Simulating the Impact of increasing oil prices on land use and mobility in the Hamburg Metropolitan Region

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Abstract: Households in Germany spend half of their income on housing and mobility. In view of the ‘Peak-Oil’ situation we are facing at the moment, an increase in energy costs can be expected over the next decades. This increase will influence both housing and mobility costs for households and (re-)shape their location and travel decisions.

In the €LAN-project funded by the German Ministry of Research we will simulate these decisions with help of an integrated land use and transportation (LUT)-model for the Hamburg Metropolitan Region and study the impact of possible political responses to the future energy scenarios. The policy scenarios will be developed by various stakeholders (representing local, regional, and federal politics and administration as well as housing, and transport companies) in a strategic management game, where they will be confronted with the results of the LUT-Simulation.

This paper discusses possible political responses to rising energy prices in the fields of taxes, land use, and transport policy and describes the structure of the LUT-model that should be applied to evaluate the impacts of these policy schemes.

Keywords: land use, transportation, energy price, simulation, management game

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1. THE PROJECT €LAN - ENERGY PRICE AND LAND USE

German households spend about half of their available income on housing and mobility (Statistisches Bundesamt 2010). Energy costs take up a significant proportion of housing and mobility costs. In the past decades, cheap oil prices favored a suburbanization of households into single family homes in automobile dependent locations. (In Germany to a lesser extent than in North America - influenced by higher energy taxes, stricter housing energy standards and land use regulations).

The time of cheap oil prices seems to be over, we are facing the ‘Peak-Oil’ situation (IEA, 2009), in which oil production stagnates, oil reserves decline faster than new oil fields are found. On the other hand the economic growth, particularly in countries such as China and India, leads to increasing energy demand. Rising demand and falling supply are going to make steadily prices of oil and its derivates very probable in the next decades - superimposed by short-term fluctuations of the market price. This will influence both housing and mobility costs for households.

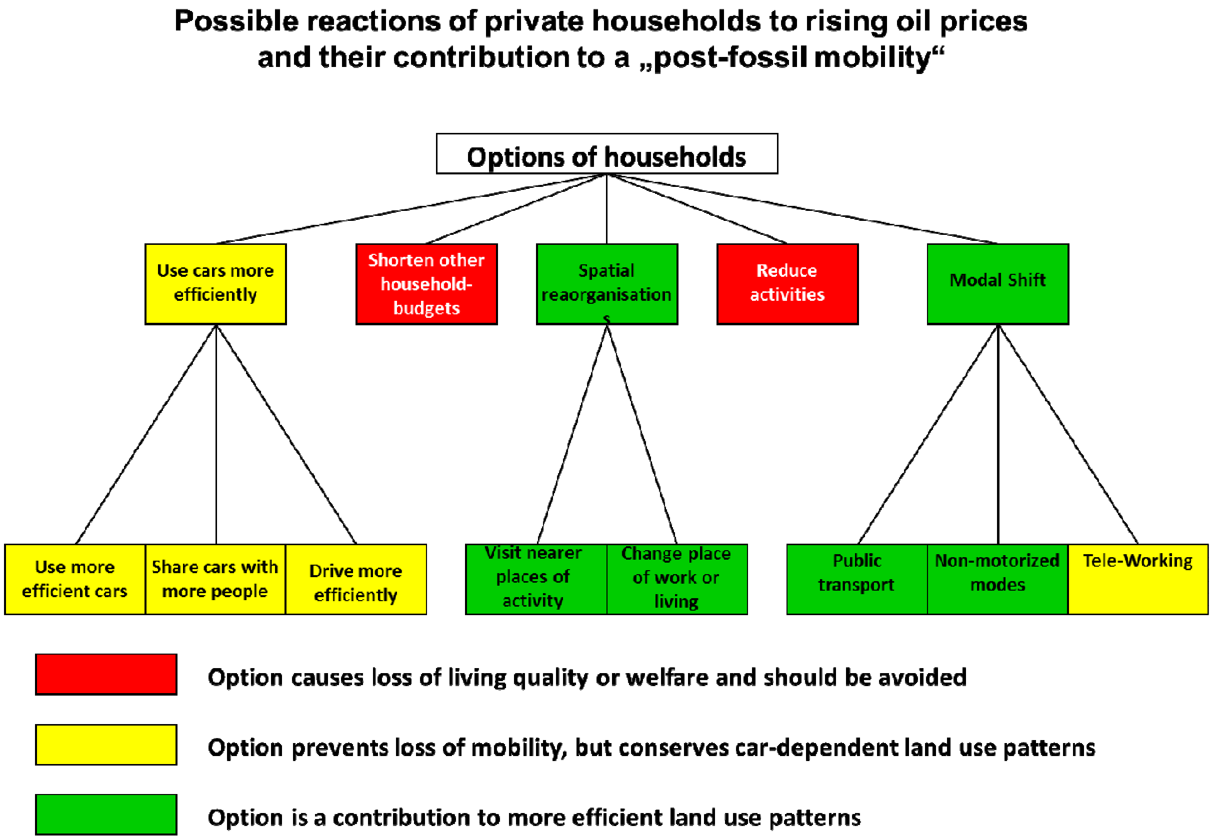

Figure 1: Possible reactions of private households to rising oil prices (Source: Gertz et al. 2008)

Households can respond to rising oil prices by cutting other budgets or avoiding activities, which cause loss of living quality. They could use cars more efficiently, which avoids a loss of mobility, but conserves an automobile-dependent land use and mobility pattern. Or they shift to other modes of transport and reorganize their activities, which might be regarded as a contribution to more efficient land use pattern.

1.1 The Project €LAN

In the project "€LAN - €nergy price and LANd use", funded by the German Ministry of Research, the consequences of rising energy costs on land use and mobility are analyzed, focusing on the following questions:

Who is particularly affected by rising energy costs?
How will households react in a short and long term perspective?
How will politics respond to such a situation?
What impact will possible policy responses have?

These questions will be addressed by a trans-disciplinary approach: The impact of rising energy prices will be simulated with an integrated land use/transportation (LUT)-model. The policy scenarios will be developed by various stakeholders (representing local, regional, and federal politics and administration as well as housing, and transport companies) in an administrative strategic simulation, where they will be confronted with the results of the LUT-simulation. The aim of this project is to observe and analyze the political decisions as well as the possible challenge to the common planning tools.

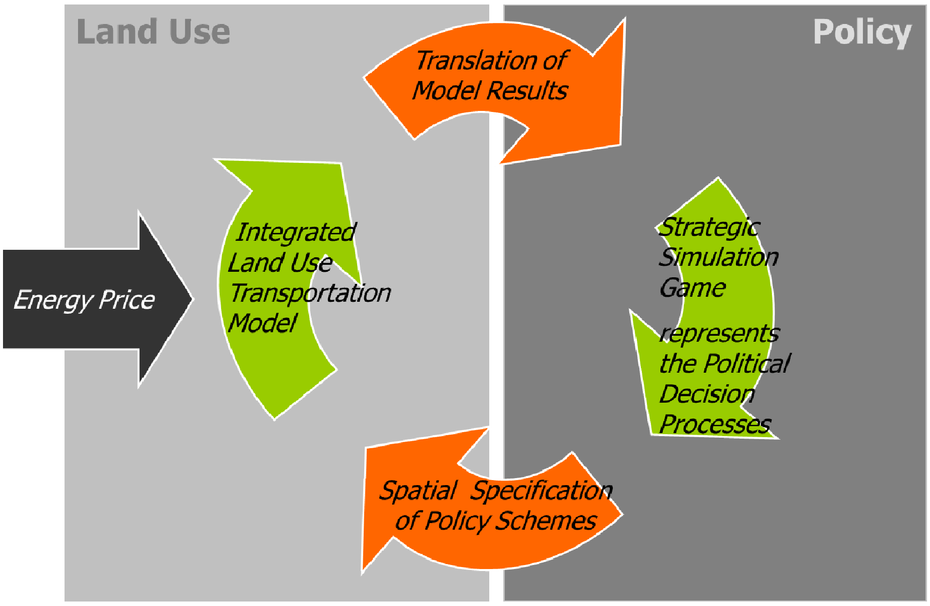

Figure 2: LUT-Model and Strategic Simulation

A team of 15 researchers from the University of Stuttgart (Institute of Regional Development Planning), the University of Cologne (FiFo Institute for Public Economics) and the Hamburg University of Technology (Institute for Transportation Planning and Logistics) as well as 3 consultants will work until 2013 on the €LAN-project. The administrative strategic simulation will be carried out in 2012/2013. The focus of the year 2011 is on the development of the integrated LUT-model.

1.2 The Study Area: Hamburg Metropolitan Region

The lower the household's income, the worse the housing energy standards of their house and the more they drive by car, the more households are affected by rising energy prices. So the question "Who is particularly affected by rising energy prices?" shapes the limit of the study area. We choose to simulate the Hamburg Metropolitan Region including its rural hinterland with a high share of long distance commuters.

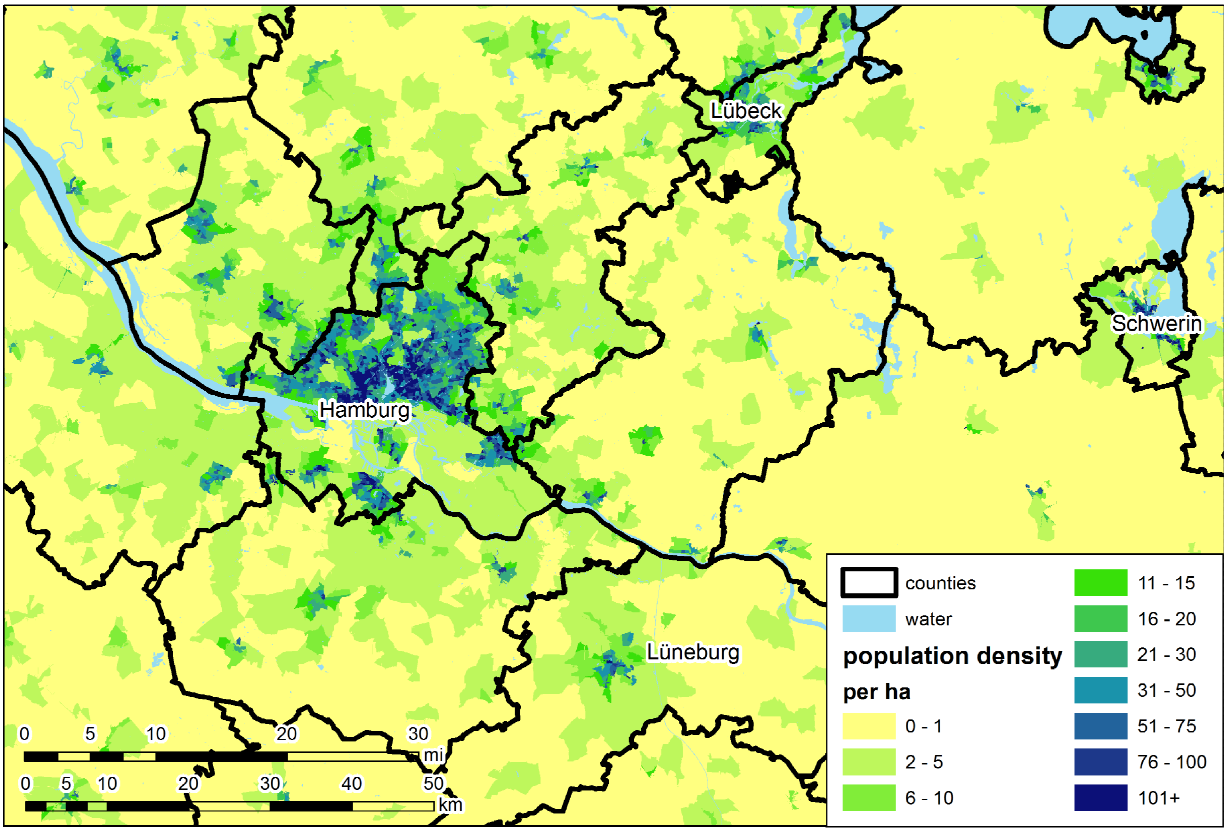

Figure 3: Population Density in the Study Area

Hamburg is Germanys second largest City with approximately 1.8 million inhabitants of which half are living in the densely populated mixed-used inner neighborhoods (dark blue areas in Figure 2). The other half is living in the outer neighborhoods with moderate density (light blue). To the South and east of the River Elbe, land use is dominated by Germany's largest harbor and industrial areas. Some large areas of open space have been preserved in the past there.

Nearly 1.5 million inhabitants live in the 6 suburban counties around Hamburg, with 300.000 workers commuting into Hamburg every day. There are large automobile-dependent suburbs in these counties, but also several mid-sized towns with a good local infrastructure and fast public transport services. In a second ring there are other regional centers (such as Lübeck, Lüneburg, Schwerin) with 75.000 - 200.000 inhabitants with their own commuter catchment area as well as smaller rural counties with low population density (yellow areas), few jobs and a high share of long distance commuters, who have to drive every day more than 50 km to work and 50 km back.

In Central Hamburg walking and public transport are the most important modes, while in the suburban and rural counties the privately owned car is the dominant mode of transport. The average distances travelled by car are half as long as in North American Metropolitan Areas, but vary heavily between central locations, suburban, and rural areas.

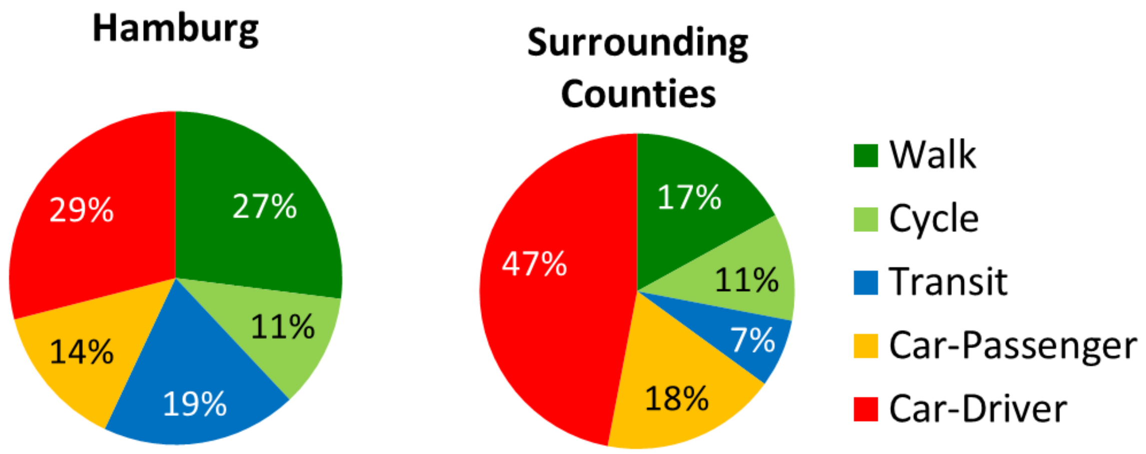

Figure 4: Modal Split in the Study Area (Source: HVV 2008)

Housing prices in Hamburg are very high in comparison to other German cities. Rents of apartments in the inner neighborhoods have been rapidly increasing during the last years to a level of 10-15 € per m² and month. Higher real estate prices can be found in neighborhoods along the River Elbe and around the Lake Alster. In many formerly working class neighborhoods, gentrification processes can be observed which leave the areas unaffordable for lower income groups. Real estate prices decrease in the suburbs with growing distance away from Hamburg. In outer suburbs, house prices have remained stable during the last 10 years or have been falling. (LBS Bausparkasse Schleswig-Holstein-Hamburg AG 2011). In rural areas (except for touristic areas), a large share of vacant houses can already be observed.

2. Rising energy prices: What effects are expected in the next decades on land use and mobility?

The population in Germany is aging rapidly. This trend manifests itself in rural areas and in the suburbs, which have been built in the 1950s until 1970s with a high share of population over age of 65 years. Hamburg's inner neighborhoods profit by in-migration of young households from other regions looking for jobs in the service sector.

2.1 Possible effects on Spatial Development

With increasing energy prices, we expect that the previously depicted effects of demographic changes on housing markets will be intensified:

Increasing costs of heating will affect particularly rural areas and suburbs from the 1950s -1970s, which have been built with low energy standards as well as moderate rent-neighborhoods which have not yet redeveloped in a different way.

The suburbs from the 1950s-1970s are often very automobile dependent with poor accessibility by public transport. We expect their attractiveness for new residents to decrease along with rising fuel prices and heating costs, resulting in high vacancy rates, when the comparatively old population vacates many houses in the next decades.

Particularly commuters living in such areas will possibly be in search of new flats in areas in the vicinity of their workplaces. This might lead to further increase in real estate prices in the central neighborhoods and raise the pressure to redevelop buildings towards higher standards (not only higher energy standards but in general greater comfort).

Low income households, living today in well accessible neighborhoods (or young in-migrators who have traditionally been moving to these neighborhoods) cannot afford these neighborhoods anymore and are forced to search for cheaper houses and apartments in the outer suburbs. There they find cheap housing, but with higher heating costs and poor accessibility without privately owned cars. They have to own one (or a second-hand one, if they can afford it) - or if not, spend more time commuting and reduce that way their time for other activities.

2.2 Possible Policy Interventions

Some possible policy interventions can be categorized into subsidies/tax, transport policy, and land management policies:

Subsidies and Tax Policies

Subsidies for Commuters (commuter tax allowance)
Subsidies for fuel efficient vehicles/electric cars
accommodation allowance
subsidies for refurbishing
regulation of rents in order to counteract the gentrification effects

social housing programs
adjustments in the energy pricing policies
subsidies for technological innovation for the automotive industry

Transport policy

upgrade of commuter rail, new light rail, orbital rail, bus rapid transit to improve accessibility
new road infrastructure to improve accessibility of suburban and rural areas and reduce travel times and congestion in the peak hours
transport demand management measures (like parking regulations, congestion charges and others) to relieve congestion in the inner neighborhoods

Land Management

- suburban municipalities try to attract new households and companies to safeguard infrastructure (such as the local school) and to increase local tax revenues
  under strong competition between municipalities and low demand for new housing this will pay off only for few municipalities
- coordination of land use policies in order to promote a better job-housing-balance at the metropolitan level
- prevent urban development at automobile dependent locations
- foster urban development in central locations
  - as brownfield/waterfront development, which raises conflicts with the harbor development
  - as infill development in the consolidated urban areas in Hamburg and the mid-level centers, which might provoke conflicts with neighbors who disapprove higher densities
  - as greenfield developments in the remaining open spaces in Hamburg, conflicting with nature preservation issues

This list of expected effects of rising energy costs and possible policy responses shows, that the land use and transport system includes rather complex feedback mechanisms and that there are no simple solutions for a sustainable land management. Therefore, the LUT-Model has to capture these complex interactions. It should be sensitive to various policy interventions and provide useful information for stakeholders to assess their impacts on different areas of interest.

3. LAYOUT OF AN INTEGRATED LAND USE/TRANSPORTATION MODEL FOR THE HAMBURG METROPOLITAN AREA

Integrated land use and transport (LUT) models have been developed since the 1970s in various parts of the world. An overview on LUT-Models can be found in (Wegener and Fürst, 1998), (Torrens, 2000), (Wegener, 2004). In Germany there are only two applications known - a model for the Dresden Region by (Rümenapp *et al*., 2004) and the “IRPUD-Model” for the Dortmund Region by (Wegener, 1998), (Beckmann *et al*., 2007).

The methods shifted from macroscopic general equilibrium models towards more behavioral oriented agent-based micro simulations of synthetic households and firms. (Wegener, 2009) points out the challenges for micro simulation models.

3.1 Basic outline of the €LAN-model

For the €LAN-Model for the Hamburg Region, work has started on an integrated model, that simulates the location and mobility decisions of synthetic households and persons. The model shall be able to represent the various possible policy interventions, including subsidies and taxation, transport and land management schemes. It will link the tax benefit micro simulation model *FiFoSim* (Peichl and Schaefer, 2009) to a micro simulation of synthetic households, firms and land use and a hybrid macro/micro-transport-model.

As the focus of the model is to simulate the impacts of price variations on location and mobility decisions of various household types, the household budget for mobility and housing is a key element of the model. It is assumed that a household generates an income resulting from work, property and benefits, e.g. social welfare from the state. Expenses for taxes and social security/insurances are subtracted from this total income. The resulting net income is spent for mobility and housing. The remaining income can be spent for other consumption goods and services or can be saved.

When energy prices increase, the remaining income is reduced. The lower the remaining income, the higher the "pressure" for the household to adapt its behavior, e.g. by choosing cheaper modes of travel, increasing the amount of weekly work hours or searching a home closer to work or a job closer to their home.

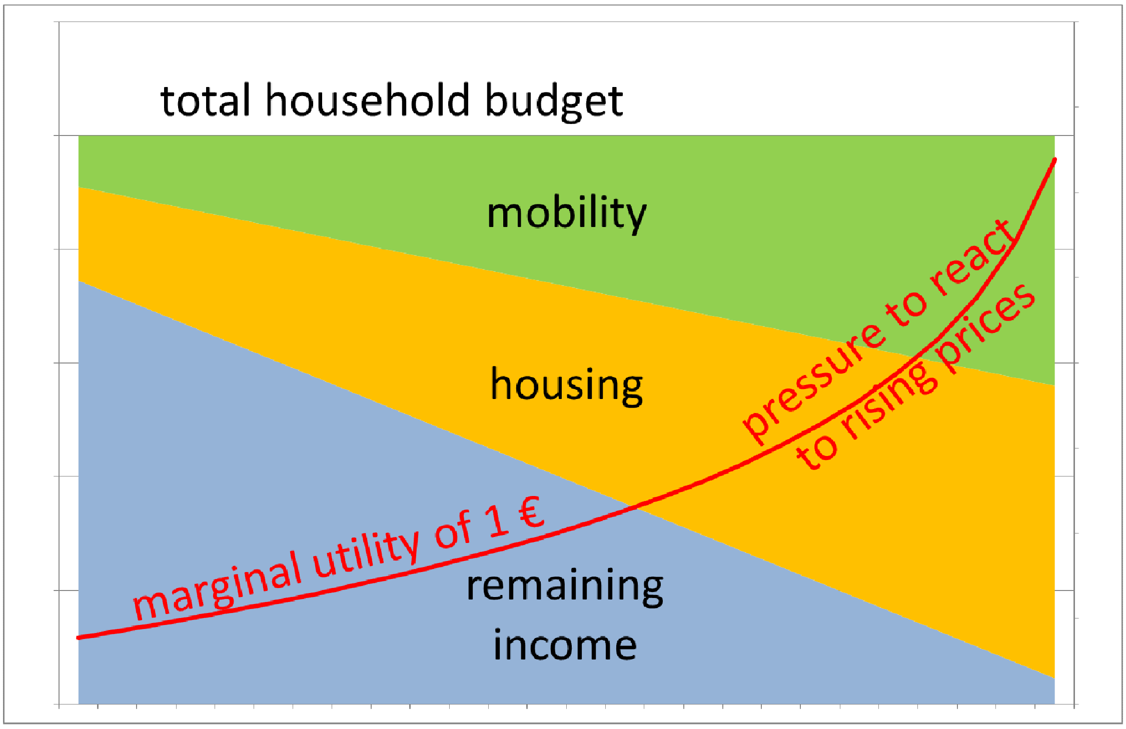

Figure 5: Energy Prices, Expenditures, "Pressure to react" and marginal utility of income

The model will simulate demographics, firm development, the labor market, location decisions, real estate market, land use changes on a micro-level, but taking the macro-economic adjustments on the labor and real estate market into account. The transport model is a hybrid model mixing a micro-level simulation of car-ownership and commuting with a macro model for traffic generation, distribution and mode choice for activities other than work and education. Commercial traffic is also modeled and simulated in a macroscopic model. The traffic assignment is static on a macroscopic level. Its focus is to provide travel times and costs used for the calculation of accessibility indicators. Finally, the Finally, the financial model will calculate detailed net incomes for each household and estimate the tax revenues for the different local, regional, and national authorities. Figure 6 shows the overall structure of the model.

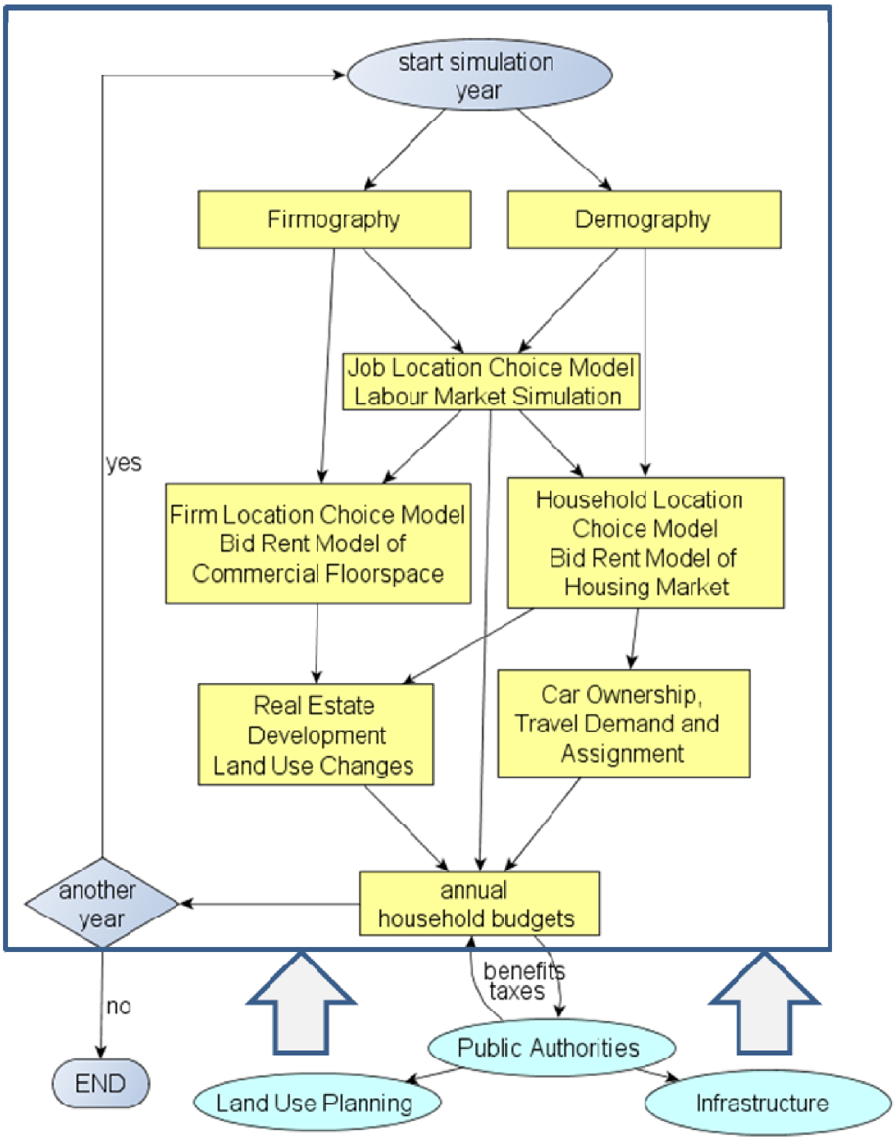

Figure 6: Model Structure

Input from the strategic simulation game is fed in by “translating” the proposed policy responses in the fields of taxes and subsidies, infrastructure, or land use planning into “inputs”, that the land use and transportation model can “understand”.

It is foreseen to calibrate the model for the base year 2010 and to run the sub-models in yearly steps until 2035. It might be sufficient to run the traffic assignment only every 5 years, because accessibility changes slowly over time.

It is planned to use the Open Platform for Urban Simulation (OPUS), developed by (Waddell *et al*., 2005) and various of the UrbanSim-submodels, but adaptions to various models to the requirements of the €LAN-project and the specific German situation regarding data availability, land use regulations, location and mobility preferences, and the labor and real estate market is necessary, which differ significantly from North American context in various aspects.

In the following chapters some of the submodules, including the data sources used in the submodules, will be explained further in detail:

3.2 Population, Firm and Building Synthesizer

The integrated land use and transportation model shall represent the transformation processes of land use and buildings in the next decades, which is shaped by individual decisions of households and firms. For this purpose, synthetic households with the corresponding household members and synthetic firms offering jobs have to be located into buildings with the corresponding residential and commercial units.

Due to limited data availability and privacy concerns, no data of “real” households and firms are used. Instead synthetic households and firms are generated and located in the study area in a way, that known marginal attribute distributions at the level of municipalities and urban districts are met, and that the small scale land use distributions is represented in a reasonable way. The iterative proportional fitting method used in other projects (Guo and Bhat, 2007, Hobeika, 2005) is not feasible in the German context due to outdated census data. Instead, we are using, similar to (Moeckel *et al*., 2003) various data sources to generate the synthetic population:

We randomly draw households and persons from the German Microcensus (an annual 1% sample survey of the German population) and enrich these households with additional socio-economic attributes from other national micro-datasets: German Socio-Economic Panel GSOEP (Hobeika, 2005), the household budget survey EVS (Statistisches Bundesamt, 2010), and anonymized national tax data (FAST, see Peichl and Schaefer, 2009). They are iteratively distributed in the study to municipalities and districts, where marginal sums and age distributions are known from official register data. In order to further distribute these households to a small scale level (synthetic buildings in 1-hectar raster cells), land use data (Meinel, 2008) and micro-geographic household data of a commercial data provider (infas Geodaten GmbH, 2010) are used. As quality, reliability, and time-reference of these data sources varies significantly, no “perfect” representation of the real population can be generated. However, we put effort on generating a synthetic population of households with consistent patterns of socio-demographic and economic attributes, that meets the (relatively) reliable marginal sums on municipality level, and that is distributed in a plausible way into synthetic buildings at the raster cell level. The energy demand of buildings can be estimated using attributes such as age of building, building type, floorspace, and condition.

While there are reliable data on the number of jobs by economic sector for each municipality, there is no official information below the municipality level. For the small municipalities in the suburban and rural area this is not a big problem, but distributing the 1 Million jobs within the City of Hamburg quite a challenge. For that purpose, we used different commercial databases, which provided information on the number of firms by sector, categorized by size. However, for larger firms this information had to be double checked, because often all branches of a company were registered at a single address, resulting in non-realistic job densities for some areas. So, the number of jobs has to be balanced with the available floor space at a certain location.

3.3 Household Relocation and Residential Location Choice

Household location choice will be modeled in three steps:

First, the household relocation decision is modeled as a binary choice (stay or search new apartment). Besides the demographic triggers (change of household composition) and job-related reasons for relocation decisions, increasing housing, energy, and commute costs can reduce the remaining household budget and push the household to find a home that is cheaper, has lower energy costs and/or where the household has lower mobility expenditures. Parameters for the household relocation model will be estimated using the German Socio Economic Panel.

Second, the household defines search criteria for the new home. This includes attributes of the new home (size, building type), a maximum price, and a search area which is determined by the current residential location (often the focus of the household's social network), the work location(s) of the household members, and accessibility to infrastructures relevant for the household type. To represent accessibilities by various modes of travel taking car availability into account, utility-based accessibility indicators from the travel demand model can be used.

Third, supply and demand are balanced using a bid rent model: For a simulation period (e.g. 1 month) a household is offered randomly e.g. 5 homes from within its search area that meet its defined requirements. For these homes a utility is calculated taking accessibility, housing attributes, and prices into account.

If there is more than 1 potential buyer or tenant, the unit is offered to the applicant with the highest utility value for that house. If a household gets more than one acceptance, it chooses the offer with the highest utility and relocates in the next month, vacating the current home. If a household is accepted in no house, it has to search again in the next simulation month. In that case, he might adapt its search criteria and search a house which doesn't exactly suit his “dream house”: He might accept a smaller home in a worse location or with lower accessibility, or - if the household budget allows this, a more expensive home or a home with more expensive commuting costs.

There are many surveys on housing preferences in Germany, asking which parameters (housing attributes, neighborhood attributes, and accessibility) were decisive for their location decision. But in order to fully understand this process of search and adaption to the reality, a survey is planned to be carried out on recently relocated households in different areas. They will be asked explicitly for their search criteria, their search area, which will be related to their current home and their job locations, and if and how they adapted their search criteria until they found a new apartment.

3.4 Real Estate Market and Land Development

Residential units that did not find a new buyer or tenant remain empty, until they are sold or rented. At the end of the simulation year, real estate owners can adapt the prices they claim for a unit, according to the market situation. If a house (or other houses in an area) are not sold or rented for a long period of time, prices will fall. If there are many households applying for a house in an area, landlords/vendors will increase prices in the next year as far as price regulations allow.

In a raster cell, existing houses might be upgraded to higher standards, energetically upgraded to reduce the costs for utilities or demolished and replaced by new houses. Units might be converted from residential to commercial or vice-versa. Depending on the net densities allowed by the land use regulations, in a raster cell, new residential or commercial floorspace is allowed to be built.

In order to simulate the development of the building stock, at the end of each year for all houses and raster cells a potential development value is calculated. This is done by estimating a hedonic real estate price model using on the “virtual rents and sales prices” from the last year. With the estimated parameters for house attributes, neighborhood attributes and accessibility for all houses a “potential development value for various development options” is calculated. If the construction cost for new units of a permissible type (including the costs for demolition and/or site development) is lower than the potential development value for that unit, and demand for that unit type can be observed in similar areas in the last simulation periods, developers are assumed to build new units.

Finally, average land prices are derived from the potential development values in the areas, varying by location and permissible land use.

3.5 Travel Demand Model

The travel demand model will use a hybrid approach of a microscopic simulation of car ownership and commute trips, a macroscopic, activity-based demand model for other trip purposes, and a macroscopic assignment.

For each worker, the place of work (or education) is determined by the labor market sub-model. The household’s car ownership and the commuters’ mode choice decisions are modeled jointly: For each commuter, the utility to choose a mode of transport for the commute trip is calculated and the logsum accessibility indicators for persons with or without car availability derived. Then household car ownership probabilities are modeled taking the workplace accessibility with and without cars into account. Finally, a monte carlo simulation determines the number of cars the household owns and, conditional upon the resulting car availability, the modes of transport for the commute trip(s) (Ben-Akiva and Lerman, 1985, Bohnet and Gertz, 2008).

A further sub-model should then model the type of the cars (size, engine type) owned by the household. Household composition, income, commute distances, average operating and fixed costs will be taken into account. For the future scenarios, assumptions on the development of operating and fixed costs for new vehicle types such as electric cars have to be made.

For other activities, we decided not to use a microscopic travel demand and assignment model in order to cut computation times and stochastic variation. Instead, a macroscopic activity-based demand model is used. Trip chaining is integrated, making the location of secondary activities depend upon the workplace location and the mode chosen for the commute trip (Rümenapp and Steinmeyer, 2007). The resulting demand matrices will be assigned to the road and public transport using the VISUM software The Linear User Cost Equilibrium (LUCE) assignment method (PTV AG, 2010: 937) provides reasonable computation times in large networks.

In both the microscopic and macroscopic travel demand models, travel times, travel costs, and other factors such as ‘transfer penalties’ are aggregated to generalized costs. In order to relate travel times to travel costs, we decided to derive values of travel time savings (VTTS) from a recent Swiss study (Rapp *et al*., 2007) according to income group and mode.

Finally, for each synthetic household the monthly mobility costs are calculated, summing up car ownership costs, the operating costs for commute trips, and average operating costs for other trips.

4. OUTLOOK

In the next month, parameter estimation for the various sub-models will be carried out, and the transport model being calibrated. The household location choice survey is foreseen to be carried out in fall 2011. So we hope to be able to test the overall land use and transport simulation running sensitivity tests in the first half of 2012.

The strategic simulation game with the stakeholders will start then in mid 2012. Even when we try to anticipate all kinds of possible policy responses to rising energy costs, the stakeholders participating in the strategic simulation game might come up with new ideas, which might require further adaptions into the model.

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