McGuckin 1998; Dowling et al. 2005). In addition to the zone's area, these functions take other zone attributes into consideration.

5 Developed Method for Estimating Intrazonal Impedances

A method developed as part of a master thesis (Okrah 2012) at the University of Stuttgart under the supervision of Prof. Dr.-Ing. Markus Friedrich adapts measures of node centrality in networks to the consistent method described in Batty (1976). In this method, trip and impedance data are disaggregated within each zone and the average trip impedance is computed. Figure 2 summarizes the developed method.

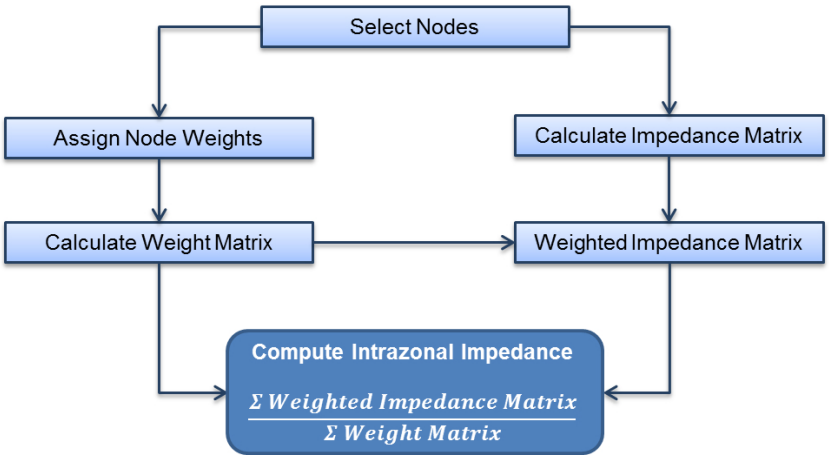

Fig. 2 Developed Method for Estimating Intrazonal Impedances

The method begins with a selection of nodes within each zone. For each zone, the impedances between selected nodes are used to create an impedance matrix. At the same time, weights are assigned to the nodes; the respective origin and destination weights are multiplied together to create a weight matrix for each zone.

In developing methods for generating connectors in travel-demand models, Friedrich and Galster (2009) highlight the importance of determining weights for network nodes within a traffic-analysis zone. They relate a node's weight to the share of trips for a zone which in reality have either their origin or destination in the node's vicinity. Similarly, for the developed method, weights are assigned to nodes based on their centrality within the network. A node's centrality determines its relative importance in a network. Different methods have been developed to measure node centrality (Freeman 1978; Newman 2004; Opsahl et al. 2010).

With the impedance and weight matrices available for each zone, the product of their corresponding values is used to create a weighted impedance matrix. Intrazonal impedance is then computed as the sum of the weighted impedance matrix divided by the sum of the weight matrix.

5.1 Reducing Analysis Zone Size

As the representation of non-motorized modes in travel-demand models becomes more important, there is a need to use traffic-analysis zones compatible with the scales of walking and cycling. Recent modeling practices tend to use more-refined zones to achieve this purpose. As stated in Kuzmyak et al. (2014), many planning authorities have updated their models using finer-grained system of TAZs providing more resolution and also opening the opportunity for including non-motorized travel in both trip-distribution and mode-choice steps.

A number of approaches have been used to redefine zone systems to make them relevant for non-motorized trips. In selecting a geographical unit for pedestrians trips, Clifton et al. (2013) consider three different options: (1) using 264 ft × 264 ft (80 m × 80 m) raster grid cells; (2) segmenting existing TAZs into smaller sub-areas suitable for walking trips; and (3) operating at the parcel level. While they eliminated Option 3 on the basis of data unavailability, Option 2 was eliminated because it required development of a procedure to split TAZ. They selected Option 1, which involved using a grid system across the entire area. However, regarding the use of a grid system across an entire study area, Moeckel and Donnelly (2015) argue that it results in many zones in rural areas with very little traffic, where spatial data is irrelevant.

Regarding the use of parcels, Kuzmyak et al. (2014) asserts that analysis is performed at a much finer scale of geospatial resolution, thus allowing for a much sharper characterization of the travel environment and the factors that affect non-motorized travel. However, although the use of parcel-level zone systems largely eliminates aggregation issues, computational and conceptual limits remain to reducing zone sizes to this level, mainly due to the large number of zones that results (Moeckel, Donnelly 2015). These include the instability of Logit models for transport-destination-choice decisions if the number of alternatives is too high, as well as the exponential increase in the size of matrices, which slows down the assignment step.

Despite the fact that data and computation costs are associated with the use of finer-grained zone systems, Liu et al. (2012) points out that the benefits of potentially more precise measurement of the variables that matter to general travel behavior have influenced recent zone system revisions. To reduce the data and computation costs associated with very fine scales of resolution, Moeckel and Donnelly (2015) suggest a gradual rasterization process where grid cell sizes vary with the amount of traffic.

As stated in Ortúzar and Willumsen (2011), greater accuracy could be achieved by using a more detailed zoning and network system. However, this would mean that over time, the problem of stability weakens this vision of accuracy as one would need to forecast — at the same level of detail — changes at the individual household level that would affect transport demand, which is a very difficult and mostly unnecessary task. Therefore Ortúzar & Willumsen (2011) contend that lower levels of detail are not only warranted on the grounds of economy but also on those of accuracy whenever forecasting is involved.

Over five decades of research and practice, some guidelines and constraints to the definition of TAZ have been established and are summarized in Martínez et al. (2009) as follows:

- Trip generation/attraction homogeneity;
- Contiguity and convexity of zones;
- Compactness of TAZ shapes;
- Exclusiveness (no doughnuts or islands) of zones;
- Equity in terms of trip generation (small standard deviation across zones);
- Adjustment of TAZ boundaries to political, administrative, or statistical boundaries;
- Respect of physical separators;
- Consideration of decision makers' preferences in determining the number of TAZs;
- Avoidance of main roads as zone boundaries;

- Selection of zone size to minimize aggregation errors caused by the assumption that all activities are concentrated at the centroid (geographical precision);
- Minimization of intrazonal trips; and
- Maximization of the statistical precision of the estimation of the OD matrix cells.

A very important criterion that is mostly overlooked in defining zone sizes is consideration of the represented transport network. Modeling involves assignment of trips occurring between TAZs onto the transport network. However, as can be seen from the above list, the only consideration given to networks is avoiding main roads as zone boundaries. While it seems intuitive that the represented network is relevant to the definition of traffic analysis zones, scarcely any empirical evidence has been presented to support this, and according to Moeckel and Donnelly (2015), the right balance between zones and network has hardly been studied systematically.

Modeling non-motorized trips requires the representation of the network elements for walking and cycling. With a network given as a fixed component, any balance between zones and network requires the modification of the zone size to match the network's scale. As inferred from Moeckel and Donnelly (2015), having smaller zones that lack a network to support feeding these zones will not improve model results. Therefore, despite the fact that reducing zone sizes will improve model results, a limit is expected beyond which further reductions will yield no further benefits.

6 Ongoing Research

The current research seeks to enhance the capability of macroscopic models in estimating non-motorized travel demand by focusing on the two possible ways to deal with the intrazonal problem: (1) estimating them or (2) avoiding them. Since estimating intrazonal trips requires the estimation of intrazonal impedance, the first step seeks to check the suitability of the method(s) used to estimate intrazonal impedances and determine if these suitable method(s) result in accurate estimates of intrazonal trips. Avoiding intrazonal trips requires the reduction of zone sizes to scales compatible with non-motorized travel and, given the absence of a clearly-defined optimum, the second part seeks to find an optimal resolution for TAZs.

The research uses data from Dachau, a town in the Bavaria State of Germany covering an area of 34.85 km² with approximately 45,000 inhabitants. The data includes a multimodal transport network, socio-demographic information for the 102 TAZs, and results from a 2009 household travel survey.

6.1 Validating Methods for Estimating Intrazonal Impedances

To test the suitability of the different methods for estimating intrazonal impedances, estimated intrazonal distances as well as estimated numbers of intrazonal trips produced by the different methods are compared.

In order to compare the estimated intrazonal distances at different levels of spatial aggregation, the 102 TAZs of Dachau are aggregated to systems with the following numbers of zones: 25, 10, 5, and 2, using different combinations of zones. For each zone system combination, the intrazonal distances estimated with the different methods are compared with intrazonal distances computed between the building blocks within the zone.

In the second step, gravity models are calibrated and estimated for each demand group using different methods of intrazonal impedance estimation. Subsequently, the resultant numbers of intrazonal trips are compared with the observed numbers of intrazonal trips taken from the survey data.

6.2 Determining Optimal Zone Resolution

To determine optimal zone resolution, the study adopts a process of creating gradual raster cells using the quad tree concept. Moeckel and Donnelly (2015) apply this approach to the model of Georgia to refine zones where population and employment were used as threshold to subdivide zones. In this study, however, total network length per zone is used as a threshold. The methodology is summarized in Figure 3.

Using Dachau's multimodal network, a hypothetical base scenario is constructed where the study area is divided into 50 m × 50 m grid zones. Each origin-destination pair is assigned a single trip per mode and the trips are then assigned to their respective networks. This serves as the valid scenario to which comparisons are made.

The gradual rasterization process begins by defining a single raster cell over the study area and calculating the total network length within that cell. If the total network length exceeds a pre-defined threshold value, the cell is split into four new raster cells. Next, network lengths in each of the four new cells are compared with the threshold value, and whenever a cell's network length exceeds the threshold value, the cell is subdivided into four smaller raster cells. This process continues until the network length in every cell is smaller than the pre-defined threshold value. At this point, trip tables from the base scenario are aggregated into the raster cells of the new zone system and assigned onto their respective networks.

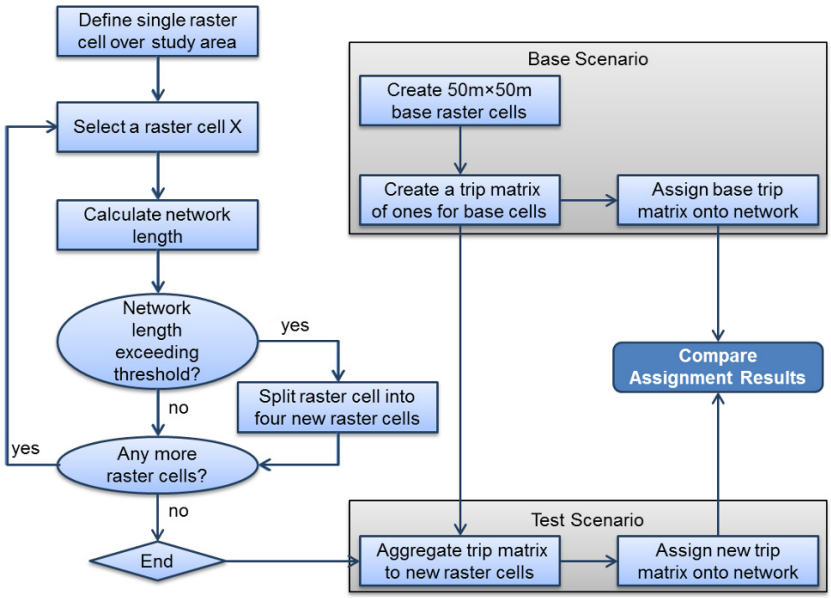

Fig. 3 Gradual Rasterization Process (Adapted from: Moeckel, Donnelly 2015)

Using different threshold values, different levels of spatial resolution are generated. The results obtained are then compared with the assignment from the base scenario.

7 Conclusion and Outlook

This chapter has summarized the role of walking and cycling in sustainable mobility, the relevance of regional models in forecasting non-motorized travel demand, and the challenges involved. The chapter has also described the relationship between non-motorized trips and intrazonal travel and has given an overview of research efforts aimed at enhancing the treatment of non-motorized trips in regional travel-demand models.

Non-motorized travel provides benefits not only for pedestrians and cyclists but also to non-users of these modes. Therefore, planning for non-motorized travel is beneficial to the society as a whole. Planning for non-motorized transport requires tools that are capable of assessing the impacts of different actions taken to encourage

non-motorized travel. In relation to regional planning, the four-step model has been identified as the standard practice, reflecting the fact that it is a powerful tool for analyzing different travel choices in a single framework. The coarse nature of traffic analysis zones, among other factors, has been identified as a limitation to the estimation of non-motorized travel in four-step models. Non-motorized trips are generally short trips, meaning that in macroscopic models, they often end up in the same TAZs in which they originate. They can therefore not be treated without recourse to intrazonal travel.

However, intrazonal trips are rarely modeled very precisely and this is mainly due to the representation of zones by single centroids, which poses a difficulty in estimating intrazonal impedances for demand calculation. Two possible ways to deal with the intrazonal problem in macroscopic models include (1) enhancing the modeling of intrazonal trips, which requires estimation of intrazonal impedances as a first step; and (2) avoiding intrazonal trips, which requires a reduction in zone size.

A number of methods exist to estimate intrazonal impedances to enhance intrazonal trip modeling. Similarly, a number of approaches have been used to reduce zone sizes to make them compatible with the scale of non-motorized travel. While intrazonal impedances are mainly estimated using approximate methods, reducing zone sizes has been carried out without recourse to transport networks such that many small zones could exist with no network feeding them. Ongoing research efforts seek to check the suitability of the methods used to estimate intrazonal impedances, find out if these suitable method(s) result in accurate estimates of intrazonal trips, and find an optimal resolution for TAZs.

The results of the research will improve planning agencies' capabilities in incorporating non-motorized travel in their travel-demand models. Walking and cycling can subsequently be analyzed together with motorized modes in a single framework, an ability that will facilitate assessing the impacts of sustainable mobility options.

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Pedelecs as New Tools for Active Mobility: 'Cheating' or Sustainable Transportation?

Jessica Le Bris

Abstract

In the last few years, a new form of transport, the electric bicycle (or pedelec), has entered the market and increased mobility options. A few empirical studies have already shown that pedelecs have the potential to reduce car trips. This chapter goes a step further and describes how and why electric bicycles enable more active and sustainable local mobility. But at the same time findings from the author's current research show that the wider adoption and diffusion of this innovation is still limited by skeptical attitudes and prejudices toward electric bicycles. Therefore, one vital aim of this essay is to deepen the understanding of the relationship between pedelecs and sustainability and to widen the discussion about their (often unrecognized) potential far beyond their stereotype as vehicle for the elderly and lazy. To raise awareness of and expand support for electric bicycles, the article indicates that consideration of social and cultural factors, including the changing of discourses about cycling and pedelecs, is significant for the successful diffusion of this innovation throughout society.

1 Introduction

Electric mobility has become a promising strategy to significantly reduce CO_2 emissions. However, while most of the attention has been focused on electric cars (thus following the path of auto-mobility), another new technological development has entered the market: *the electric bicycle*. In contrast to the electric car, the electric bike (often called a pedelec, from *ped*al *elec*tric *c*ycle) can make a significant contribution not only to reducing traffic pollution but also to sustainable mobility

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and urban development.[1] Furthermore, it can improve individuals' quality of life in numerous ways, as I will discuss later in this article. But its full potential can be realized only if it is recognized as a viable mode of transport by all sections of the society, regardless of the age, physical condition, or social milieu. Otherwise, its wider adoption within society will be limited.

What elements influence our selection of certain transport modes? More precisely, with regard to the new mobility option of electric bicycles, why do some people cycle while others do not? Mobility research has identified numerous factors that contribute to how we choose our transport modes.[2] Today, it is widely accepted that not only infrastructure elements support or hamper people's willingness to cycle, but social, psychological, biographical, and cultural factors also have an influence (Gather et al. 2008; Steg 2005; Schlag, Schade 2007; Hunecke 2006). The highlighting and examining of the importance of these subjective or "soft" factors[3] that influence our mobility behavior — and thus affect the acceptance of novel forms of mobility such as the electric bicycle — is a central aim of this article.

I begin (in section 2) with a discussion of global variations in cycling stereotypes, to show how much the interpretation of a product with the same functional attributes can differ between countries. Section 3 introduces the main subject of the article, the electric bicycle, as a new mobility tool and innovation in the context of cycling and its potential to enhance sustainable mobility. Based on my own empirical research experience, section 4 discusses images and stereotypes of pedelecs that can have a negative impact on their acceptance and limit their further diffusion.

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1 Following the Brundtland Report, the World Business Council for Sustainable Development (WBCSD 2004) defined sustainable mobility as "mobility that meets the needs of society to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological requirements today or in the future."

2 In this paper, mobility is understood as encompassing potential movement and not just the actual physical movement undertaken between points A and B (Becker et al. 1998; Kagermeier 2007; Gather et al. 2008; Ahrend et al. 2013; Held 2007). Stressing even more strongly the social aspect of the idea of mobility, Canzler and Knie (1998) described mobility as the possibility of acting (mobility as "*Möglichkeitsraum des Handelns*").

3 The common distinction between "soft" and "hard" (or objective and subjective) factors has very often led to a similar differentiation of planning measures or policies. This development has been strongly criticized by various authors who stress that planning should always include both sides of this divide, i.e., social and emotional aspects as well as physical conditions such as infrastructure. Furthermore, the so-called "hard" factors are always interpreted differently and there is no "objective" reality (e.g., Deffner et al. 2006; Schwanen et al. 2012; see also Schiefelbusch 2010).

It is important that future promotion strategies take these factors into account. Finally, the article closes with an outlook on future research approaches (section 5).

2 Images of cycling around the world

When people think about different mobility cultures[4] that exist around the world, they usually have particular images and stereotypes of the "typical cyclist" in mind.[5] For example, how do you imagine a typical cyclist from the Netherlands, the country with the world's highest percentage of bicycle use? You probably have in mind a man, a woman, or even a child riding a normal bicycle on the way to work, or shopping, or as they undertake some other daily activities. He or she might be dressed in business attire or in leisure clothing. In the Netherlands, people of all social backgrounds and ages use bicycles as a mode of daily transport. Cycling is a normal phenomenon on the streets.

Now for the next example: How do you imagine a typical cyclist from the United States? Many of us might have difficulty conjuring up a picture of a typical American cyclist at all, as the United States is stereotypically viewed as a nation of car mobility, scattered cities, and with no space for pedestrians. Nevertheless, if one makes contact with the U.S. cycling scene, one may get the impression of a kind of alternative underground movement, with American cyclists functioning as activists and fighting for more cycling rights and space on the streets.[6]

Along with this activist image, the other stereotypical American cyclist would be dressed in a professional-style cycling outfit — most likely a young, athletic-looking man with helmet, cycling gloves, bike glasses, and a water bottle, looking as if he is preparing for the next Tour de France.

When we turn to East Asia, another very different image arises in our minds — probably someone who looks as if he is living with his house on the bike. To

4 For further reading on cycling cultures, see Aldred (2012).

5 I do not intend here to give a complete overview of existing stereotypes and images about cycling. Rather, these brief examples underscore the point that widely varying images of cycling exist between countries and that the practice of cycling is interpreted in very different ways.

6 One example reinforcing this image is the "critical mass" movement, whose roots go back to San Francisco (a relatively green-oriented city by American standards) in 1992. When a "critical mass" takes place, hundreds of people on bicycles come together and ride the roads of their city. Since its beginnings, this activity has been understood as a "monthly protest by cyclists reclaiming the streets" (www.urban75.org).

people from Europe or North America, the amount that an Asian can carry on a single bicycle is amazing.

The purpose of playing with these stereotypes is to depict the wide variety of images of cyclists and meanings of cycling around the world. Comparing our image of an American cycling activist or bicycle racer with that of a cyclist from the Netherlands makes clear the huge difference in understandings and perceptions of what cycling stands for. We can see that the practice of cycling is strongly dependent on the wider cultural context of a particular region or country in which it takes place.

As we also know from social studies in the discipline of science, technology, and society, and especially from the concept of social construction of technologies, or SCOT (Pinch et al. 1984), meanings and their associated connotations are not given *a priori* but are socially constructed and negotiated, and they can change over time. Hence, when studying the acceptance and rejection of innovative technologies, one cannot leave the social world outside. An innovation is not simply about finding the best and most functional new solution; rather, its success depends heavily on the interpretations of social groups who use (or decide not to use) the technological artifact.[7] One artifact can mean totally different things to different people, and meanings and notions can change considerably over space and time. Mobility is thus more than just movement; it is a social product full of meaning (Cresswell 2006).

With this excursus on global cycling stereotypes and how meanings can change over time as background, we will now take a closer look at a new cycling phenomenon: the electric bicycle. How has this new technology been viewed or accepted? Even though it could be seen as a functional upgrade of the conventional bicycle, it still seems to have the image of a "silver-age" vehicle primarily for use by the elderly, as studies of the acceptance of electric bicycles in Germany (to be discussed in section 4) have shown. Hence, the sustainable dimensions offered by an electrical bicycle seem to have not yet been fully recognized.

7 For more information, see the concept of "interpretative flexibility" (Pinch, Bijker 1984) and the development of the "safety bicycle," as well as Axsen, Kurani (2011) on the concept of "reflexibility."

3 Pedelecs and their sustainable dimensions

Electric bicycles are described differently in different countries or regions.[8] This chapter focuses on "pedelecs", a subgroup of electric bicycles, in which the power support is activated only whilst pedaling.[9] Legally, these "pedelecs" are considered bicycles; hence, no insurance or driving license is needed, nor is there a mandatory requirement for a helmet or any age restriction (BMVBS 2012).[10]

As Pooley and Turnbull (2000) stated, pedelecs offer nearly all the same advantages as bicycles, such as low cost, flexibility, and environmental benefits, but they also offer a lot more. They can be seen as a technological extension of a bicycle in that they enable longer trips, a higher average speed can be achieved, strong winds can be more easily overcome, higher transport loads are possible, and the demands of hilly topography—one of the greatest constraints for cyclists—are removed. In short, pedelecs enhance active mobility,[11] enabling people to ride faster, farther, and without concern for the topography. As a result, they cycle more often (Urbanczyk 2012). By enabling more active mobility, the pedelec becomes a highly interesting local mobility option, not only in cities but also in rural regions.

Beyond these individual advantages, the pedelec gains even more importance as a future and sustainable mobility solution in view of worldwide developments such as rising gasoline prices, global warming, increasing levels of urbanization, and high-density cities (GoPedelec 2012). In terms of energy use, Parker (2008)

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8 Depending on the region, electric bicycles are also called "e-bicycles", "e-bikes", "electric bikes", "booster bikes", "power bikes", or "e-velos". In some reports, they are described as "EABs" or "electrical assisted bicycles". While some terms are used equally, for others there are profound (technical) differentiations and diverse regulations, which in the end "shape" the use of electric bicycles. One of the biggest differences is the requirement to pedal or not.

9 According to the European Union's Directive 2002/24/EC, pedelecs are defined as "cycles with pedal assistance which are equipped with an auxiliary electric motor having a maximum continuous rated power of 0.25 kW, of which the output is progressively reduced and finally cut off as the vehicle reaches a speed of 25 km/h, or sooner, if the cyclist stops pedaling."

10 In contrast, the so-called "S-pedelec" or "speed-pedelec" can reach speeds of 45 km/h, but users must have a driving license and insurance and must make tax payments. Another subgroup of electric bicycles, called "e-bikes," is more like an electrically powered motorcycle as no muscle power is needed at all.

11 "Active mobility" requires the use of one's own muscle power (e.g., while cycling or walking) and includes a health aspect, whereas "passive mobility" refers to forms of mobility technologies that rely on carbon-based energy sources, such as automobiles and motorcycles (ECF 2013).

stated that pedelecs are the most energy-efficient form of transport, beating motorcycles, cars, and public transportation. In addition, if the energy to charge the battery comes from renewable sources, it can achieve the status of a zero-emission vehicle just like a conventional bicycle, but with much higher usage potential. Parker (2008) observed,

> "The solar electric-charged Pedelec's and E-bikes will have the potential to be the most important form of motor transport in cities to replace car trips of less than 10 km and to access public transport for longer trips. The Pedelec and E-bike will certainly be needed in outer suburbia when the oil crunch comes".

Moreover, from a social-science perspective, another very important aspect of pedelecs is their potential to reduce car traffic by supporting a shift from cars to cycling. Even though pedelecs are a new topic in social science and mobility research, the last few years have seen the first empirical studies undertaken. Most of these have sought to identify the transport mode replaced by the pedelec, so as to evaluate the environmental threats or benefits that may result from its further adoption. The studies found that the new technology seems to hold more opportunities than threats; nearly all of them indicated that the pedelec is replacing not only trips on conventional bikes but also a significant number of car trips (e.g. Buwal 2004; Drage et al. 2010; BASt 2013; UBA 2014). In addition, the pedelec has increased bicycle mobility in general (Kairos gGmbH 2010; Mader, Mader 2011; Le Bris forthcoming).

But what about other long-term effects of this new product on an individual level once it has been purchased, apart from its impacts on mobility behavior? Surprisingly, the pedelec's effects on daily life have played only a minor role in research studies so far. But as findings from the author's current Ph.D. project show, these impacts have been crucial in the adoption and use of pedelecs.[12] Among the most interesting discoveries in this qualitative study, many users noted that the pedelec has made cycling not only less stressful but has even made their lives a lot easier — another feature that enhances the pedelec's sustainability. Following are some sample comments (translated into English by the author, with observations related to broader life impacts in italics):

12 During the Ph.D. research, about 40 interviews with pedelec users living in the metropolitan region of Munich were conducted in order to explore the adoption and appropriation of the new technology.

- "Since I got the pedelec, life has been significantly easier. You arrive relaxed and are not sweaty anymore and (…) at the end of the week, *you still have energy for some other activities like hiking in the mountains*."
- "It is a great thing. During peak hours, I need only about 10 minutes more than going by car. (…) I can take all these little hidden rat runs. I got my fitness training done while commuting. In the end, *I canceled my membership at the fitness studio and as a result, since I got the pedelec I have had more time for my wife*."
- "It has changed my life. I am not using it on my daily trip to work, but it is a totally new way of cycling in our free time. Today we are *doing bike tours that are much more ambitious* and we are cycling in areas where we would have never gone by bike before. It is now possible to *explore totally new regions* by bike and still be independent from the car."
- "Since I got the pedelec, *I feel at home in the city*. Everyone knows and greets me with my big trailer and my little kids doing my shopping within the tiny city center. I am still kind of exceptional there. (…) Before the pedelec, I did all my shopping by car, going to the big supermarkets outside the city, and rarely went to the little shops at the center."
- "The pedelec *has saved my marriage*! Since my wife got one, we can enjoy our Sunday rides again, and we are not arguing the whole time anymore that I am too fast and not taking care of or looking after her."

Importantly, most of the pedelec users interviewed did not have these positive effects in mind prior to their purchase of the item. Instead, most of them noted that rational factors, such as the pedelec making cycling easier or faster, motivated their purchase. Hence, before the pedelec was integrated into their lives, the new owners were not aware of the social and symbolic dimensions offered by it. Over a short period of time, the pedelec has created its own usages beyond its functional and rational utilization motives. It not only makes riding a bike more convenient, but also has a structuring effect on daily life and an impact on social relations (Le Bris forthcoming). Overall, user comments, such as those quoted above, provide striking examples of a changing user–technology relationship, its (positive) unintended consequences, and the emergence of individual meanings of the pedelec that differ from person to person.[13]

The results of this study make it clear that pedelecs can not only play a significant role in the reduction of car traffic but also improve individuals' quality of life. These

13 For further literature relating to these findings, see Kaufmann et al. 2004; Tully 2014; Degele 2002; Oudshoorn, Pinch 2008; Canzler, Kesselring 2004; Dourish 2003; Rammert, Schulz-Schaeffer 2002.

insights and the findings of other studies suggest that the pedelec is an important sustainable mobility option that can help make our lives easier and make cities and regions more livable at the same time.

To support the adoption of pedelecs, it is thus important to highlight not just the functional reasons for purchasing one (i.e., faster and easier travel) but also the social and symbolic features of this innovation — aspects that are often less considered when new technologies emerge. Accordingly, the next section looks at what people *without* any experience of electric bicycles have in mind when they think about pedelec riders.

4 Images and stereotypes of pedelecs, and the resulting limitations on adoption

In the previous section, we saw that pedelecs, as an innovation in the field of cycling, clearly offer the potential to support more sustainable mobility. They fulfill all three dimensions of sustainable development: the economic dimension (pedelecs are highly energy-efficient and use minimal resources in terms of energy, cost, and space), the social dimension (mobility for everyone, social inclusion, health aspects of active mobility, strengthening quality of life), and the ecological dimension (reducing car trips, supporting sustainable city development).

But as the findings of several empirical studies have shown, even though the product itself has many functional advantages on an individual level (faster than a normal bicycle, cheaper than an automobile), various concerns about the product remain. Although there are a growing number of pedelec user groups and the product's image may be changing (UBA 2014, ILS 2013), its initial image as a vehicle for persons with disabilities, the elderly, the lazy, and the unathletic has yet to be fully dispelled (University of Tübingen 2011; Hammer 2012; Le Bris, Rothfuss 2015; Mauthner 2014; Le Bris forthcoming). When random people on the street were asked whether a pedelec would be an acceptable alternative mode of transport for them, the following statement was typical of one of the most common reactions among non-users: "An electric bicycle? For me? Do I look that old already?"

In a survey of young apprentices and trainees within the Neckaralb region (a relatively hilly rural area in southwest Germany), more than 40% of people said that riding a pedelec is "just for less athletic people" and nearly 40% said it is "just

for old people" (Le Bris, Rothfuss 2015).[14] In another German study (University of Tübingen 2011; Hammer 2012), even more people said that pedelecs are only for people who are very unathletic or in bad shape and thus unable to ride a conventional bicycle. In effect, pedelec riding is regarded as a way of "cheating".[15]

Although nearly all of the pedelec owners interviewed as part of my Ph.D. research were highly enthusiastic about their new transport option, they still confirmed these existing stereotypes when sharing their own experiences:

- "There are stupid comments all the time, such as 'You are much too young for this,' 'You don't need this,' or 'Why do you have this?'"
- "Sometimes people say, that's only something [to use] when you are 70. (…) Those who are younger than I look very skeptically at me and say things like 'Oh, he got a pedelec, so he isn't able to ride his normal bike anymore.'"
- "[People say,] 'He looks like a bull but too lazy to pedal himself.'"

In this context, one bicycle dealer offered an interesting comment: "The very first question I ask my clients is 'How self-confident are you?'" meaning that if you cannot stand any critical comments, regardless of whether they are invalid, stupid, or irrational, you had better get used to them or else not buy a pedelec. In fact, one common feature of nearly all pedelec owners was a certain carefree attitude about their self-image: "I don't care what the others say about me, sad for them they don't see the opportunities pedelecs could provide them!"

14 The Azubi-E-Bike project (www.azubi-e-bike.de) took place from 2012 to 2014. A total of 881 students and interns in the Neckaralb region (aged 15 to 25) were asked about their actual mobility behavior and their attitudes toward pedelecs. The survey followed a quantitative research design (Le Bris, Rothfuss 2015). In a second phase of the project, participants could try out a pedelec for one week and then completed a survey in order to analyze the effects of their trial experience on their attitudes.

15 Similar observations were stated by Engel (2012), and in other surveys carried out in North America (Dill, Rose 2013; MacArthur et al. 2014; Shao et al. 2012). Nevertheless, many of those who tested a pedelec in the Azubi-E-Bike project expressed positive reactions, interest, and curiosity about this new vehicle, and some passers-by asked if they could try one or said they were a little bit jealous of this transport innovation. At the same time, some riders received critical comments, such as "that is just a bicycle for grandfathers or grandmothers" or "if you're going to ride a bicycle, then do it the real way" (Le Bris, Rothfuss 2015).

Nevertheless, some users pointed out that they had to mentally challenge themselves and their own concepts of what pedelecs represented to them,[16] as illustrated by this comment from a recent pedelec owner:

- "I have always thought this is stupid. 'I don't need any help while riding' was the attitude in my head somehow (…) because we have been athletes all our lives."

After all, this innovation still has prejudices and stereotypes to overcome. This opens up a discussion about the connection between *the role of sports and riding a pedelec*. The last comment, in particular, makes clear that riding a bicycle (at least for some people) is strongly associated with being sporty and athletic; therefore, people who need electric support are regarded as non-sporty or unathletic. Certainly, the pedelec makes cycling easier and many people are buying them for precisely this reason, but this is just one of the factors that might motivate someone to ride a pedelec. One's attitude depends heavily on the purpose for which the electric support is used. One great effect of the electric support is not as a replacement for but as an extension of the rider's personal muscle power; as explained in section 3, by using the same power as previously used on a conventional bicycle, one can travel longer distances in less time, thereby saving time, transport heavier loads on a bicycle trailer, or get extra power for hilly roads that might otherwise be avoided. The key point to keep in mind is that pedelec users are exerting just as much effort as before, not less; the pedelec simply widens one's "motility" (Kaufmann et al. 2004).[17]

But all these advantages can be outweighed by the prejudice and fears that riding a pedelec makes you look lazy or marks you as an ignorant "cycling cheater" who has turned into a couch potato. Of course, this is a strong exaggeration, but sometimes one can get the impression that this is part of the image of pedelecs, making it "not cool" at all for young people to ride one.

But what makes a vehicle or mode of transport "cool" or at least acceptable? In Germany, young people can get their driver's license to operate a small motorcy-

16 This refers to the theoretical concept of social norms. Within Ajzen's (1979) theory of planned behavior, subjective norms are one of the central factors influencing our mobility behavior. Within Rogers's (1983, 2003) diffusion of innovation theory, "norms of the social system" are declared to be an influencing factor in the adoption of new technologies or the processes of innovation and decision-making.

17 There is a difference in the German-speaking literature between *Mobilität* (potential for movement) and *Verkehr* (traffic, or actual movement). Within the English-speaking literature in the field of social science (e.g., Sheller, Urry 2006), the word "motility" is sometimes used to stress the social aspects of mobility and transport; the term "mobility capacity" is also used in this way.

cle or scooter (a gasoline-powered moped, with a 25 km/h speed limit) at age 15. As a result, bicycle use is replaced by the new motorized bike (as is use of public transport). Yet not a single young person surveyed in the Azubi-E-Bike[18] project indicated that shifting to a moped was seen as "uncool" (Le Bris, Rothfuss 2015). In contrast, it is seen as very "cool" to get to work or school on these little motorbikes, even though the conventional bicycle is not used anymore. And no one ever says that these bikers are now unathletic or lazy! So why is a shift from a bicycle to a moped regarded as cool and trendy whereas switching to an electric bicycle is regarded as uncool? Where do these images or associations originate? Perhaps they have something to do with the previously mentioned connection between cycling and sports, even where the bike is used not for workouts but for daily trips and simply as a means of transportation.

In sum, the pedelec offers great potential for sustainable development and diversity of uses, but also carries with it a set of both positive and negative images and stereotypes. This fundamental point must be kept in mind by entities seeking to support the further diffusion of electric bicycles. But as we saw when discussing the various stereotypes of cycling worldwide, meanings, associations, and discourses are not necessarily fixed; they do change over time and space and *can* be influenced.

5 An outlook for planning strategies and a basis for future research

This last section suggests future research approaches that could open up a more profound understanding of the social aspects of the emerging practice of pedelec riding. These approaches could also function as a basis for the development of further promotion strategies.

Pedelecs can be seen as a new mobility tool beyond the bicycle, and the innovation offers a wide range of different sustainable dimensions. But their further diffusion depends heavily on society's acceptance of them. Therefore, it is crucial that efforts to develop marketing strategies supporting the adoption of pedelecs consider the meanings, associations, images, and pictures related to them (along with "hard factors" such as infrastructural aspects). These factors can influence acceptance in two ways, either supporting or limiting the pedelec's further adoption. But as we have seen, they are a product of social construction and thus are changeable. Consequently, a first step in this field should always be to identify the social and

18 http://www.azubi-e-bike.de/

cultural factors that influence acceptance, and if negative associations are found, the second step is to try to change them. One aspect of such a rebranding here would involve changing the existing discourse, which connects cycling to sport and views the bike as an athletic tool, toward an understanding of cycling as a form of transport and the pedelec as a mobility tool for use in daily life.

Furthermore, it is crucial that politicians and local actors recognize pedelecs' potential to support sustainable development. But what do politicians on all levels, as well as city planners, actually think about this mobility tool? Is the pedelec really valued and therefore integrated in planning activities, rather than occupying a minor role (if any) in cycling-promotion strategies?

Another highly interesting field is the rise of electric cargo bikes. Do these have a different image from pedelecs in general? Here again: Are politicians as well as private users acknowledging their full potential?

Scientific data on the actual health benefits of riding a pedelec would also help to support the development of accurate images and fight wrong perceptions, such as that pedelec riders are, or will become, lazy.

For future studies that offer a base for the development of planning strategies, it would be worthwhile to look at theories of social practice (e.g. Shove et al. 2012; Warde 2005; Holtz 2013; Strengers 2010). Pedelec riding is still in its infancy and could develop in different ways. As theories of social practice indicate, a practice such as cycling is a highly complex product that emerges out of a great range of elements and overlaps and "competes" with other existing practices, such as driving, over space and time. Following authors such as Shove et al. (2012), practices depend on the alignments of the three components: *materials* (physical infrastructure, bodies, and artifacts), *competencies* (skills and know-how, but also rules and regulations), and finally — the main focus of this paper — *meanings* (images, symbols, associations, and aspirations).[19] Change can be produced only when the complex interdependencies that build up, form, and shape a practice are taken into account and strategies focus not purely on physical or infrastructure conditions but also on creating positive meanings and helping to build up new sustainable routines. Thus, a transformation of our (car-dominated) mobility system can be successful only if all the elements that hold a practice together are rearranged and modified. Similarly, nourishing new sustainable habits and practices must always take place in conjunction with a displacement of unsustainable practices, as both compete for the attention of future practitioners whose adoption of a practice sustains it (Schwanen et al. 2012).

19 Within this perspective there is no differentiation between soft and hard factors; all are equal components and an integral part of social practices such as cycling.

Pursuing this theoretical concept further, mobility practices always compete with each other. Therefore, it is not consistent (and certainly not successful) to talk about sustainability on one hand while still following the traditional path of auto-mobility on the other. The practice of pedelec riding will have a chance to take hold only if it is *comfortable and easy to perform*. We must always keep in mind that its private valuation will depend on how it compares to other mobility options.

Another important point in terms of planning considerations can be derived from social practice theories: mobility is not only about pure mechanical transportation from point A to point B. Rather, feelings and emotions during the experience of movement represent a big part of why and how practices are performed and sustained. As practice theorists state, the desire to undertake a certain practice comes not from mental thought alone; rather, it follows the performance and is a product of the practice itself (Warde 2005). This theoretical insight strongly supports the idea of offering wide-ranging opportunities for testing pedelecs, which have already been shown to conjure up the magical "pedelec smile" on riders' faces after their first ride. The corporeal experience of movement and the feelings derived from all the human senses that produce positive emotions will shape attitudes toward pedelecs.[20] So pedelec test rides, preferably combined with mobility education strategies, should play an integral part in every pedelec promotional initiative. The Azubi-E-Bike project (Le Bris, Rothfuss 2015) stands out as an example of best practice in this area.

Above all, promotion strategies should put an extra focus on dispelling the existing, culturally embedded images and prejudices and support the establishment of positive meanings and associations around pedelecs. It is important to get away from the perception of pedelecs as "a step back" or a vehicle for unathletic or older people. Hence, marketing and communication campaigns should reinforce the idea that a pedelec can serve as a powerful extension of the conventional bicycle,

20 To investigate the acceptance of the new forms of electric car mobility, many studies have been based on Rogers's (1983, 1995) diffusion of innovation theory within the field of socio-economics. Even though from this theoretical base it can be stressed that the "triability" of new products is crucial to the success of its diffusion, the approach mainly focuses on rational factors of the innovation; symbolic, social, emotional, or physical aspects of the experience (such as how one feels while riding or the surrounding affective atmosphere) play only a minor role. (For a critique of the diffusion of innovation theory, see Axen, Kurani 2011). But as the findings from empirical studies have shown (Le Bris, Rothfuss 2015; Le Bris forthcoming), these factors are fundamental to convincing people to adopt or accept an innovation. As opposed to most theoretical approaches, social practice theories stress the importance of physical and emotional impacts.

or "bike 2.0" — a modern and innovative transportation tool and a technological upgrade that brings a lot of fun to riding a bike!

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Part IV
Conclusions and Outlook

Individual Contributions Toward a Common Objective

Stefan Klug, Julia Kinigadner and Montserrat Miramontes

Abstract

In this book, sustainable mobility is discussed at different scales and from different perspectives. One approach is to understand it as a political concept, highlighting the importance of governance for innovation, i.e., the identification of new problems and solutions and the implementation of new measures. Another way to comprehensively understand the concept is through the application of the life-cycle approach as a broader framework. Alternatively, if we look at one particular example of a mobility tool, such as the pedelec, a wide range of sustainable dimensions, such as public health, energy consumption, emissions, and costs, can be tackled as they relate to this tool. Important factors in efforts to achieve sustainable mobility are technical progress, the involvement of stakeholders and actors, and the given or planned transport infrastructure. From an individual perspective, other aspects of sustainability gain importance, such as affordability for transport demand sector of tourists, convenience for employees on work-related trips, and accessibility of opportunities for knowledge workers. Moreover, the contributions in this book demonstrate the strong need to integrate land use and transport more effectively. Through such integration, non-motorized modes of travel used in neighborhood mobility gain more importance. Innovations, such as new modeling approaches, are required to give greater emphasis to sustainable modes.

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1 Introduction

The central and common element of all contributions in this book is the concept of sustainable mobility in metropolitan regions, which is approached from many different perspectives. The topic can be discussed on a general level, as illustrated by Anderson and Tschoerner who provide new concepts and innovative policy approaches, or by looking at individual groups with particular mobility concerns, as Le Klähn does for tourists, Roller for a specific type of employees, Sterzer for individuals with low income, and Zhao et al. for knowledge workers.

Another group of authors has discussed new options for changing the current practice of mobility to increase the level of sustainability. Büttner provides suggestions at different levels of spatial development to address rising mobility costs. Okrah suggests another change, namely to improve modeling techniques to place a greater emphasis on trips undertaken by the slower modes of travel, such as bicycling and walking. Le Bris's study focuses on a specific new form of mobility, the e-bike, which combines the individual advantages of the bicycle with the higher speed of motorized mobility options.

2 The common objectives

Although the individual contributions are different, the common objective of contributing to sustainable mobility in the metropolitan region of Munich is clear. In the following two chapters of this book will be taken as an example to describe how the individual chapters represent different approaches with the same ultimate objective.

Tschoerner investigates the use of the term "sustainable mobility" in policy and governance and develops new approaches to understanding mobility. She indicates that the use of this term is often far removed from the key ideas of Brundtland (see the introduction to this book). In contrast, it has become a dynamic political concept that changes over time as new actor constellations shape the debate. The concept of sustainability is inherently normative and political; therefore, governance plays a key role in developed "structures" as well as in a specific set of "processes." In governance for sustainable mobility, actors identify new problems and solutions, form new policies, implement new measures, and expand and grow their coalitions in interaction with new actors. Based on a case study of cycling promotion in the city of Munich, Tschoerner finds that the governance approach helps operationalize the complex idea of sustainable mobility and thus contributes to its analysis.

She indicates that not only the state but also civic society, media, and new forms of governmental organizations are involved in governance for sustainable mobility. She concludes that the governance approach enables clearer analysis and consideration of the social, historical, and systemic factors steering the direction of change. This perspective introduces discussion on how, if, and to what extent knowledge, expertise, and rules need to be reconsidered or revised. However, the decision whether to have this discussion is up to political actors.

While Tschoerner highlights the governance approach in contrast to other frameworks used to measure sustainability as a fixed policy goal, Anderson suggests another way of comprehensively understanding sustainable mobility, one that subsumes this concept within a bigger framework and proposes a life-cycle approach. He focuses on the interdependencies between urban and building scales, considering both the building and transportation sectors. Based on his analysis, Anderson concretely addresses some fields of political action. On the legal level, he calls for integrated government directives, including consideration of embodied impacts, in the transport sector and beyond. One obvious example is electric mobility because the crucial factor for ecological balance is not tailpipe CO_2 emissions but the source of electricity production used to power the vehicles. Focusing only on tailpipe emissions can be misleading as electric mobility may result in net emission increases.

To continue with the example of electric mobility, Le Bris investigates the role of pedelecs (or e-bikes), a new mobility advance beyond the standard bicycle, in sustainable mobility. Rather than focusing on life-cycle sustainability, she addresses a wide range of sustainable dimensions from the users' perspective, including public health, energy consumption, emissions, costs, etc. Le Bris argues that, for the environment, pedelecs are the most energy-efficient form of transport. However, she also acknowledges that the pedelec becomes a zero-emission vehicle only when its energy is derived from renewable sources. To support the adoption of pedelecs as an alternative to cars, Le Bris suggests developing marketing strategies that consider the meanings, associations, images, and pictures related to pedelecs that can influence their acceptance. To develop effective marketing strategies, the most influential social and cultural factors must first be identified.

Reduction of vehicle ownership and of the mode share of private cars is at the core of sustainable mobility strategies. While the first priority is to reduce total traffic, followed by shifting traffic to environmental friendly modes, a third strategy is to encourage more efficient use of existing vehicles, e.g., through car-pooling and car-sharing.

3 The individual perspective

Another important element considered in this book is the perceptions and attitudes of individuals. The book's second section addresses specific target groups from the viewpoint of sustainable mobility. However, here the meaning of sustainability shifts somewhat from the ecological toward the economic or social dimension due to the focus on individual needs. Le Klähn, for instance, develops strategies to promote sustainable transportation modes among tourists. Her survey results indicate that tourists focus on the convenience, comfort, and affordability of travel modes rather than on their eco-friendly characteristics. She opts for integrated planning, which requires the involvement of and cooperation among multiple stakeholders. Moreover, she suggests soft measures, such as frequent market research to provide updated information on tourist behaviors and expectations. Emphasis should be placed on mobility management measures, including marketing and information at tourist offices, points of interest, and major transportation hubs such as railway stations and airports, to encourage and facilitate the use of public transport among tourists. However, creating awareness is inadequate. Practical conditions affecting the use of sustainable modes need to be addressed as well, e.g., by better integration of the public transport and bike-sharing systems.

In an economically growing metropolitan region, Munich's transport system is used mainly by employees, both for commuting and for other trip purposes. Roller's study investigates corporate mobility, considering working conditions in combination with employees' place of residence. She investigates the manner in which it determines the mobility of individuals in traveling to, from, and while at work. From an individual's perspective, it is crucial to consider the employee's entire life situation and the life circumstances faced during one's working life to develop sustainable mobility strategies. Various factors can either increase or relieve the stresses and strains of corporate mobility. Corporate travel structures the lives of many employees, particularly those whose work entails frequent business trips. These employees' mobility experiences alter the ways in which they work and spend time with their families, how they function as role models at home, and the manner in which they handle their social and work-related relationships. Corporate mobility is structured by both work-related requirements and private needs, and it also has a structuring function with regard to how individuals live their lives. Strategies for a mobility management approach that limits the social costs of employees and protect their well-being should consider individuals' work-related circumstances and personal conditions that influence their travel needs and preferences.

Sterzer's and Zhao et al.'s contributions are also focused on employees, but they examine the impact of the housing and work locations of specific groups, i.e.,

low-income persons and knowledge workers. Both groups are of particular interest for different reasons—namely, the lack of knowledge workers in the region and the special challenges faced by low-income households in a high-priced region, such as Munich. Commuting is the result of the interaction between one's location of residence and workplace, influenced by the individual (who chooses his or her residence and workplace) and the spatial context. In general, daily mobility behavior depends on transport supply, individual preferences, and the density of opportunities in a certain catchment area. Low-income groups have limited location choices in competitive housing markets. Sterzer therefore focuses on the social dimension of sustainability, considering participation and accessibility as prerequisites. Mobility must be ensured for everyone to avoid "transport poverty," which results when the limitations of options affect people's social lifes (for spatial, temporal, financial, and/or individual reasons).

Sterzer demonstrates that this problem of poor social sustainability occurs not only in rural but also in urban areas despite their greater transport supply. Consequently, low-income groups often have to compromise on their residential location. They usually face a conflict between the broader scope of opportunities and more affordable mobility options offered by inner-city locations, on one hand, and their higher housing costs on the other hand. Each household resolves this dilemma in its own way. And find individual solutions within this tradeoff situation. An overall conception of the situation is needed, however, to coordinate issues of social and transport policies impacted by income-related residential and mobility patterns. These issues include decentralized supply, the promotion of alternative travel modes, and the integration of transport and land-use planning. In this manner, different population groups' needs can be considered.

Knowledge workers, studied by Zhao et al., represent a different group in terms of their mobility behavior due to their different lifestyles, demands, and values. This group aims at optimizing all their life circumstances at the same time, i.e., their career opportunities, housing conditions, and mobility behavior. Analyzing a comprehensive survey dataset, Zhao et al. proves three hypotheses. First, the Munich Metropolitan region is transitioning from a monocentric to a more polycentric structure, resulting in a redistribution of employment functions. Second, the overall spatial extent of people's commute has enlarged in the last decade; many workers do not work in the same county that they live in, resulting in imbalances between jobs and housing. Third, the specific composition of the labor force, the types of employment opportunities, and mobility behavior must all be considered to explain the magnitude of commuting flows effectively (instead of simply numbers of inhabitants, jobs, and commuting time).

These last two studies reveal that in the process of choosing a residential location, tradeoffs occur between housing costs and transport costs. The resulting commuting distance can be considered as an indicator of the effectiveness of employment and housing distribution. In consequence, the extent of sustainability of mobility is significantly influenced by individual constraints in terms of both money and travel time.

4 The need to integrate land use and transport

There is a strong need to adjust and integrate land-use planning and transport planning, particularly with regard to public transport. The classic policies here are the promotion of transit-oriented development and urban development at public transport stations or hubs (as discussed in the introduction to this book). However, in a high-priced region, such as Munich, cost concerns play an important role. Büttner therefore investigates the factors that contribute to individual mobility costs along with increasing residential costs. Lack of consideration of individuals before choosing a new housing location often results in housing misallocation in areas with low accessibility, where the car is the dominant transport mode. As a result, people living in those areas are saddled with unsustainable mobility behavior and are vulnerable to rising mobility costs.

Büttner suggests the development and use of appropriate accessibility tools for decision makers, presenting a methodology based on three elements: scan, explore, and prepare. "Scan" means undertaking a regional-level vulnerability assessment that can identify communities at greatest risk due to future increases in mobility costs. Next, specific situations are explored by developing storylines with stress tests on an individual scale, providing a common language that everyone (planners, decision makers, and households) can understand to display the effects on households' social and economic participation under financial strains. Third, to help these communities prepare for their future, an isocost accessibility analysis is undertaken on a spatial scale. This analysis indicates how various price shock scenarios reduce the activity range of individuals. Büttner suggests strategies at different levels. At the municipal level, he opts for focusing on local supply and mixed land use as well as on citizen engagement. At the regional level, he encourages municipal cooperation and public transport expansion in line with spatial development. Moreover, he suggests promoting new mobility services based on non-motorized transport or ride-sharing solutions, such as carpooling and community buses.

When a better mix of land use makes it possible for people to reduce their travel needs, the modes of neighborhood mobility, cycling, and walking assume greater importance. Okrah suggests an improvement of the current methods of transport demand modeling to pay more attention to non-motorized transport, highlighting pedestrian and bicycle travel as more sustainable modes. He aims to overcome the lack of modeling of intrazonal traffic and create a better understanding of non-motorized travel behavior. Two approaches to macroscopic models are proposed: reducing zone size to avoid classifying such trips as intrazonal and enhancing the modeling of intrazonal trips. Okrah concludes that these approaches will permit the analysis of walking and cycling together with motorized modes in a single framework.

5 Conclusion: Factors contributing to sustainable mobility

The contributions in this book recognize individuals' intrinsic need or desire to travel to various places for different purposes, such as acquiring goods and services, working, studying, and meeting other people. When one is choosing a transport mode to perform activities at a given location, other factors become relevant. These can be divided into internal factors related to the individual's characteristics, such as age, gender, occupation, and income; the type of household in which he or she lives; and external factors, such as the socioeconomic, cultural, and political environment.

Numerous external factors are highlighted throughout this book. The case of pedelecs, for example, demonstrates how *technical progress* can provide sustainable solutions in individual mobility. Another example, not featured in this book, is the diffusion of sharing and pooling concepts, enabled by progress in information technology and the implementation of mobility stations. This enables a shift from owning one specific vehicle toward using whatever mode is most appropriate for a specific purpose. It is the base for inter- and multimodality.

One key consideration in sustainable mobility that is frequently highlighted in this book is that the chances of implementing sustainable mobility solutions significantly depend on the *actors and stakeholders involved*. Le Bris's main finding is that the further diffusion of pedelecs heavily relies on society's acceptance thereof. This acceptance is affected by public policy, city and transport planners, and the extent to which citizens recognize pedelecs' potential to support sustainable development. Le Bris concludes that achieving change requires the consideration of the complex interdependencies that form and shape a practice. Strategies must go beyond physical or infrastructure conditions as well and aim at creating positive

perceptions and helping to build up new sustainable routines. Promotion strategies should strongly focus on dispelling existing, culturally embedded images and prejudices and supporting the establishment of positive meanings and associations related to pedelecs. Similarly, Anderson indicates that the success of Munich's second suburban rail trunk route (2. Stammstrecke) in reducing environmental impacts significantly depends on the role of additional stakeholders beyond the local transportation agency, e.g., how the new route is integrated in urban development and subject to changes in mobility patterns. These findings demonstrate an obvious need for interdisciplinary collaboration.

The location and distribution of travel opportunities for individuals are shaped by geographic characteristics and by the urban structure (mix of land uses, city shape, density, and diversity) and can thus be influenced by *planning instruments*. The frequency and length of trips to different locations and the choice of a travel mode are impacted by the accessibility of the location by different transport modes. Accessibility, as Büttner indicates, can be defined as the ease of reaching various opportunities from a given location using a particular transportation system. Preconditions for sustainable mobility are thus a dense and mixed urban structure, a high quality of public transport service, and infrastructure for cycling and walking, all of which provide better mobility alternatives than private cars. Furthermore, other important aspects to consider are the individual needs, perceptions, and attitudes of individuals who ultimately decide when, how often, to which destination, and by which transport modes they travel. Here, mobility management plays a crucial role in providing tailored solutions. Diverse approaches are required depending on the different roles that individuals fulfill, e.g., focusing on local residents, tourists, and/or employees.

In terms of travel times and costs, accessibility is highly influenced by the configuration of *transport infrastructure* (roads, railways, parking lots, stations, interchanges, waterways, bridges, ports, and airports), the connectivity of the transport network, and the availability and affordability of vehicles (cars and bicycles) and mobility services (public transport, car sharing, bike sharing, and information). Mode choices are also influenced by the quality of infrastructure, vehicles, and mobility services.

Anderson emphasizes the need to quantitatively assess the induced impacts of large infrastructure projects, such as the second trunk route, to determine their overall environmental footprint. In Anderson's view, a key policy endeavor to reduce greenhouse gas emissions is influencing and developing the urban form. He observes that cities and metropolitan regions have to determine the environmental consequences of policies impacting the urban form. His main suggestion

is to quantify the impacts in the built environment on a per capita basis to enable international comparison.

To promote sustainable mobility, it is necessary to shape the influencing factors toward both more sufficient and more efficient mobility. First, the need for transport should be reduced by optimizing the location of different land uses, including not only workplaces and residences but also leisure, shopping, and recreation areas. Overall, efficient mobility is enhanced by a transportation system that allows goods to be delivered and people to satisfy their needs by reaching different destinations in a safe and affordable manner with the minimum use of resources, such as space, energy, money, and time, and the least environmental damage.

The core question is how individuals can contribute to the common objective of sustainable mobility. The main insight and a common thread throughout all contributions is that for us to promote sustainable transport effectively, the involvement and cooperation of many different actors, including the final users, is crucial.

Perspectives on Sustainable Mobility in Metropolitan Regions: Shaping Mobility Cultures

Sven Kesselring and Gebhard Wulfhorst

Abstract

Traditionally, mobility research originates from a transport perspective. However, in today's metropolitan regions, a dramatic change is being observed in mobility that is driven by technological and social innovation. This change is reflected through the transformation of scientific analysis and real-life policies from a transport perspective to a mobility perspective.

How should we investigate, govern, and manage this change? In this concluding chapter, we present the necessity for the same and some ideas for future research and development. This outlook is based on the experiences of the first phase of the mobil.LAB doctoral research program and articulates questions that need to be addressed in the second phase of this program.

Future research will be based on the understanding of mobility as a cultural phenomenon. We therefore consider the concept of "mobility culture" as a basis on which to highlight strategic directions. Selected state-of-the-art insights, challenges, and options regarding more sustainable mobility in metropolitan regions are presented in the following topics:

- New mobility concepts: from selling cars to delivering services
- New mobility practices: from mode split to reflexive action
- New mobility policies: from transport departments to mobility networks
- Shaping sustainable mobility cultures: from theory to practice

Our ambition is to share perspectives on relevant issues concerning sustainable mobility in metropolitan regions. We want to contribute toward the exploration, transformation, and realization of the mobility of tomorrow. We look forward to continuing the discussion on our reflections in research and practice.

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1 Background

1.1 Objectives for continuous research on disruptive realities

The doctoral research group mobil.LAB has developed to an extent where research on *mobility*, and not simply on transport planning, is conducted. By no means should this be understood as a superficial change. On the contrary, sustainable development requires everyone involved to undergo a profound change of perspective (Klein 2014). Increased resource scarcity, climate change, the greater distances being traveled, and the negative social, economic, and ecological consequences of traffic volume compel us to develop the potential for action by individuals, organizations, and entire cities and regions with regard to "a policy of resilience" (Pickett et al. 2014). A policy that primarily aims to handle the increase in transport operations will not suffice. This type of policy alone cannot handle the regional and global consequences of our highly mobile societies and fossil-fuel-consuming lifestyles.

Based on existing research and the experience of the mobil.LAB group, we consider understanding mobility as a fundamental principle of modern societies and a central conceptual issue (cf. Canzler 2013; Bonß, Kesselring 2001). Ultimately, today, mobility constitutes the cultural basis of modern economies and societies. Thinkers including Karl Marx, Georg Simmel, and advocates of the Chicago School of Socio-Ecology (Park 1925; McKenzie 1921) first stated these ideas. However, mobility as a quasi-natural reality is influenceable. In fact, it is subject to constant social and cultural change, and therefore can also be influenced and designed by politics and society. Thus, it is no longer sufficient to use a (predicted) demand for transport as a given input variable for transport planning and as a reason for justifying and building transport infrastructure.

In integrated mobility concepts, the mobility options available should be designed in such a way that travel demand, as a target, complies with the criteria for sustainable development, such as regional climate protection targets. For a successful design, it is imperative that mobility in its current complexity be taken into account. Design forms—from government strategies and participation to co-creation and self-regulation—must be found that enable mobility to be viewed as a socio-technological constellation of a culture that revolves around mobility, and thereby enables its further development in a viable, ultimately successful way. In the age of the Internet of Things, Industry 4.0, and post-fossil mobility strategies, mobility must be seen as much more than transport (Dennis 2013; Schindler et al. 2009). Instead, the idea of "several mobilities" (Urry 2000; Sheller 2014) should be used as a starting point. As it has been addressed in the conclusions of the book

(see conclusion chapter by Klug et al.), sustainable mobility policies will become a „project", focused on how to develop strategies that ensure mobility without the consequences that an excessive use of automobiles brings with it. Concretely, this means that the conversion of the automobile industry into a mobility industry must be enforced and that planning and development processes must be initiated, through the joint collaboration of economy, society, and politics, so as to enable multimodal mobility at both local and regional levels (Canzler 2015). Metropolitan regions are the drivers of change, and their stakeholders must strive for better solutions for the future. This is why we focus our research on that scale.

The specific research program of the mobil.LAB group consists of critically investigating the development of the metropolitan region of Munich as a case study. However, above all, the work being conducted here seeks to establish a high-quality foundation for policy-making, economic, and social strategies aimed at sustainable development. Therefore, mobil.LAB plays a role in the implementation of science into practice as well as in the application of practical experiences in research. This research program's potential to contribute to regional perspectives on mobility, and to the development of science and the economy, has been widely acknowledged. The cooperation of its fellowship program with regional partners has led to transdisciplinary approaches. The group has become an impact hub (cf. Wulfhorst et al. 2014). The Munich metropolitan region has provided an exemplary local study as well as the basis for comparative studies with both national and international references. The Munich region, with its prosperous economic and scientific development, has a special responsibility to develop innovative solutions to global challenges.

Using accessibility research as an example, we can show how this change is reflected in mobility research and in the program. In the designs for a "car-friendly city" (Reichow 1959), the physical adaptation of an urban space to the technical object, the car, was the main focus. However, for an ecological and socially sustainable mobility policy humans, and not objects, must be at the heart of our reflection. The "human scale," as the Danish architect Jan Gehl refers to it, is most important here.

Building on previous accessibility research (Wulfhorst 2008; Büttner et al. 2014) the development of multimodal transport networks can be taken into consideration in combination with location development. Ideas for this purpose have been designed and developed in the successful European COST Action *Accessibility Instruments for Planning Practice* (cf. Hull at al. 2012).

In a sustainable mobility strategy, transport not only serves as a utility-based means to ensure accessibility to goods and services for individuals and certain groups, but also represents a significant connecting factor in diverse networks and a space for social integration (cf. Miciukiewicz, Vigar 2012).

New priorities must be determined with regard to creating sustainable mobility policies (Banister 2008; Rajé, Grieco 2004). Instruments and policies that improve the accessibility of places play a decisive role with regard to the provision of socially equitable and solidarity-based mobility ("mobility justice"; Sheller 2012). This emphasis on equitable mobility permits all persons to take part in public life and to have the same options when choosing a place of work as well as in social integration and cohesion. The optimization of a given transport system is of secondary importance.

A central element for future orientations is our reaction to the fact that the mobility landscape and especially the mobility economy change at a rapid pace. Overall, we expect that the radical change of the transport and mobility economies will result in a key branch of the German economy having to practically reinvent itself. Examples of this are the increasingly offered, and in demand, mobility services that are based on sharing and using instead of owning, the major debate on electric mobility and the fact that sharing-strategies are increasingly being heralded as the future of (auto-)mobility.

1.2 Mobility culture as a framework for strategic orientations

There has been a significant increase concerning literature on sustainable mobility. The topic is no longer a niche subject and has now become a core area of research. The economic activity arising as a result of electric mobility, and the overall coalescence of mobility, energy, and communication topics have been of great importance.

The model of a mobility culture as taken from Kuhnimhof and Wulfhorst (2013) (see Figure 1) can serve as a framework of orientation. It is based on earlier works of Götz and Deffner (2009) and Klinger et al. (2010) and it depicts those thematic fields in which the program has already built up competencies with regard to the necessary changes toward sustainable mobility cultures. As a working model, it can be viewed, on the one hand, as a continuation of the thematic structure of the first phase, which encompasses transport systems, travel behavior, culture of transport, and transport policies (cf. Figure 3 of the introductory chapter). On the other hand, it shows that, in combination, political decisions, spatial structures, and the social perception of mobility have an important effect on cultural circumstances, which structure mobility in practice. In relation to this, the topic of mobility culture, as a central element of the theory of sustainable mobility, is introduced. This topic may serve as a guiding principle for future research in the second phase of the mobil.LAB program.

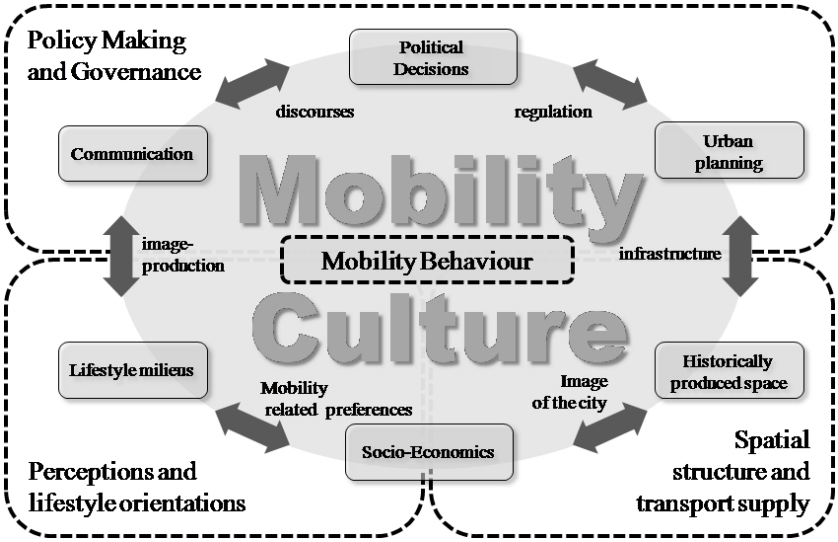

Fig. 1 Mobility culture as a framework for future research directions (Kuhnimhof, Wulfhorst 2013, p 57)

In order to structure this diversity in terms of content, we have defined four main thematic focus areas for the future research program. Below, we shall present the current state of research in each area, along with remaining challenges and potential future research directions. The four areas are as follows:

1. New mobility concepts: from selling cars to delivering services
2. New mobility practice: from mode split to reflexive action
3. New mobility policies: from transport departments to mobility networks
4. Shaping sustainable mobility cultures: from theory to practice.

In the first of these research directions, we will discuss selected approaches for new mobility strategies. We will examine a spectrum of topics, ranging from infrastructure related to accessibility research and the construction and design of transport systems to business models for innovative mobility services such as free-floating car sharing or operational fleet management. The sustainability of the radically changing mobility economy mentioned above will also be considered.

The second area of focus deals with social change in mobility practices, both within and outside organizations. Questions related to work-induced mobility are significant here. Phenomena such as mobile work, the designing of business trips, changes in commuting between work and home, and between job locations are emphasized. In addition, we will consider such topics as the changing mobility practices of youth, the diminishing identity-creating function of cars, and general questions relating to technology use and alternative forms of overcoming spatial problems (including virtual mobility).

The third section moves from transport policies to mobility policies by decidedly considering the topic of the structural shift of mobility mentioned at the beginning of this chapter. Previous research has shown that, at a discursive level, the conceptual shift toward mobility policies is already occurring. We will critically investigate this shift and identify the kind of research still necessary to support this crucial aspect of developing sustainable mobility in metropolitan regions.

The last thematic field deals with the development of an interdisciplinary mobility theory based on mobility culture. On the one hand, a connection is established with current theoretical discussions about sustainable mobility and "mobile risk societies" (cf. Kesselring 2009). On the other hand, the concept of mobility culture will be taken up as a framework for the development and implementation of sustainable mobility. Based on preliminary work conducted in a joint project on mobility cultures in megacities (Kuhnimhof, Wulfhorst 2013), we have concluded that one cannot talk about a single mobility culture; rather, very different cultures of mobility can develop and already exist depending on their respective contexts.

The following sections present some reflections on each of these research and development directions.

2 Future research and development directions

2.1 New mobility concepts: from selling cars to delivering services

The traditional system "that is dominated by automobiles" (Burkart 1994), based on individual vehicle ownership, is increasingly being adapted due to the establishment of alternative mobility concepts. New drive trains, autonomous vehicles, car- and bike-sharing platforms, and vehicles for last-mile delivery are signs of a new and overall significantly more efficient and high-performing system. This changing system must be designed for sustainability (Rode et al. 2015). Seamless

accessibility, door-to-door connections, and the elimination of the need to drive oneself are all promoted as offering a new type of flexibility, which enables higher productivity while traveling. The vision of a sustainable, safe, and efficient multimodal transport system is a guiding principle underlying concepts such as "smart cities" or "smart mobility" (cf. OECD, ECMT 2007; Dassen, Hajer 2014; Klug 2013) and a particularly strong driving force in urban development.

Several researchers within the mobil.LAB have dealt with aspects of this general development, using bicycle policies or the discussions surrounding the introduction of electric mobility in Munich as examples (cf. chapters of Tschoerner and of Le Bris in this book).

Aspects of accessibility play a decisive role in the process and significantly influence mobility behavior in urban regions (cf. Naess 2009; Gerike et al. 2013; Büttner et al. 2011). A multimodal energy-efficient mobility system can be created only if the interfaces—the nodes—between different modes of transport function as they should. Many attempts to develop integrated transport strategies that merge public and individual transport have occurred since the 1930s (cf. Meyer 2014). Most of these have failed because the completely different social-technical constellations and networks formed around different means of transport have not been taken into account (ibid). The mobility culture shown in Figure 1 has historically contained very heterogeneous subsections. Nowadays, highly complex and specific networks of infrastructure, regulations, spaces, lifestyles, discourses, concrete technologies, and utilization practices exist for each travel mode: cars, trains, bikes, etc. These local fields of mobility culture and their social-technological constellations must be fully comprehended so that we can develop ways to achieve convergences among them.

In order to make this goal possible, innovative land-use and transport policies concepts must be analyzed together. Concretely, questions arise as to how transport networks and locations are connected to one another and how, as a result of this knowledge, an integrated spatial development can be designed that complies with the principles of sustainable development. In this context, spatial design is the main focus, particularly location development for urban functions at the transport nodes. In sustainable mobility, planning questions relating to the design of social networks and communication networks—for instance, access to high-speed data networks—must also be borne in mind.

Another important element of sustainable development is the careful handling of the space available as a resource. The mixed and diverse use of places that are highly accessible by public transport connections is a challenge and therefore a necessary key competency of spatial and urban development in the future. Railway stations play a central role in transforming urban space, both socially and from an economic and structural point of view. This "urban generator" function has, up to

now, not been researched systematically, and certainly not in a manner that views the challenges as an interdisciplinary problem involving diverse disciplinary cultures of planning, as well as financing and operational competencies. Research and planning must also consider the public sector's ongoing, long-term lack of funding resources and the resulting need to develop useful and efficient new partnerships (cf. Wulfhorst 2003, 2009; Wulfhorst et al. 2013).

In connection with our research program, the dynamics of change and future options for the Munich metropolitan region have been investigated in an extensive study carried out at the Technical University of Munich (TUM) and called *Residence–Work–Mobility* (cf. Thierstein, Wulfhorst et al. 2016). In addition, dissertations completed in the mobil.LAB provide starting points from which to expand research into the interactions of the built environment, energy, and mobility (see for example the life-cycle assessment in the chapter of John E. Anderson in this book).

Other new mobility options are also gaining greater significance. Developments such as individualized mobility services, the increasing distribution of sharing systems, and the availability of new vehicle categories such as electric bicycles extend the range of possibilities to meet different mobility needs in a customized fashion. Moreover, further technical developments such as highly automated driving have also taken place in conventional automobiles. If a driver can lean back and relax while the car essentially drives itself, then cars become even more direct competitors with the public transport network, as the latter no longer has the "not having to drive oneself" advantage.

This development would be unthinkable without the introduction and spread of innovative technologies. The availability of mobile and stationary microcomputers on the one hand, and server-based and cloud computing structures on the other, make mobility options virtually available everywhere and therefore enable greater flexibility to the users of mobility services, reducing the need for personal vehicle ownership. Such multi-modal mobility services will provide more options and accelerate exchange and communication, rather than replacing physicyl trips.

A closely connected and important field is that of economic structure, which deals with the changing demands on both internal logistics and the mobility of employees. The effects on purchasing behavior, for example, and on the shopping, delivery, and service journeys connected to it must be taken into account. A quantification of the social effects of transport is an exciting research question in this context. A related question is how social cohesion can be measured and defined.

Key research orientations might consider these topics:

- Interactions between innovative mobility services, spatial structure, and mobility behavior;
- Basic principles and effects of multimodal services; and
- Highly automated *vs.* autonomous driving.

2.2 New mobility practices: from mode split to reflexive action

The term *mobility practice* is used in reference to Max Weber's sociological concept of practice, because—unlike the more common term *mobility behavior*—it emphasizes the complexity of modern (more reflexive) decision-making (Bonß, Kesselring 2001). Transport research often seeks simple "levers" that make it possible to control people's behavior. However, approaches built on *homo oeconomicus* have frequently been unsuccessful, because human behavior follows other logics beyond purely economic and goal-oriented ones. Cognitive dissonance (Festinger 1957) characterizes human actions and leads to seemingly irrational decisions and practices in transport use. Newer approaches to mobility research therefore say that there are certain "structural stories" (Freudendal-Pedersen 2009; Shove, Walker 2010) that determine action. Therefore, one also speaks of lifestyle orientations and mobility preferences (cf. Kuhnimhof, Wulfhorst 2013). In the changing technological environments in which mobility takes place today (e.g., intelligent transport systems, autonomous driving, mobile information and communication technologies) this complexity increases even further. Familiar routines are being questioned and, through more flexible processes in the world of work, in particular, at very specific steps in the biography are becoming the subject of conscious decisions. Those who work on the move, make frequent business trips, commute over long distances, or have to travel between sites, often cannot rely on simple routines. Even those who travel by car to work every day cannot simply assume their actions to be self-evident. Today, company employees are confronted by new services and mobility concepts (carpooling networks, job tickets, company mobility management, etc.); in this context, mobility has to be justified, and the fact of moving is in competition with other choices. However, mobilty will remain influenced by the social status as well.

We believe that we are witnessing a profound transformation in mobility, which is why, for example, the International Motor Show (IAA) in Frankfurt responded in 2015 by holding an exhibition with the programmatic title *New Mobility World*. Mobile life and work, according to Elliott and Urry (2010), have been profoundly altered by the fusion of spatial movement and communications and the penetration of everyday life by mobile technologies. These processes of change can be observed in the organization of everyday family life, as sometimes even a family dinner turns into a project that needs to be coordinated and planned using Doodle or Outlook. Although autonomous driving has not yet been fully realized, early discussions of its anticipated impact have changed the social understanding of movement and mobility in space and have become the object of planning processes in cities (see for example the discussion of Vision Mobility 2050 for the region of Munich within

the Inzell Initiative) (Wulfhorst et al. 2014; Kesselring 2015). An advertising slogan such as "the ultimate driving machine," used by BMW in the 1980s and 1990s, would probably not have the same resonance today.

The emergence of new options in the field of mobility goes hand in hand with an increase in multimodality, and especially with new options when thinking about mobility. Canzler and Knie (1998) have argued that mobility comes from the head. In this sense, the thinking—i.e., the cognitive landscapes of mobility—is currently undergoing dramatic change. Our emotional relationship with the automobile has been subject to enormous changes (Sheller 2005; ifmo 2013). On one hand, the choice among different modes of transport accompanies the multimodal organization of everyday life. But in fact, it also depends on the individual social rationale of people, of the next generation. Thus one no longer simply travels in one's own car, but instead chooses those mobility options that best match the specific situation or are most comfortable. The so-called practice turn, which addresses the normalization and routinization of everyday actions and opens up a new view of the modifiability of activities like mobility, needs to be taken into account (Shove et al. 2012; Dick 2009). In addition, sustainable mobility actions become "reflexive" (Beck 1993; 2008), that is, they must be justified because they are the subject of conscious decision-making. Previously, motorists traveled by car and anyone on a bike was an environmentalist; today, we are dealing with hybrid or multiple types of mobility. A former Munich mayor and the mayor of London have shown that they can ride a bike to work, and publicly shared bicycles are used across the social spectrum (Sustrans 2015; Cox 2015).

Against this background, the choice of transport and its combinations will also affect the criteria of economic, social, and environmental sustainability. The question arises as to whether, with the interaction of reflexivity and sustainability, new patterns of mobility will emerge.

There are many indications that social change in mobility practice will increasingly (but not only) take place in cities (cf. Jensen 2006; Lanoy 2015). Looking at the now extensive literature on mobility decisions, three dimensions and causes can be systematized:

1. A new multi-optionality has emerged because alternative forms of mobility have lost their niche character. Business models and services are economically relevant, and transport networks have been transformed into resource-efficient, socially sustainable systems.
2. A fundamental change in the public discourse on mobility has occurred, promoted by the development of new services and perceptions in everyday life.

3. Changes in communications and mobility technology act as a catalyst for these social dynamics.

This is associated with modern city lifestyles (part-time jobs, living-apart-together, Airbnb cultures, etc.), the younger generation's preference for "work-life balance," the growing significance of private life, and the readiness to consider economic constraints in return for personal quality of life. The willingness to exchange time for money by choosing a relatively slow long-haul bus signifies a new model of price elasticity. These economic consequences represent new possibilities for individuals. Related questions concern the acceptance of new mobility services and concepts (e.g., privacy concerns).

In addition, changes in mobility styles and values are occurring among the young generation. New technological possibilities allow other forms of experience and perception of space that interact with the aforementioned emerging forms of space management and coordination of social relationships and networks. With regard to diverse populations, an important question is whether those who pursue knowledge-intensive activities, also known as the creative class or knowledge workers display different mobility behavior and, if so, why.

Future research might focus on

- Changing work environment(s);
- Impact of information and communication technologies on mobility practice;
- Changing mobility patterns;
- Mapping of changing framework conditions in models.

2.3 New mobility policies: from transport departments to mobility networks

One of the main theses of this research program is that the transformation of the transport system into a multimodal mobility system is already underway (see Canzler, Knie 2015; Vannini 2010). This change is necessary but not sufficient in its present form. Coping with the challenge of climate change and the social consequences of the mobilization of modern societies in a sustainable fashion also requires a paradigm shift in planning and mobility policy by public authorities as well as in corporate human resource policies. Otherwise, the social, ecological, and economic foundations of modern metropolitan areas cannot be permanently maintained.

Currently, planning is still dominated by a logic according to which the continuous growth rates in road, air, and cycle traffic must be addressed by the development

of transport capacity. Companies will continue to operate according to the logic that more mobility means more sales and thus more prosperity. Companies with an operational mobility policy based on the principle of "meet more, travel less" are still the exception (see Kesselring, Vogl 2010). More options of communication rather act as an accelerator of exchange and travel, than substitution of trips. Similarly, developments in vehicle technologies are primarily focused on maintaining the model of long-distance mobility. Although in public discourse the topic of electric mobility is high on the agenda, most patents being registered are still for the conventional internal combustion engine. Industry is focusing on developing electric motors with a range comparable to that of the conventional automobile. Thus, the opportunity to establish another concept of mobility based on shorter ranges may be lost. Even economic studies prove that the equation "more spatial mobility = more prosperity" is not only dubious, but perhaps economically irrational and life-threatening.

Transport, as a major contributor to CO_2 emissions in industrialized societies, constitutes one of the main starting points for sustainability policy (Urry 2013). The necessary paradigm shift requires that policy and planning (especially in the functional urban area of metropolitan regions) interact in realistic and desirable mobility scenarios, rather than relying solely on quantitative (projected) levels of growth in transport demand (Banister 2008). Therefore, rather than naive optimism about the future, effective transition research that aims to discover possible ways out of our existing path dependencies is called for. Existing innovation paths (Meyer 2014) must be understood in terms of their dynamics and their underlying mechanisms in order to serve as starting points for socio-technological change. A successful transport policy requires consideration not only of the socio-technical constellations of mobility culture, but of their active creation and use.

In addition to the integration of technology, infrastructure, environment, norms, values, and points of view, it is vital—particularly for the (re)design of mobility policy—to take into account the incentive systems of different organizational and institutional contexts. Different stakeholders within the political sphere operate with highly divergent incentive systems in institutional contexts (Meyer 2007). Within transport policy, there exist many different priorities: promotion of a specific mode of transport, formal correctness of administrative processes, and successful economic development, among others. If we add other stakeholders from the mobility culture perspective and their integration in socio-technical configurations, the picture becomes even more complex. But without the specific consideration of these various networks, a new mobility policy cannot succeed. To ensure a sustainable mobility policy, institutional and financial resources must be used more effectively than in the past.

The local and regional levels play a crucial role, since it is here that concrete and context-sensitive global and national strategies for sustainable development can be implemented. Authors such as Hajer (2009) and Resel et al. (2002) have argued for institutional innovations. Hajer called for a "smart urbanism," warning against trusting in technology alone to solve the mobility problems of highly dynamic urban societies (see also Canzler, Knie 2015). Rather, the need is to develop regional governance structures and understanding mobility policy as a common task. As the monopolistic control paradigm of politics has pushed the transport sector to its limits for a long time, viable and convincing alternatives to existing policy, design, and administrative routines are clearly still in their infancy. Therefore, one objective of our research program is to identify ways in which the topic of sustainable mobility could be understood and addressed as a common task of policy, planning, administration, industry, trade unions, and civil society.

Against this background, Munich is an excellent laboratory for "smart urbanism" and for innovative mobility policy. Since the 1980s, which saw the beginnings of so-called cooperative transport management, new modes of regional cooperation have been adopted by various stakeholders. At the instigation of BMW and the city of Munich, the so-called Inzell Initiative (named after the town in which its first meeting took place) was founded in 1995, bringing together a wide range of stakeholders concerned with the future of mobility. Inzell has developed into a regional forum capable of arriving at consensus solutions to contentious issues at the regional level. In 2013, a future vision of mobility for the Munich region in 2050 was put forward. The aim of this project was to develop forward-looking and sustainable strategies for the region, and to lay a foundation for further cooperation (see Mailer et al. 2014). In keeping with a policy of collaborative planning (Healey 1997), a remarkable attempt to combine and share regional capacities, expertise, and social responsibility has been undertaken. This initiative has put Munich at the cutting edge from the perspective of critical planning theory (Flyvbjerg 2012; Sager 2008; Sandercock 2003), which sees in these approaches a promising way to combine "rationality and power" (Flyvbjerg 1998) while being responsive to all stakeholders.

The above considerations also constitute a critical response to the challenge posed by the current United Nations initiatives to define overarching so-called Sustainable Development Goals. We believe that, in this undertaking, the UN has underestimated the possibility that regions can substantially determine their own development in sustainable ways. Indeed, it seems that once again hope has been invested in top-down management instruments, which fail to account for the complexity of the local context of sustainability policies.

Instead, we advocate the development of regional governance models networked across several political levels, which will not simply fall victim to a naive "cockpit-ism"

(see Hajer et al. 2015). Research thus far has shown clearly that the Munich region has far-reaching potential for action that goes beyond such top-down models. The central stakeholders rely on a complex but coordinated process of communicative planning. Their goal is to integrate urban development, energy, social, and mobility issues in their interactions.

These reflections might contribute to integrated mobility concepts, such as the one intended by the Munich metropolitan region. Our research program can play an important role by introducing ideas and concepts into the current debate.

Possible research topics include the following:

- Development of a multi-level governance model for sustainable mobility in the Munich metropolitan region;
- Smart cities–smart mobilities? A critical discourse analysis on the future of sustainable mobility using the example of the Munich metropolitan region (compared to the Stuttgart region and possibly other national or international examples); and
- Integrated planning tools and methods for sustainable residential and mobility development.

2.4 Shaping sustainable mobility cultures: from theory to practice

We have noted that, in the context of sustainable mobility, a naive optimism about top-down control should be addressed critically. The question is what possible alternatives to top-down planning and policies might look like. We certainly cannot depend on the emergence of a comprehensive grassroots movement, or on spontaneous change of mobility behavior through a massive change of values and attitudes. This would be as absurd as a purely techno-centric alignment of innovation and industrial policies. In particular, so-called "practice theory" (Reckwitz 2002) has shown that instrumental influences designed to change behavior toward sustainability do not work. Shove (2010) demonstrates that simplifications of complex relationships between behavior, policies, and culturally influenced perceptions are ultimately counterproductive. She therefore calls for a social science–based approach to sustainable transition processes. This implies that policies designed to promote and initiate sustainable mobility developments need to go beyond the dominant ABC (attitudes, behavior, choice) paradigm of social change. "Moving beyond the ABC is not simply a matter of changing attitudes and behaviors within policy" (Shove 2010: 1282). Rather, it is about bringing the ideas and visions implied

in people's lifestyle orientations and culturally shaped perceptions (for which Freudendal-Pedersen coined the term "structural stories" in 2007) in line with social policies and spatial-material structures.

It is also important to analyze how very specific ideas and ideologies of and about mobility are defined and solidified in institutional routines and mobility cultures. Operational mobility policies have now been relatively well studied (see Millar, Salt 2008; Huchler 2013; Hislop 2013; Götz et al. 2010; Kesselring 2015). In other areas, such as planning, industrial and innovation policy, or in the development of new mobility technologies, such analyses are still lacking.

Diverse literature and innovative research approaches of cultural studies have influenced mobility research (see the overview in Vannini 2010). Based on the above considerations (see Figure 3 in the introductory chapter), we therefore formulate an integrated approach, which puts the term *mobility cultures* at the center in the sense that there will be a differentiation of various sustainable mobility cultures.

The frequently cited upheaval in the mobility economy is concomitant with a fundamental social change in mobility in the mobile risk society. One expression of this change is the automobile's looming decline in importance as the central means of transportation in modern society (cf. Tully 2009; 2014). The functional diversification of mobility offers, and the spatial and technical organization of mobility and transport is leading to unprecedented multi-optionality for individual, collective, operational, and institutional mobility practices. On the one hand, this increases the opportunities for sustainable mobility, especially in urban areas; on the other hand, it poses profound questions for stakeholders and their mutual cooperation, as well as for political culture and the flexibility of policy, along with the political realm's well-established forms of conflict resolution and consensus building (Altvater 2007; Glaser 2007; Kesselring 2007).

Following the model of mobility culture (presented in Figure 1 above), a number of research requirements involved in formulating an approach to an interdisciplinary mobility theory emerge.

Ultimately, the following four levels need to be linked conceptually:

1. The level of policy formulation and political-economic strategy formation (at the regional policy level, company level, citizen level etc.).
2. The mobility actions of individuals, but also organizations and institutions (e.g., corporate mobility regimes, or individual mobility decisions on residence, transport, communication, and forms of interaction).
3. Closely related to item 2, the question of the discursive structures that affect mobility actions, the perceptions and lifestyle orientations of individuals.

4. The spatial structures and mobility services that are affected over a long time period by concrete decisions within the prevailing socio-economic conditions, which thus form the historically developed image of the city.

In our attempt to address these issues systematically, theoretically, and conceptually oriented research projects should be used as sources in conjunction with thematically related case studies in practice.

Future research will envision

- Mobility cultures for the future of the metropolitan region,
- The relevance of new mobility theories for planning in mobile risk society.

3 Perspectives on implementing sustainable mobility in metropolitan regions

Collective learning is required for implementing more sustainable mobility in the real life of metropolitan regions. Regions seeking to learn together and implement practical change will want to draw on research knowledge; useful research will rely on practice-oriented experience. Therefore, beyond inter-disciplinary approaches, we also have to work toward cementing transdisciplinary settings.

The mobil.LAB doctoral research group intends to serve as a new source of such cooperation, where university teachers, experts in applied science, and doctoral candidates from multiple disciplines will share their experiences and knowledge. The group could be an impact hub, where real-life observations are required for the development of a new theory and where research contributes substantially by developing practical applications and solutions to specific questions.

Over the past years, thanks to the intensive dialogue built up between doctoral students and university lecturers from different disciplines, we have been able to develop the fundamental concepts of the program significantly. Ideas from the entire period of four years have been incorporated into a working paper on the common understanding of sustainable mobility in metropolitan regions, the current version of which can be viewed on the laboratory's home page (www.sv.bgu.tum.de/mobillab).

The program has been extended by the Hans Boeckler Foundation for the next three to four years, and we hope to establish an interdisciplinary network of experts who will help in the development of relevant research.

In this regard, mobil.LAB aims to function as an open lab, involving practice partners in our research. We will also provide internal and external events, such as methodological colloquia and public lecture series. Expert workshops and international conferences will generate and disseminate new results. Again, findings will be published extensively.

We are looking forward to continuing the exchange and discussion. Feel free to contact us for any further dialogue.

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