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E-Mobility in Urban Areas and the Impact of Parking Organisation

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Abstract: In this paper we explore the preconditions and requirements in order to enable the renewal of the vehicle fleet towards e-cars without weakening eco-mobility (public transport, biking, walking). We follow a linked approach of arranging charging infrastructure and regulating the parking spaces. We analyze the results of this approach by modeling different scenarios for the case study city of Vienna with the LUTI (land-use transport interaction) model MARS (Metropolitan Activity Relocation Simulator). Four different policy scenarios are modeled and the results compared. We look at changes in transport behavior (modal split and vehicle kilometers), the emissions and the impact on public transport ridership.

Key words: E-mobility, parking organization, modal split, dynamic modeling, human behavior.

1. Introduction

E-mobility is currently facing a promising boom, which readjusts both the requirements and possibilities of organizing a future transport system. The chances of individual e-mobility to reach certain transport policy goals are obvious – minor dependency on fossil fuels and the reduction of greenhouse gases and air pollutants. However, lower user-specific operational expenses, exceptions from environment-based cordons of certain classes of vehicles (low-emission-zones, etc.) and the omission of "environmental reasoning" for certain user groups can lead to counterproductive system effects and a net-growth of private motorized transport (PMT). Various urban administration authorities have set themselves objectives such as the strengthening of public and non-motorized transport.

We show which kind of organizational structures are necessary to enable the renewal of the vehicle fleet towards e-cars without weakening public transport, cyclists and pedestrians. We describe and present four different scenarios which were influenced by different transport policies.

Corresponding author: Harald Frey, Dipl.Ing. Dr. Research fields: feasibility studies, transport modelling and the interdependency of transport and settlement structures.

2. Method

The analysis was carried out with three models. Two models (SERAPIS) served for calculating the fleet composition for conventional, hybrid (in the following named as cars) and electric vehicles (e-cars) for the city of Vienna and the hinterland.

SERAPIS (Simulating the Emergence of Relevant Alternative Propulsion technologies in the car and motorcycle fleet Including energy Supply) is a dynamic model that simulates the fleet development, the shares of the different propulsion technologies, hence the demands for the electricity economy and the potentials for reducing CO_2-emissions.

With the transport-land use model (MARS) the traffic behavior in the model region was simulated. The MARS (Metropolitan Activity Relocation Simulator) model was developed at the Research Center of Transport Planning and Traffic Engineering at Vienna University of Technology [1]. It is a Land-Use Transport interaction model which simulates the mutual interactions between the land-use and the transport system [2-4]. The model zones from the model described in this paper cover the

23 Viennese districts and the Vienna hinterland.

The MARS model was connected to SERAPIS via two variables: the operating costs, calculated in MARS, served as input variable for the SERAPIS models; and the fleet development as an output of SERAPIS served as input for MARS.

The data basis covers demographical data for the case study area, transport relevant data (level of motorization, modal split, etc.) and transport policy goals.

3. Scenario Overview

Beside the extrapolation of status quo and existing trends of relevant traffic indicators (Business as usual - BAU), we designed three different transport policy scenarios (E-car, Equidistance, Equidistance + E-car). The background scenarios cover the development of crude oil price and subsidies for e-cars as well as different fleet developments for e-cars which are the basis for each scenario. We combined the transport policy scenarios with different background scenarios in order to define and model four policy runs.

Table 1 shows the assumptions for our four scenarios (subsidies for e-cars, transport policies).

3.1 Background Scenarios

In this paper we assume a progressive increase of the crude oil price until the year 2030. Compared to the base year 2010 the price will double. Our assumed

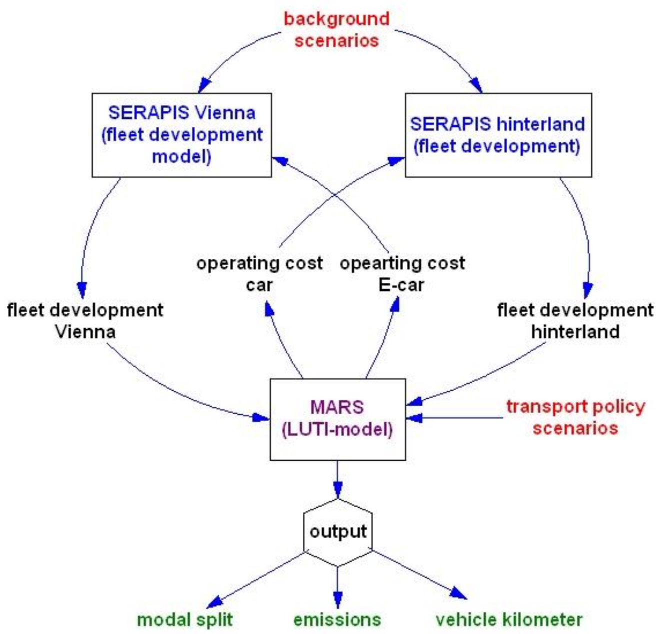

Fig. 1 Links of the three models and external input.

Table 1 Scenario setting in Vienna.

Scenario			BAU	E-car	Equidistance	Equidistance + E-car
Sub-sidies	**funding for e-cars**	low	X		X	
		high		X		X
Transport Policies	**density of charging stations**	low	X		X	X
		high		X		
	availability of public parking spaces	low			X	X
		high	X	X		
	parking fees for e-cars	yes	X		X	X
		no		X		
	fuel duty	low	X	X		
		high			X	X

crude oil price development was compared with several studies [5-10] and projects and for the two scenarios (BAU, E-Car) the fuel duty equals the level in the year 2010 in Austria (0.43 EUR/liter for petrol, 0.30 EUR/liter for diesel) and remains constant. In both equidistance scenarios the fuel duty increases constantly over time up to +30 % in the year 2030 (0.59 EUR/liter for petrol, 0.41 EUR/liter for diesel).

We differentiate the level of subsidies for e-cars between the E-car and the Equidistance scenarios. In the E-car scenario the subsidies increase rapidly in the first year to 5,000 EUR/vehicle and then decrease until the year 2021. Further we distinguish between the development of the gross and net purchase prices of e-cars. The net purchase price does not regard differences by sales tax, engine related insurance tax and standard fuel consumption tax.

4. Transport Policies

We modeled four different transport policy scenarios varying in the following parameters:

1. Spatial arrangement of the charging infrastructure and parking places for e-cars.

2. Walking time from trip origin to the charging stations, respectively the parking place.

3. Parking fees (level and location).

5. Fuel duty for diesel cars and gasoline cars. E-cars are excluded.

Each scenario was calculated separately for e-cars and cars for the case study area of Vienna and its hinterland.

4.1 BAU Scenario

The BAU scenario extrapolates the current development. No massive infrastructure changes are considered. The charging infrastructure for e-cars in Vienna is organized in collective parking garages with a low density (<5%). Charging infrastructure in public streets is not provided in this scenario. In comparison to conventional cars the walking time to charging & parking places for e-cars is therefore very high (~5 min.). Both, e-cars and conventional cars need to pay inner city district parking fees. In the Urban Hinterland the private car is easily accessible. The scenario is based on the fact that in the surroundings of Vienna people can park and charge their car nearby their house or their apartment. The access time is short (about 0.5 minutes).

A lot of detached houses have their private parking place (minimal walking time to the car) and most of the communities have no parking fee.

4.2 E-car Scenario

The E-car scenario is based on a strong increase in the density of charging infrastructure in public spaces in Vienna (>30%). Therefore, the walking times from trip origin to the charging infrastructure alternatively to the parking place for e-cars is equal to the access time for cars (~1 min.). Parking for e-cars is free (the parking fees in parking garages are reduced) and no taxes similar to the fuel tax are levied. The parameters for the Vienna Hinterlands remain similar to the BAU scenario.

4.3 Equidistance Scenarios

4.3.1 Principle of Equidistance

Pedestrians act in their walking behavior according to a certain function of attractiveness [11]. Short walks offer 100 % attractiveness, longer walks have far less. Pedestrians assess time subjectively and therefore value their walks considering their surrounding areas.

Walther [12] found, that the access walks of pedestrians to public transport stops, and the access and egress times to parking places of cars play an important role in transport mode choice. Humans do not perceive an increase of the access or the egress time linearly but exponentially. The longer these access and egress paths are, the manifold they are perceived.

If it is possible to park a car in the basement parking garage of one’s house, or in the public space directly in front of one’s home or work, the car presents a 100 % attractive accessibility. A public transport stop 400 meters away holds less than 20 % of attractiveness in inner city surroundings. Thus people are going to prefer their car, if somehow possible.

To create equal opportunity conditions between car and public transport equidistance between the parked car and the next public transport station of for all activities is necessary.

Cars and other PMT (private motorized traffic) need to be parked in centrally organized parking garages distributed over the city, resulting in at least a distance equal to the distance of frequently operating public transport stops.

4.3.2 Equidistance Scenario

In the Equidistance scenario the charging and parking for e-cars and parking cars are organized in collective parking garages. The charging infrastructure for e-cars is provided in collective parking garages (>5%). Thereby the access time (walking) is increased for conventional cars to 3 minutes in the city equal to e-cars in this scenario.

There is a commercial control over parking space area-wide in Vienna. Parking fees for cars are increased until 2020, have to be paid city-wide and are also compulsory for e-cars.

The fuel duty is increasing over time until the year 2030 (+30 % of the base value). but is not assigned to e-cars. A similar energy consumption tax for e-cars is not implemented. The conditions for the Hinterlands do not change to the previous scenarios.

4.3.3 Equidistance + E-car Scenario

There are two major differences between the Equidistance and the Equidistance + E-car scenario:

1. The number of e-cars in the system is higher due to higher subsidies.

2. The organizational form for parking/charging space is equal (collective parking garages) but more garages are equipped with charging possibilities in this scenario (>30%).

The other settings remain the same.

5. Evaluation of the Results

The scenarios were modeled under consideration of the transport policy goals of the city of Vienna for the year 2020. The Vienna transport master plan defines the following modal split objectives for Vienna in the year 2020:

- Reduction of PMT trips to 25 % of all trips.
- Increase in bicycle share to 8 % as quickly as possible.
- Increase in public transport share from 34 % to 40 %.
- For commuting flows from the Vienna hinterland the distribution between public transport and PMT should shift from 35 % / 65 % to 45 % / 55 %.

6. Results

We analyzed the results of the scenarios concerning the changes in transport behavior by looking at the changes in modal split.

6.1 Changes in Transport Behavior

The scenario E-car shows no relevant change in transport behavior compared to the BAU scenario. Some car user switch to e-cars, but the share of public transport users, pedestrians and cyclists stays constant. The sole increase in funding of e-cars without changing the organizational structures for parking does not change the modal split very much (see Figure 2).

The scenarios Equidistance and Equidistance + E-Car show crucial changes. Figures 5 and 6 depict the modal split for the year 2020 and 2030 in Vienna. The combination of equidistance with an increased funding of e-cars is the most effective way of changing transport behavior.

The modeled measures in these two scenarios also enable the achievement of the transport political objectives of Vienna. Basically shifts from car to public transport occur.

The picture looks different for the in-commuters. Many people living in Vienna’s hinterland have the possibility to park their car or e-car near their home respectively on private ground. Due to the policy that only destination locations in Vienna include a charged parking organization the modal split changes are modest (see Figure 3).

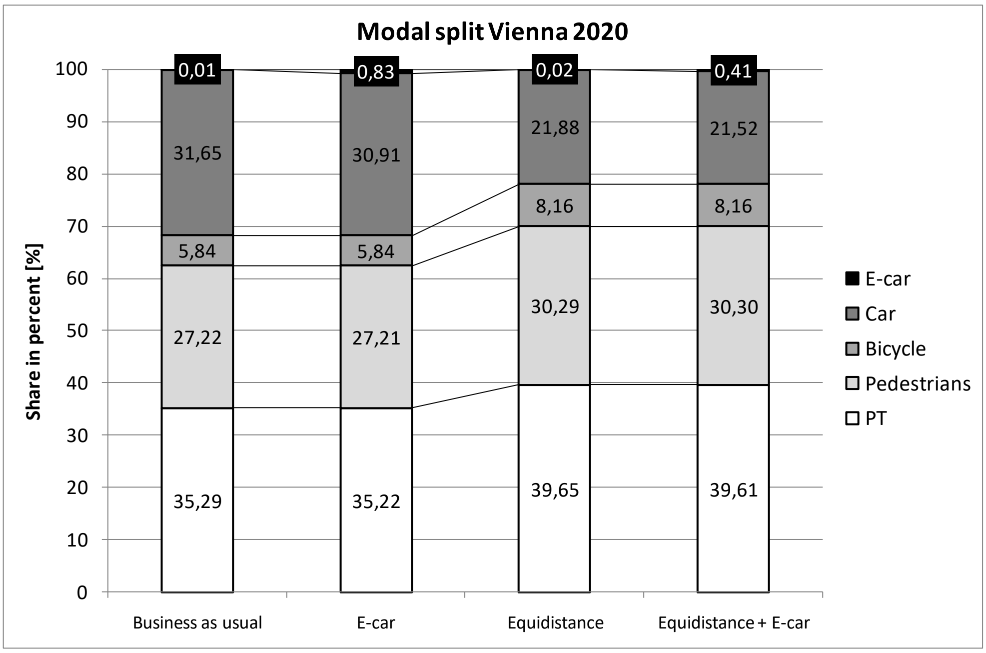

Fig. 2 Modal split Vienna 2020 - comparison of the scenarios.

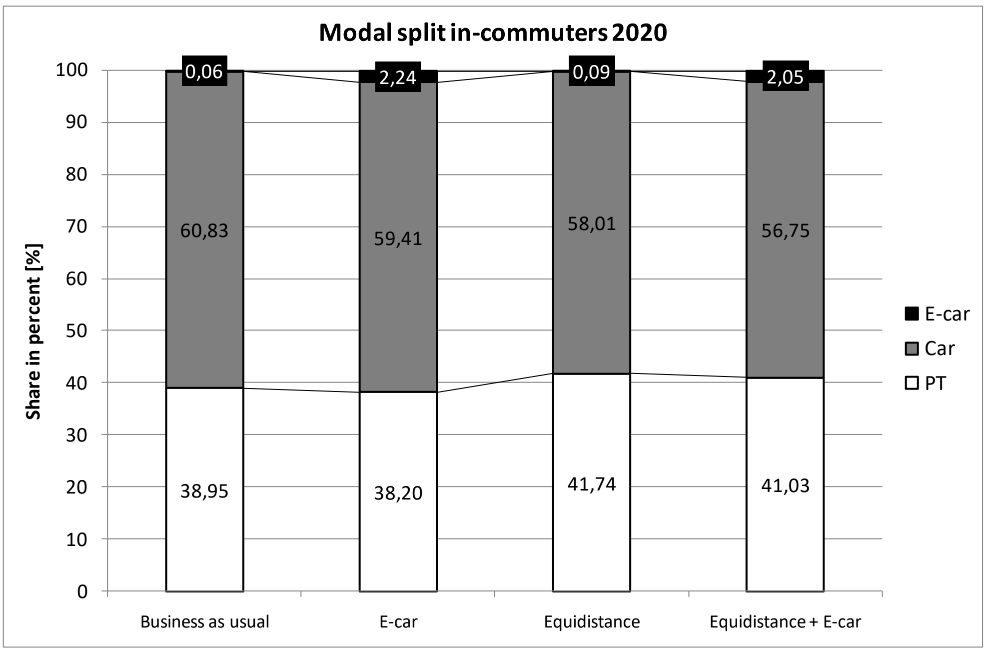

Fig. 3 Modal spit in-commuters 2020 - comparison of all scenarios.

6.2 Emissions

Table 2 shows the reductions of vehicle kilometers, NO_x and CO_2 emissions in the year 2020 compared to the BAU scenario. As can be seen the most effective scenario in terms of reducing these emissions is the Equidistance + E-Car scenario. In Vienna more than half of the primary emissions can be reduced in this scenario.

6.3 Impact on Ridership in Public Transport

Whereas the ridership in public transport increases in the Equidistance scenario in Vienna as well as in its hinterland the percentage decreases in the hinterland in

Table 2 Vehicle kilometers, NO_x and CO_2 emissions in the year 2020 compared to the BAU scenario.

Reduction of vehicle-km, NO_x and CO_2 emissions in the year 2020 in relation to the BAU scenario [in %]			
	E-car	**Equidistance**	**Equidistance + E-car**
Veh-km Vienna	-2.1	-29.3	-30.4
Veh-km in-commuters	-1.7	-6.6	-8.2
NO_x Vienna	-16.4	-31.2	-41.6
NO_x in-commuters	-15.9	-8.1	-22.0
CO_2 (total)	-3.8	-14.9	-17.9

Table 3 Ridership in public transport changes for the 3 policy scenarios.

Increase/Decrease of ridership in public transport [in %]			
	E-car	**Equidistance**	**Equidistance + E-car**
Vienna	-0.2	2.0	2.0
Hinterland	-4.4	1.2	-2.5
Total	**-1.5**	**1.7**	**0.5**

the scenario Equidistance + E-car. The massive one-way advancement of e-cars (near parking places and charging stations) has negative effects on the transport policy goals and takes effect especially in the car-oriented suburban areas of the city. The promotion of car-traffic and infrastructure for cars decreases the ridership in public transport. In the city of Vienna these negative effects can be diminished because of the parking organization based on the principle of equidistance.

7. Conclusion

We show in this paper that the one-way promotion of e-cars contradicts the transport policy goals of the city of Vienna. The results can be applied for other cities which plan to organize traffic in a more efficient and sustainable way. One of the key measures to strengthen the modal split of non-motorized traffic and public transport lies in the parking organization. As soon as car drivers have to park their cars in collective parking garages a more equitable choice of means of transport is possible. The principle of equidistance and collective garages fits perfectly into the requirements for a livable city structure. E-cars are able to support these needs as far as the charging infrastructure is allocated in central parking garages and not in public space. Structures which permit short access and egress times to the car, promote PMT. Some negative effects of fossil fuel powered cars, like carbon dioxide emissions, can be reduced by e-cars. The problems of congestion, use of space, energy consumption and accidents cannot be solved by e-cars. In order to benefit from e-cars without counterproductive effects, an implementation of charging infrastructure under consideration of the principle of equidistance is necessary.

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