THE IMPACT OF SHARP INCREASES IN MOBILITY COSTS ANALYSED BY MEANS OF THE VULNERABILITY ASSESSMENT

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ABSTRACT

The combination of peak oil and scarcity of fossil fuel with political instability in oil producing states might cause sharp increases in mobility costs in the near future. In this research, municipalities will be tested regarding their susceptibility to sharp increases in mobility costs by means of the vulnerability assessment. Therefore, this ever-growing increase is leading to mobility impairments for certain social classes. The amount spent on mobility costs of the household budget is rising dramatically.

To see which regions are in danger of increasing mobility costs the vulnerability assessment has been performed with a combination of indicators for the dimensions exposure (e.g. fossil fuel consumption), sensitivity (income) and resilience (accessibility to jobs by public transport) within the Munich region as well as the Lyon region.

The feasibility of transferring the vulnerability assessment to different regions and households based on the socio-demographic and transport data is crucial to test the future viability.

Displaying and visualizing the vulnerable locations through mapping can assist in the development of sustainable spatial and transport policies to cope with issues arising from increased mobility costs (e.g. social exclusion…).

Keywords: mobility costs, vulnerability, resilience, fossil fuel, sustainable mobility, peak oil, accessibility, GIS

1. INTRODUCTION

The majority of people still rely on fossil fuel powered modes of transport for everyday mobility, despite the recent attempts of governments to decrease the growth trend towards individual motorized mobility. However, the economic rise of BRIC countries – Brazil, Russia, India and China - is increasing the need for more and at the same time affordable oil.
In the current global economic situation an oil price increase has a dramatic impact on a country's economic development, as has been proved in the last oil crisis. History offers worrying messages and the last oil crisis was just a few years ago in 2008.

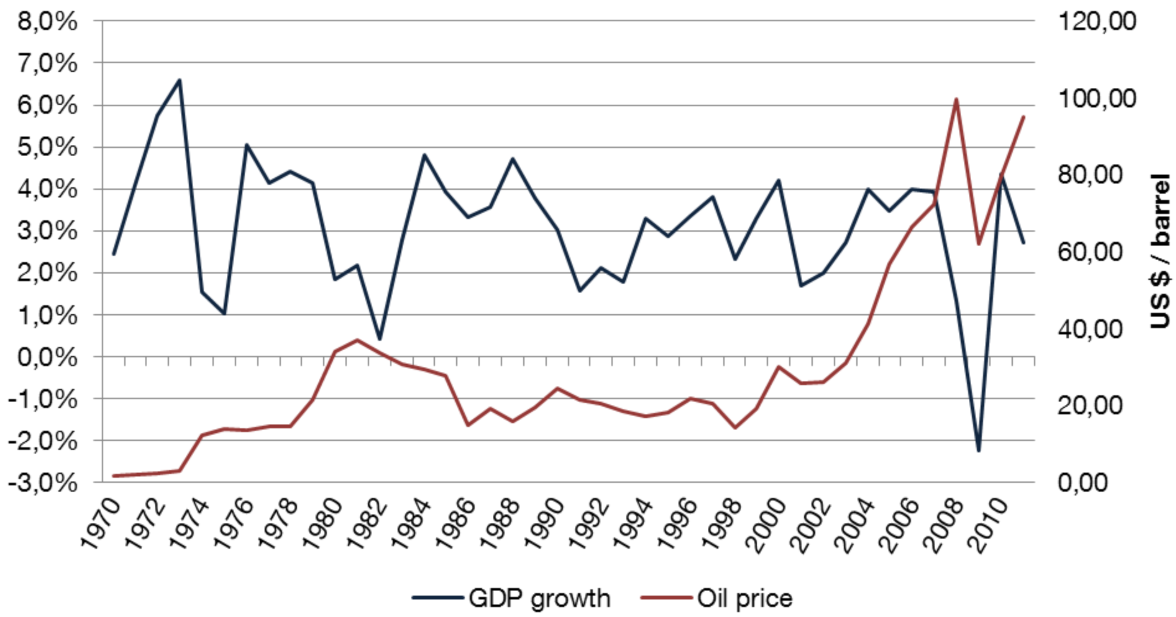

Figure 1: Development of the oil price and world GDP growth from 1970 till 2011. Source: Based on data by World Bank database for the GDP growth (2012) and Earth Policy Institute (2012))

Figure 1 shows the development of the real oil price from 1970 till the present compared to the real GDP growth rate in that time frame. Scarcity of fossil energy and the uncertainty of peak oil combined with political instability in oil producing nations will result in higher mobility costs in the near future. During the last oil crisis the oil price jumped from about US$40/bbl in 2004 to more than US$100/bbl in just four years. Meanwhile the world's real GDP growth rate declined from almost 5.5 % to 4% in that same time frame. Shortly afterwards, the global economy collapsed, which shows a strong correlation between oil price and economic growth. Furthermore, the events in 2008 confirmed a pattern seemingly in place since the 1970s.

Due to extreme variability in oil prices any accurate prediction is difficult. The drop of the real oil price in 2009 was immediately followed by a sharp increase from about US$60/bbl to US$100/bbl in 2011. Still, it is plausible to conclude that the (fuel) prices that households have to pay remain at a high level and will continue to escalate (Energy Information Administration, 2012).

Based on the combination of fear and uncertainty another oil crisis cannot be ruled out or predicted, that will lead to a sharp and sudden leap in costs. Therefore, an examination of the vulnerability on a regional level is needed in order to see which municipalities are susceptible to sharp increases in mobility costs.

2. VULNERABILITY ASSESSMENT

The resilience of the study regions Lyon and Munich (see chapter 3) is analysed by the means of the vulnerability assessment. The concept – which was formerly used to test the susceptibility to e.g. famine and food security, hazards, climate change (Adger, 2006) - is in this research adapted to regional vulnerability in the case of dramatic increases in mobility costs. The following subchapter will explain the methodological approach.

2.1. Methodological approach

> "Vulnerability is most often conceptualized as being constituted by components that include exposure and sensitivity to perturbations or external stresses, and the capacity to adapt" (Adger, 2006).

According to this, Kasperson et al. (2006) divides vulnerability into the following three dimensions:

1. **Exposure** is the contact between system and stress.
2. **Sensitivity** is the degree to which something/someone is affected by exposure to stress.
3. **Resilience** is the ability of something/someone to absorb perturbations or stresses without changes in its fundamental structure or function that would drive it into different state.

In this case the context is an increase in fuel prices and the subsequently effects are analysed on the regional scale of municipalities.

Within the vulnerability assessment the measurement of vulnerability is a crucial issue. As underlined by Leary and Beresford (2007) vulnerability is a non-observable, complex, and multi-dimensional concept. Consequently, researchers are in the process of developing appropriate indicators for a wide range of different fields.

2.2. Thematic adaption regarding mobility costs on a regional scale

Until now, the concept of vulnerability has not taken into account transport related fields like mobility costs (Adger, 2006).

> “The challenge for vulnerability assessments is to find explanations […] that are […] robust and applicable to a wider set of contexts. This can be facilitated by working at regional scales” (Leary and Beresfort, 2007).

In order to adapt the vulnerability assessment to the issue of increasing fuel prices, appropriate indicators have to be collected and specified. A range of indicators can be used to measure levels of vulnerability at a municipal level.

- Who will be **exposed** by an increase in fuel prices?
  Those that have a high **fossil fuel consumption**.
  Therefore, the appropriate key indicator is the municipal average of vehicle kilometres per capita by private cars (see chapter 4.1).

- Who will be **sensitive** to rising fuel prices?
  Those that have a relatively **low income**.
  Therefore, our analysis in Munich uses the municipal average of net income and in Lyon the unemployment rate as key indicators (see chapter 4.2).

- Who will be **resilient** in the case of increasing fuel prices?
  Those that have **alternatives to the private car**.
  Therefore, the appropriate key indicator is the accessibility to jobs by public transport (see chapter 4.3).

- Who will be **vulnerable** to an increase in fuel prices?
  Those that are **highly exposed** and **highly sensitive** combined with a **low resilience**.
  Therefore, the vulnerability index is calculated as the sum of the listed indicators (see chapter 4.4).

In general transferring this methodology to other regions or even thematic questions is possible. However, in the case of comparing and benchmarking different study regions, this framework and indicators have to be adapted in respect to issues like data availability. To ensure a certain level of comparability the same or at least similar/comparable data needs for to be chosen.

3. STUDY REGIONS

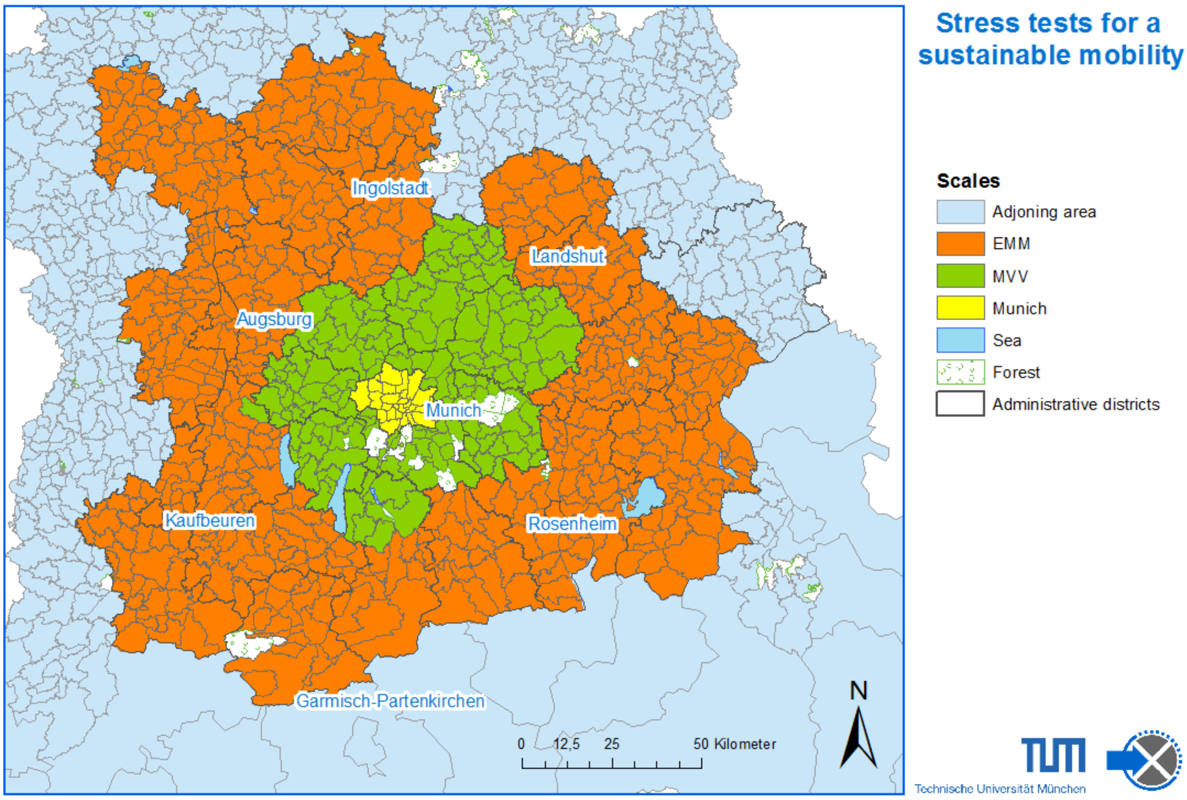

Figure 2: Analyzed scales: Munich Metropolitan Region (EMM), Munich Region (MVV) and City of Munich

The Munich Metropolitan Region (EMM) with its population of 5.5 million is located in the south of Germany and includes several important cities like Ingolstadt and Augsburg. Destinations for tourism like Garmisch-Partenkirchen in the German Alps are also part of the Munich Metropolitan Region. The total area is more than 24.000 km² with an average GDP of about 209 billion €. The purchasing power for the inhabitants is at 23.000 €. The average daily distance by private car is 23.5 km, while the commuting distance is 17.6 km. For benchmarking and analysis, the proper scales have to be chosen. Therefore, most analysis will focus on a smaller scale like the Munich Region (MVV) so it is comparable to Lyon Metropolitan Area (see Table 1).

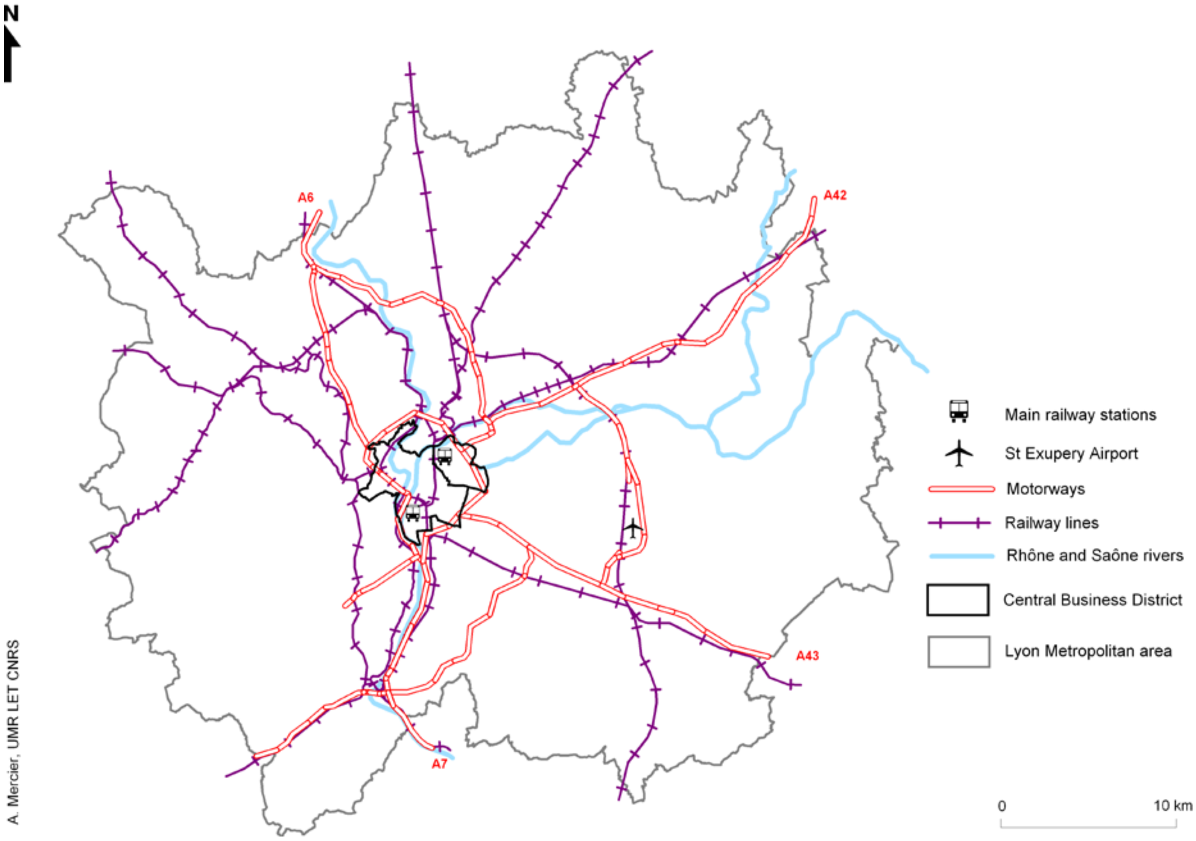

Figure 3: Lyon metropolitan area, with main transport infrastructures

The Lyon Metropolitan area (see Figure 3) is the second largest metropolitan area in France (after Paris) and covers more than 3,356 km² and contains 296 “communes” (the smallest administrative subdivision in France). The overall metropolitan area has a population of 1.7 million people (INSEE RGP, 1999), and a population density of 508 inhabitants per km². Population growth is significant (0.8% per year) and higher than in any other French Metropolitan region (Paris, Marseille, Lille). Population tends to be concentrated in the central zones (Lyon and Villeurbanne) and their outlying “communes” with densities higher than 900 inhabitants per km². The Lyon Metropolitan Area offers more than 800,000 jobs (in 1999) for 765.000 employees living in the area.

Table 1: Benchmarking of the regions

	Grand Lyon	Lyon Metropolitan Area	Region Rhone Alpes	Munich	Munich Region (MVV)	Munich Metropolitan Region
Area	510 km²	3.356 km²	43.698 km²	311 km² (2009)	5.470 km²	24.094 km²
Average income per person	18.280 € per year (per household income)	N.C	18.997 € per year	23.145 € per year	39.172 € per year (gross income)	21.518 € per year
GDP	52 Billion €	N.C	188 Billion €	73.8 Billion €	N.C	209.48 Billion €
Inhabitants	1.257 Mio	1.757 Mio	6.160 Mio	1.364 Mio (2009)	2.603 Mio	5.5 Mio
Length of public transport	1.232 km	N.C	2.660 km (train – RFF)	625 km	5.377km	N.C
Population density	2.455 inhabitants per km²	509 inhabitants per km²	141 inhabitants per km²	4.400 inhabitants per km²	494 inhabitants per km²	282 inhabitants per km²
Rate of unemployment	11.40 %	8.8 %	9 %	5,0 %	2,12 %	N.C
Cars per 1000 inhabitants	N.C	Around 455	Around 525	503	546	

Source: Bayerisches Landesamt für Statistik und Datenverarbeitung, 2010.

For benchmarking a general comparison of the two study regions is needed. Therefore, a wide range of structural as well as mobility data was collected. Grand Lyon will be compared to Munich, Metropolitan Region Lyon with Region Munich and Region Rhone Alpes will be benchmarked with Munich Metropolitan Region. Therefore size and population will fit quite well and will enable a detailed comparison (see Table 1). In this paper the results are based on the analyses of the Metropolitan Region Lyon and Region of Munich due to the importance of this regional scale.

4. REGIONAL VULNERABILITY IN CASE OF SHARP INCREASES IN MOBILITY COSTS

4.1. Exposure assessment

Munich case study

For measuring exposure two sources to obtain data are used. The first is a national database of regional statistics (GENESIS online, operated by the public statistics agencies of the German states) that provides population data (see Table 1). The second source is the regional transport model which is run jointly by the city of Munich, the regional public transport authority (MVV) and the public transport operating company of the city of Munich (MVG). This model allows the calculation of vehicle-kilometers travelled (VKT) by the inhabitants of each municipality within the coverage of the MVV network. This key indicator for measuring exposure was chosen because vehicle-kilometers travelled (VKT) are directly related to fuel consumption.

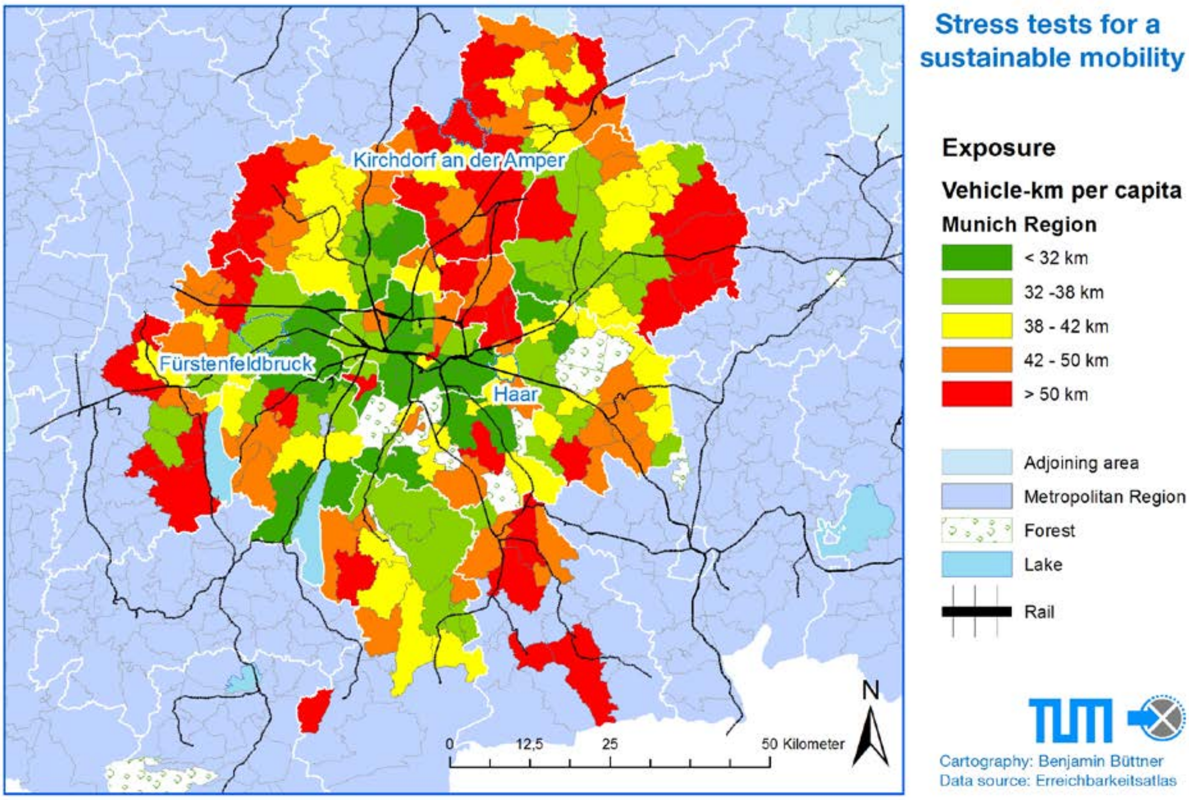

Figure 4: Municipal average of vehicle-km travelled per inhabitant for Munich region

The red municipalities (administrative districts) show a very high exposure due their high VKT per inhabitant. In average the inhabitants use their car more than 50 kilometers for daily 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 characterized by close to no public transport service mostly located in rural regions. Hence the red municipalities are very car dependent.

Lyon case study

Using a 2006 travel survey, car user trip data was extracted according to travel analysis zones. This allowed the computation of daily vehicle distance per Grand Lyon resident.

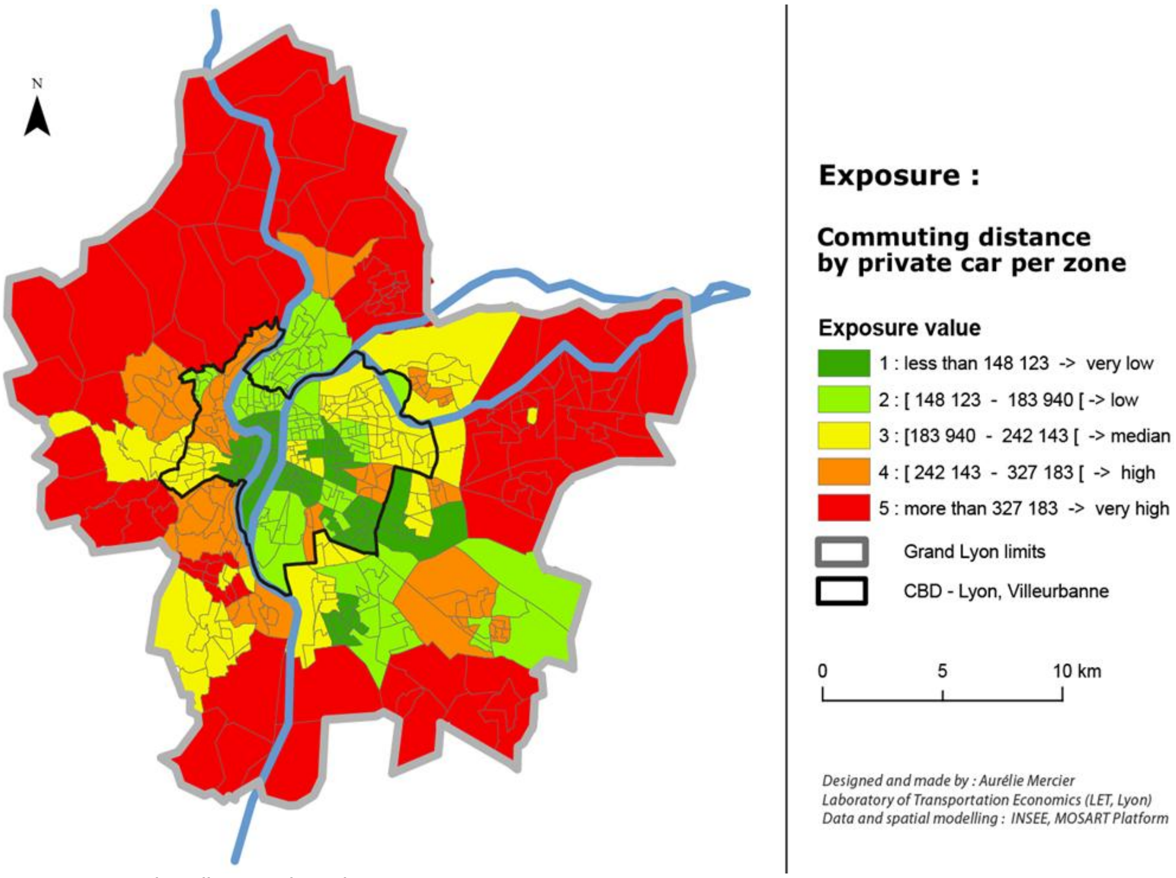

Figure 5: Commuting distance by private car per zone

Commuting distance by private car is higher in municipalities located in the second belt than in the city center or in the first belt. Indeed many inhabitants located on the suburbs have to access the city center for working. Therefore travel distances are longer than for inhabitants living and working in the city center. Moreover from the second belt, car is often more efficient than public transports to access the city center, in spite of congestion in peak hours. Second belt municipalities are not well served by public transport: frequencies are very low and travel time often longer. Urban sprawl and peripheral locations result clearly in a higher level of exposure. In the city center, high impact of metro and tram lines is observed. In areas served by metro or tram, commuting distance by car is lower than other areas always located in Lyon or Villeurbanne.

4.2. Sensitivity assessment

Munich case study

The measurement of sensitivity relies on the two indicators 'unemployment rate' and 'average monthly income'. Both datasets are drawn from the GENESIS online database provided by the Bavaria department of data and statistics (2010). They are available on municipality level. The values of these indicators are illustrated in the maps below.

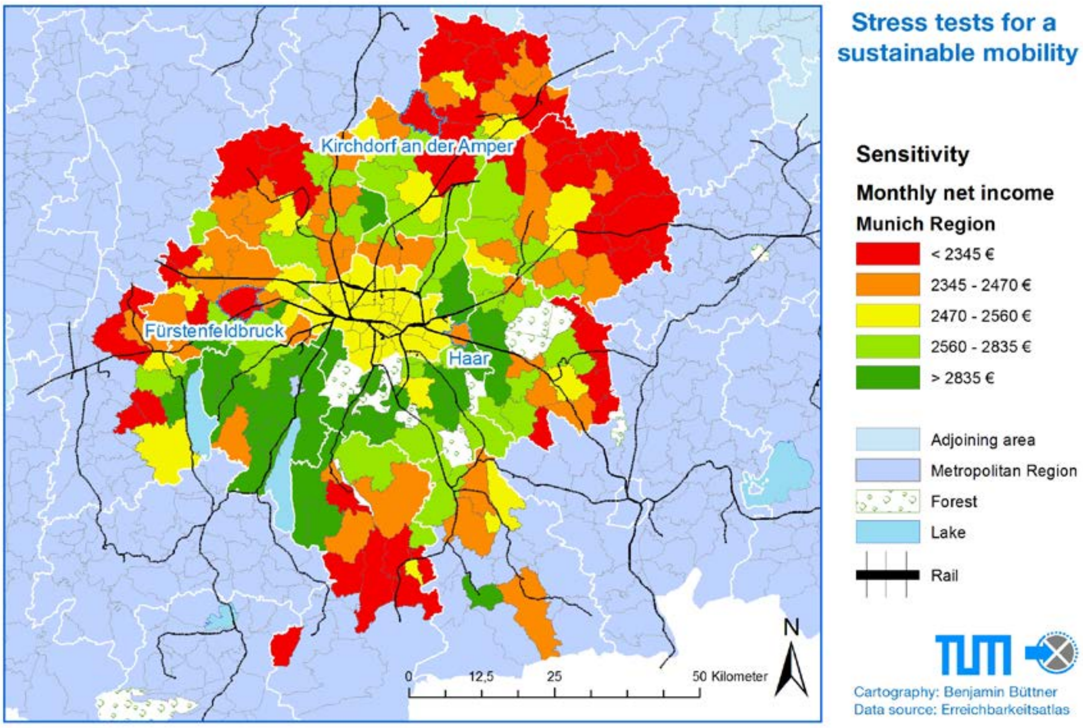

Figure 6: Monthly income in the Munich metropolitan region

The average monthly net income for employees is illustrated in Figure 7. Sensitive municipalities are located mainly at the outskirts of Munich region. On the one hand, combining less than 2.345€ net income with a high VKT these municipalities will suffer severely in the face of an increase in mobility costs. On the other hand, the southwest municipalities have a very low sensitivity due to their relatively high net income of above 2.835€. Therefore even with high number of VKT the green municipalities will not be struck as hard as poorer car dependent regions.

Lyon case study

At the Lyon metropolitan area level, the unemployment rate is calculated as follows: Unemployment rate is equal to the number of jobs seekers enrolled at Pôle Emploi (2009) divided through the total population (2008). Monthly income refers to data from INSEE. The median income has been chosen to represent sensitivity.

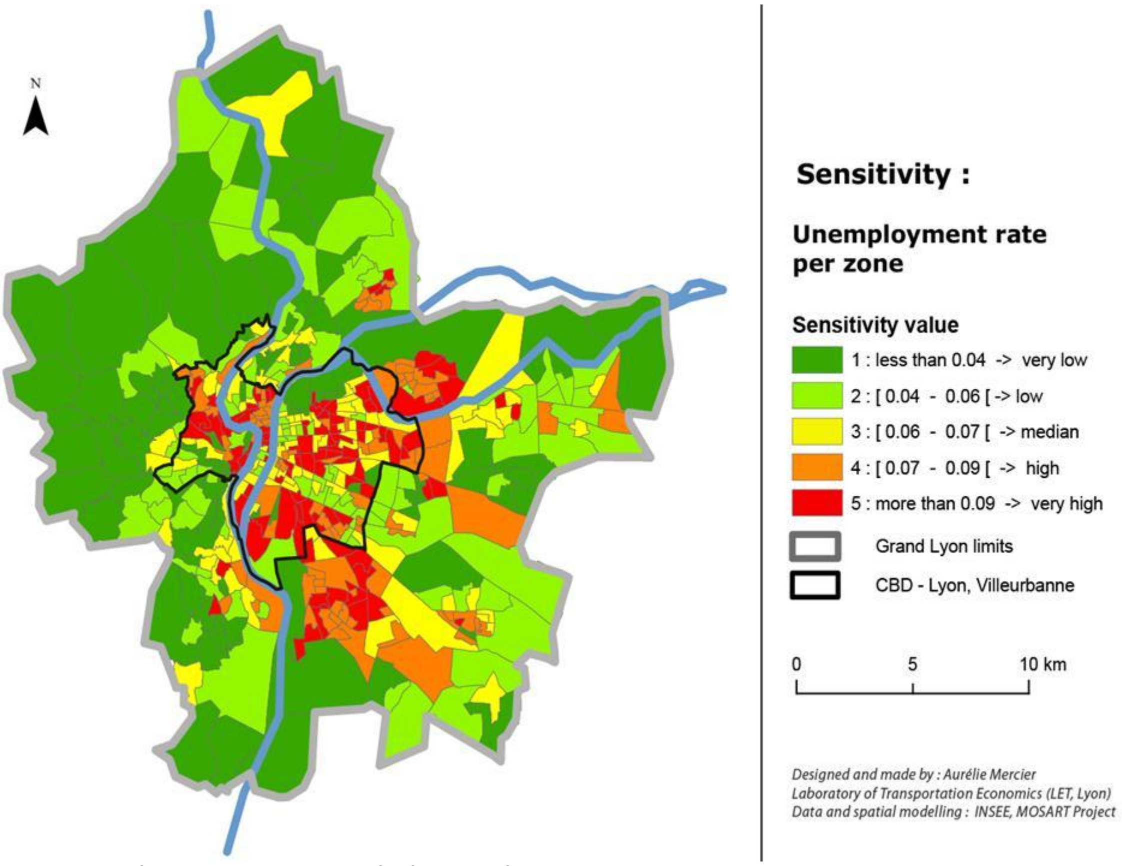

Figure 7: Unemployment rate per zone in the Grand Lyon area

Sensitive areas are mainly located in the city center (municipalities of Lyon and Villeurbanne) and in the east first belt of Grand Lyon. The west belt of the Grand Lyon is not sensitive. Unemployment rate is often lower than 4% of the working population.

Note that in the city there is a significant disparity between areas. The 8^{th}, 9^{th} and the city of Villeurbanne are more sensitive than other parts of the city center. In these zones unemployment rate is higher than 7% and, in some parts higher than 9%.

4.3. Resilience assessment

The level of resilience is measured by accessibility to jobs by public transportation.
Accessibility can be defined by the ease with which opportunities may be reached from a given location using a particular transportation system (Morris et al., 1978). Among the different measures proposed in the literature, the gravity-based measure is used in this case. The following expression is considered after Hansen (1959):

$$A_i = \sum_{j=1}^{n} E_j \exp^{(-\beta C_{ij})}$$

where E_j represents opportunities in zone j, C_{ij} denotes the travel cost (or generalized cost) between zones i and j, β represents cost sensitivity parameter and n the number of zones.

In this case, the opportunities are defined as jobs due to their high importance in generating traffic.

Munich case study

The accessibility to jobs by public transport during the peak period in the morning serves as key indicator for resilience. Figure 9 displays the total number of accessible jobs within one hour for every municipality.

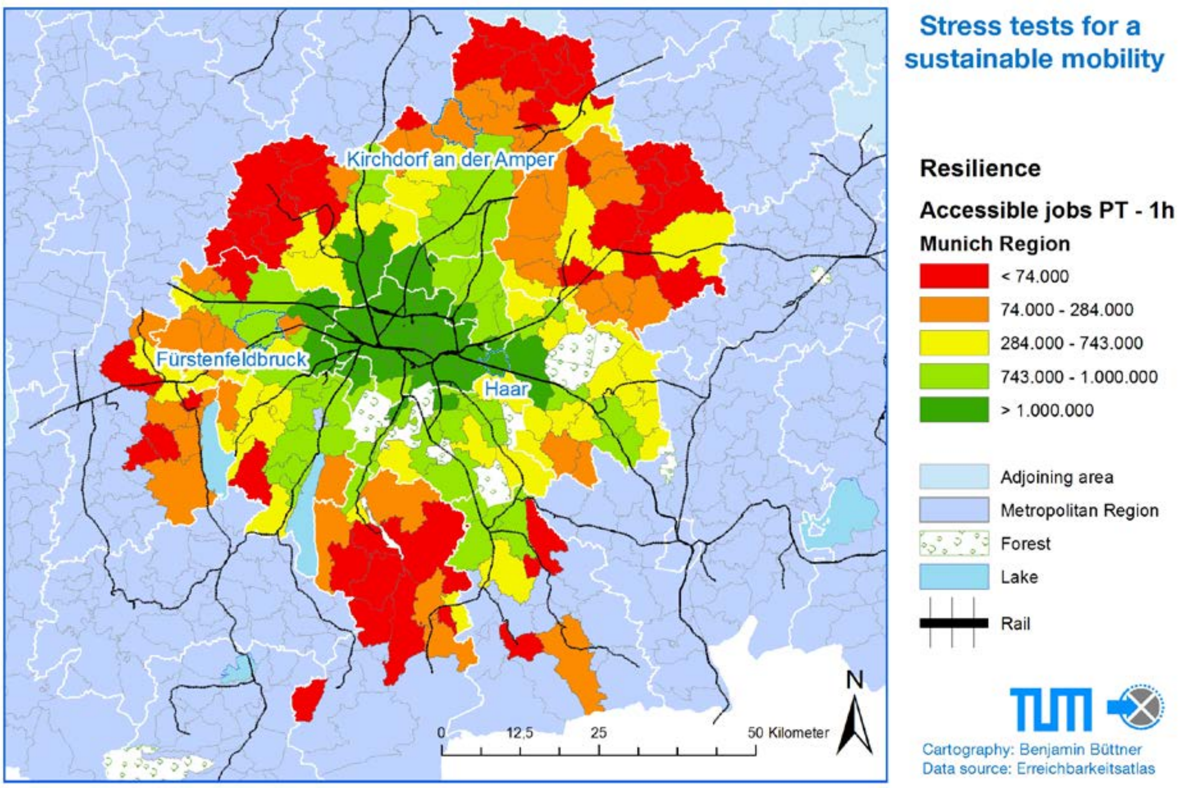

Figure 8: Accessibility to the number of jobs by public transport within in the Munich Region

From the green municipalities more than 1.000.000 jobs are accessible by public transport within one hour. Red municipalities are lacking proper supply of public transport and in most cases closely located jobs. The inhabitants in structurally weak municipalities have limited alternatives to shift to non-fuel powered modes of transport. Thus, the inhabitants are not resilient in the case of escalating fuel prices.

Lyon case study

Isochrone accessibility to jobs is measured for public transport commuters, in the morning peak period. Travel time is computed using a “shortest path algorithm”. Connection and waiting time are also considered for public transport trips.

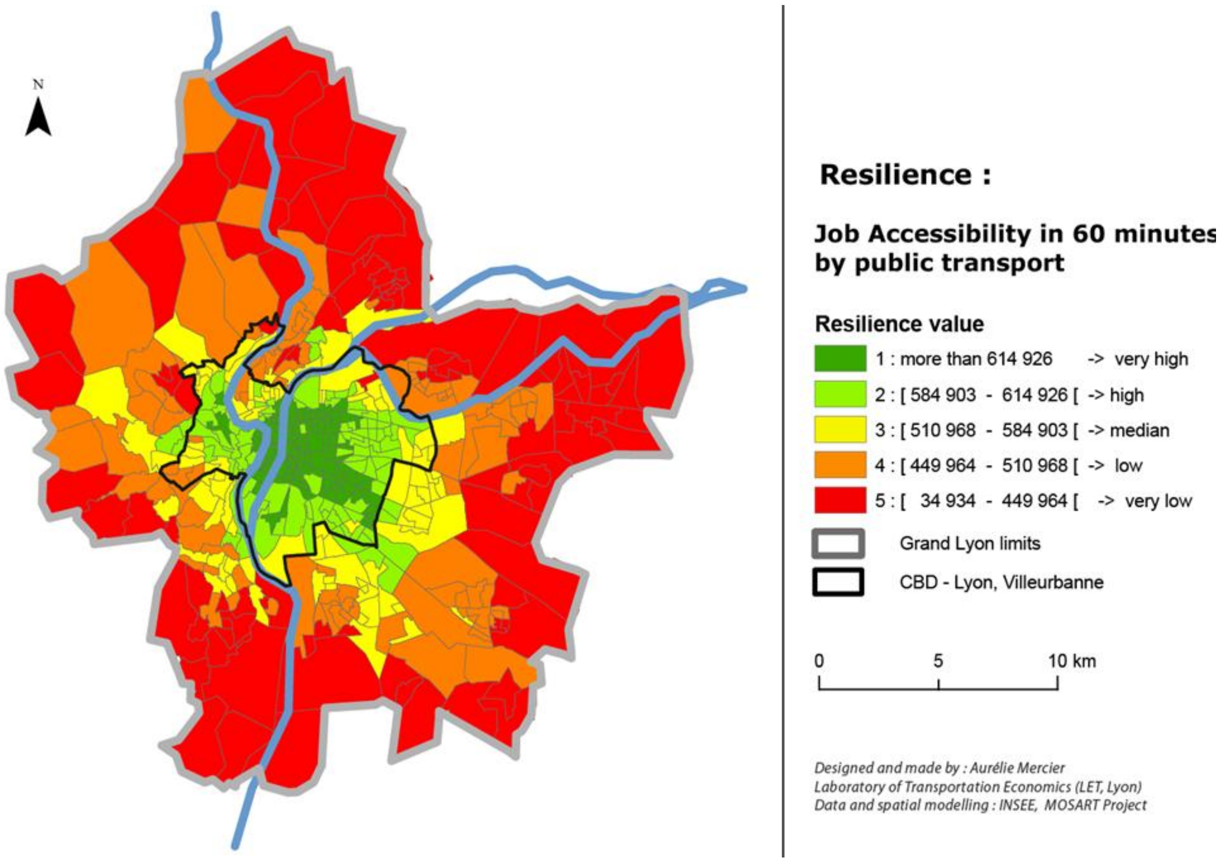

Figure 9: Job Accessibility in 60 minutes by public transport in the Lyon Urban area

The structure of accessibility is given by concentric circles around the city center. The higher distance from the city center is, the lower the accessibility.
Level of accessibility and resilience are highly dependent on tram and subway lines which offer high levels of frequencies and travel speed to link to the city center. Note that the regional rail lines can also offer high level of resilience for inhabitants located around them.

Higher levels of service of these lines are mainly observed during morning and evening peak periods. So it is possible to live in a peripheral area but to benefit from a low vulnerability during the peak period when public transit operates at high frequencies. It is also important to notice that it is a targeted resilience. For instance you can shift from car to public transit for the daily trips between home and work. But for other kinds of mobility (leisure, shopping…) this change may not be possible and thus people are less resilient for these types of trips (see Büttner et al. 2012).

4.4. Vulnerability assessment

Munich case study

The vulnerability index is calculated based upon three key indicators for the dimensions exposure, sensitivity and resilience as described in chapter 2.2. Due to the different measures of valuing the three indicators, the order of magnitude varies from each other to a large extent: exposure has a range from 10 to 100 for driven kilometers, sensitivity ranges from below 2.345 € till more than 2.835 € of net income and resilience from up to 1.000.000 jobs accessible by public transport. In order to make the three indicators qualitatively comparable to each other, a rank from 1 to 100 has been applied to the indicators.

The following assumptions are adopted when assigning the ranks: the more one drives (highly exposed), the more vulnerable she or he is; the less one earns (highly sensible), the more vulnerable; the better public transport accessibility one has (highly resilient), the less vulnerable. From minimum to maximum value of the three indices, the ranks are respectively from 1 to 100 for Exposure, from 100 to 1 for Sensitivity and from 100 to 1 for Resilience, which means with a higher rank, one is more vulnerable. Thus the vulnerability index is defined as the sum of the rank values of these three indices.

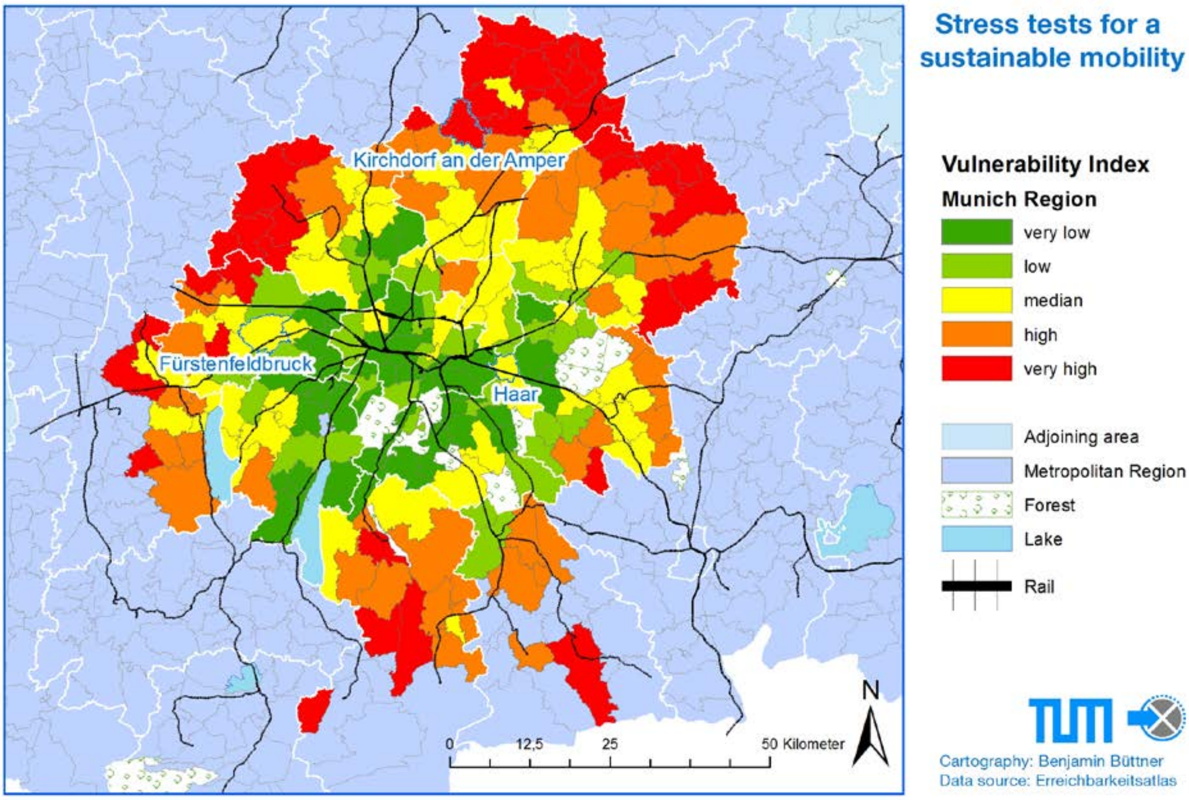

Figure 10: Vulnerability assessment concerning an increase in fossil fuel for Munich region

The green municipalities show low vulnerability to escalating fuel prices in Figure 10. These municipalities are able to cope with sharp future increases in fuel costs. In contrast, the highly vulnerable red municipalities will suffer heavily due to heavy car dependency and use as well as a low average net income. The majority of the vulnerable municipalities are located in between the railway axes or in the peripheral outskirts. Therefore, for a resilient development of the region transit oriented development close to high level public transport stations has to be further fostered.

To maintain the quality of life within these vulnerable municipalities there is an urgent need to allocate mobility alternatives (e.g. public transport supply) as well as facilities/activities for daily needs (e.g. supermarkets, jobs, schools).

Lyon case study

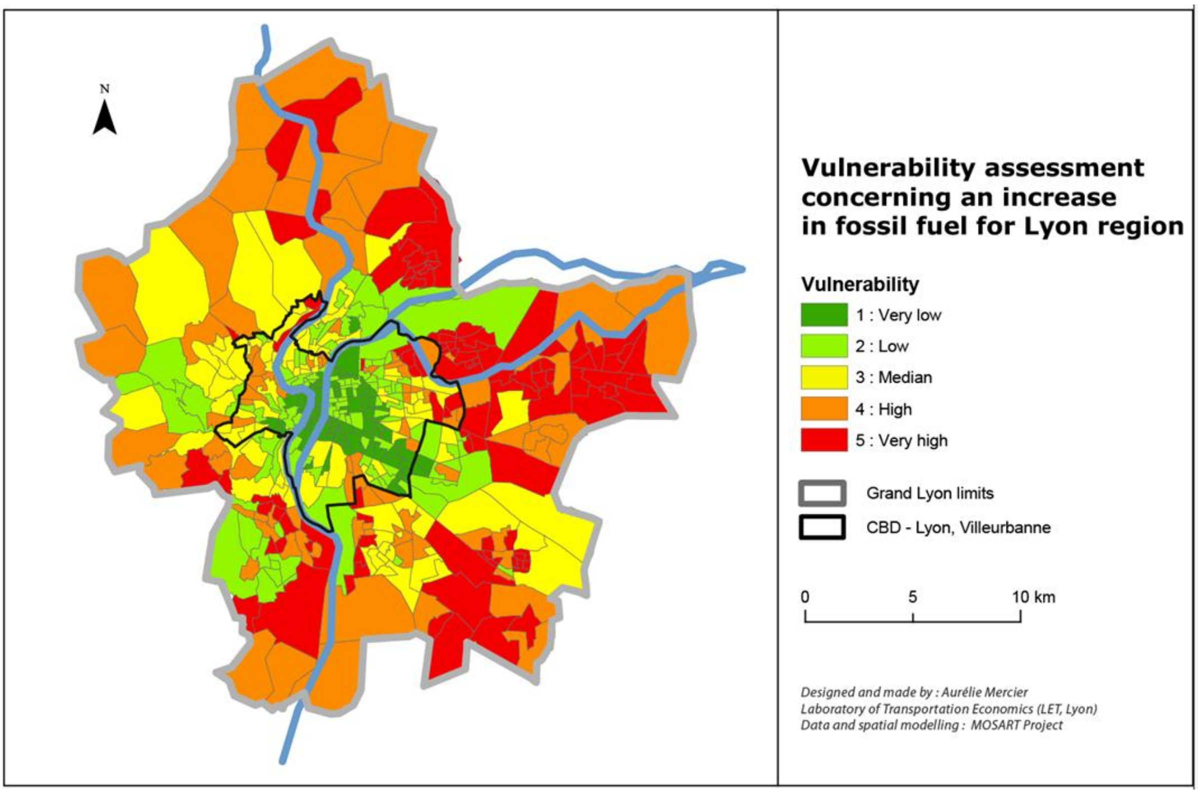

Figure 11: Vulnerability assessment concerning an increase in fossil fuel for Grand Lyon

As for the Munich case study, the vulnerability index is calculated based upon three key indicators for the dimensions exposure, sensitivity and resilience. It is not surprising to observe that zones located in the city center have a very low level of vulnerability. Indeed, in spite of unemployment rate often higher than 6%, these zones are not very exposed owing to a high quality of services offered by public transport lines like tram or subway. Outside the city center, north-eastern and southern municipalities are faced with higher levels of vulnerability. Because of a lack of public transport lines, their inhabitants have to use a private car for their daily trips. Their resilience level is very low. This vulnerability explains why the “Region Rhône-Alpes”, the public authority in charge of local trains, has developed an ambitious program of new trains, and even tram-trains, with a higher frequency. The result is a growing saturation of these trains during peak hours, another source of vulnerability.

5. DISCUSSION AND OUTLOOK

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

However it is not advisable to state individual impacts of increasing mobility costs on municipal averages. Therefore, an analysis of households has been performed in the study regions, to point out the individual effects and differences persons are facing (see Büttner et al. 2012). As a result of drastic stress tests scenarios, individual strategies are formulated for maintaining social and economic participation, even while tripling gas prices.

Severely affected municipalities by increasing fuel prices have been elaborated for Munich as well as for Lyon. In these case studies the vulnerability assessment has been proven to be a very capable platform for discussing how to prepare municipalities with the respective decision makers (compare Turner et al., 2003). Recommendations, strategies and policies can be developed upon this. In the end this will lead to more sustainable mobility behaviour and ensures the quality of life for all, no matter the spatial location or the social standing.

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