Evaluating Options of Viennese Commuters to Use Sustainable Transport Modes

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***Abstract*—The 2-degree guardrail of global warming, together with accelerating urbanization and growing scarcity of oil, demands a redesign of todays' sprawling cities in order to limit greenhouse gases and bring about efficiently built-up structures. In 2001, 42 percent of commuter paths within Vienna are traveled by private cars. This week-daily, recurring traffic pattern causes tons of Co2 and supports low-density housing at urban fringes. In front of this background, we employ an agent-based simulation model to evaluate if commuters in Vienna who currently use motorized modes (especially car-drivers) have options to change to low-carbon transport modes (pedestrian, bicyclist, public transport) without raising costs of travel time. Using a detailed network, the identified present and alternative routes can be displayed as edge-, node-, or zonal through-traffic, highlighting differences in transport mode usage throughout the city.**

Keywords-commuter traffic simulation; multi modal transportation network; sustainable city; agent-based modeling

I. INTRODUCTION

Economic life in cities today stipulates employees commuting to their workplace (and back again) at rush hours. A commuter is a person who doesn't work at his/her residence, but rather leaves it for their workplace, adopting a week-daily spatial-temporal rhythm. The traffic load caused by these daily paths, irrespective of transport mode, is called commuter traffic. With regard to sustainability aims, bicyclist traffic and pedestrian circulation are transport modes of zero carbon emission. Public transports' usage of fossil fuel causes greenhouse gases, yet compensates these by high rates of passenger occupancy, less overall space for infrastructure and hierarchical service line organization. On the contrary, automobile transports' low occupancy rates cause extensive energy consumption, high output of toxic emissions [1] and long-term effects on land-use allocation [2], i.e., urban sprawl. For example, workplace locations tend to agglomerate while residential locations tend to spread out [3]. Vienna clearly exhibits this pattern, which one of our spatial analysis, based on finely grained statistical data (2001: Statistics Austria, retrieved: July, 2013) has shown. Thus, todays' patterns of private car commuting are a mirror image of cheap oil availability and low restrictions to built-up densities in past urban planning decisions.

If the 2-degree guardrail of global warming, agreed upon in Cancun 2010 [4], is to be taken seriously, a re-design of today's' cities, facing accelerating urbanization until 2050, is crucial. This re-design has to involve both re-densification and reduction of traffic-related emissions, because land use and transportation are a closely intertwined system [5]. In this paper, however, we focus on evaluating status-quo commuters' possibilities to change to "greener" transport modes than they currently use. The reason is that quicker adaptation to rising oil prizes [6] can be expected in the domain of transport mode choice [3].

First, we introduce the utilized data and explain the motivation of our agent-based simulation model. Next, we describe the details of our shortest-path algorithm and compare it to existing literature. Finally, we will discuss benefits and weak points, unsolved issues and future work.

II. MODEL DESCRIPTION

A. Data Description

In a preliminary study [unpublished], district-wise census data (from 2009: Statistics Austria) on commuters who live and work in Vienna, distinguished by the transport modes pedestrian, bicycle, public transport and private car (2001: Statistics Austria, retrieved: July, 2013), were used to build a commuter model. Holding modal split equal, commuter relations were spread to the level of 281 sub-districts, using the weights of employee and workplace distribution, both taken from the Viennese Transport Model of the City of Vienna [7]. Furthermore, this model provides separate GIS transport networks (pedestrian, bicycle, public transport, individual transport), each consisting of nodes and directed edges. In these, maximum speed limits and metric lengths are attributed to the edges (Figure 1).

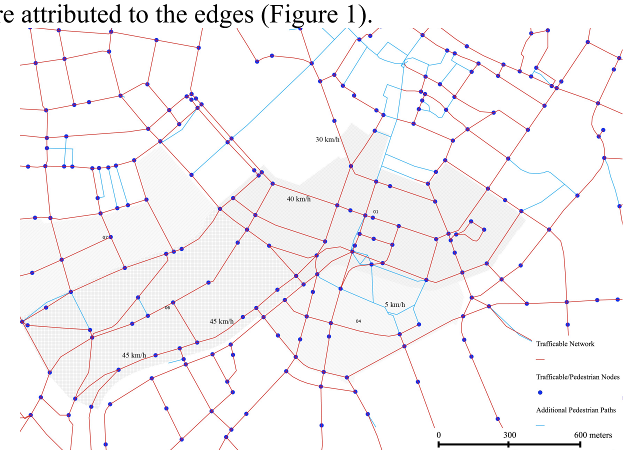

Figure 1. Networks of pedestrian circulation and individual transportation, for the latter examples of maximum speed are displayed.

B. Scientific Background

This information enables us to calculate basic travel time necessary for passing an edge, (travel time = metric length / maximum speed), while running the simulation. We use this indicator as weight during path finding. This way, we can highlight status quos' advantageous usage of fast lanes and highways in individual traffic and research if changes from, e.g., this mode to pedestrian circulation bring about either travel time rises or travel time savings for a single commuter traveling from one zone to another. Travel time is an important indicator in transportation science: being a function of speed and distance, fast transport modes have enlarged travel distance distributions to big amounts because time used for mobility is, on average, almost constant since years [8]. Thus, rising travel time durations for commuting, due to transport mode shifts, are unlikely to be accepted unless hard constraints in the form of monetary costs or regulations are employed. Vienna has recently introduced parking bans for non-Viennese residents, prohibiting surface parking for incoming commuters. Since then, regional trains are on overload. For Viennese residents, parking management has been established in many districts too, partly forcing commuters to switch to other modes. However, our focal point is a precedent one: Can commuters' switchover to low-carbon transport modes be advantageous in terms of time-savings?

C. Model Design

The progression of our simulation model is as follows: in the first step, commuters are distributed to random vertices within their residential zones (source zones). These vertices need to belong to the networks initially required by the commuters, e.g., employees singularly using their private car are distributed to vertices of the individual transport network. Likewise, target vertices are selected in their workplace zones (destination zones). Using travel time on the respective network as weight for procession along the graph, the commuter now determines their initial shortest path, the total duration of which is stored. After all commuters have done so, we have our baseline model of shortest paths for the status quo situation in Vienna. Now, in our reallocation model, commuters try to optimize their baseline paths with regard to travel time by changing to alternative transport modes. Table 1 shows, which alternative modes are allowed for consideration for a current mode, indicating that switches to sustainable transport are preferable.

TABLE I. OPTIONS FOR SWITCHING CURRENT MODE OF TRANSPORT

Current Transport Mode	Allowed Next Transport Mode
Individual Transport	Public Transport, Pedestrian
Public Transport	Pedestrian
Pedestrian	Pedestrian

Concerning transport mode availability, this decision table is strictly logic: once a commuter has, e.g., abandoned his car to use public transport instead, he cannot use it anymore in his subsequent path [9]. Note that we have left out bicycle traffic in this study because its network is largely identical to the pedestrian network, except for higher velocities at the edges.

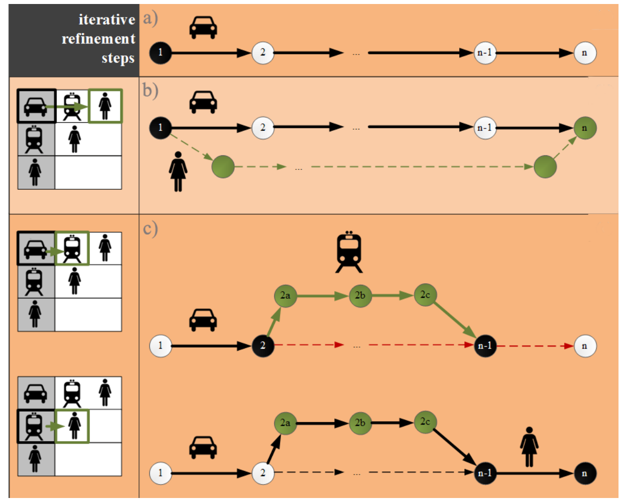

Figure 2. Decision process of a commuter in the reallocation model as based on Table 1.

Figure 2 shows a representation of the agents' decision process, evaluating their options of changing transport modes. Originally, the agent uses his private car (Figure 2a). First, they try to get to their destination by foot (Figure 2b), which does not result in travel time-savings. Consulting Table 1 for other allowed options (here: public transport), which are available at the 2nd node of their initial journey, they try again (Figure 2c). Taking this mode brings them to another current node. Looking up which other modes are available then, pedestrian mode is used to access their final destination node.

D. Model Execution

We have imported the GIS-network data, describe above, into a NETLOGO 3D model [10], extended by a plug-in for shortest path inquiry. Arrival data is loaded from spreadsheets obtained in the commuter model. Due to lack of data, arrival times could not be considered, thus, our simulation pictures rush hour traffic as an "interesting" time span. In detail, the simulation executes the following steps:

- For each agent using a current mode, there are allowed next modes.
- The agent evaluates mode switch options at a current node. It examines if there are alternative routes with the allowed next modes in the following manner: if there is a route with an alternative transport mode which meets the baseline route again, the agent changes his transport mode and takes this route (Figure 2). If the last current node is not the destination node, the agent iterates this process: it examines Table 1 again and takes one of the allowed next transportation means in order to arrive at his final node.
- Once the agent is at his destination node, the travel costs of the alternative route are compared to the

baseline route. In case there is a benefit, the alternative solution is accepted. In all other cases, the agent backtracks to the node at which the disadvantageous fork was conducted. It continues to the next node along the hitherto existing route and tries to switch transport modes again.

III. Discussion

Reviewing the preliminary outcomes of our promising work-in-progress research, there are the following issues, which deserve second thought:

- The given GIS-networks do not reflect reality in the minutest detail. Agents of our model may only change their transport mode, where the different networks (pedestrian, bicycle, public transport, individual transport) explicitly meet at nodes. The outcome is that less mode shifts are performed. The introduction of catchment areas would be useful to enable smoother transfers if, e.g., car-driving agents are in the surroundings of, e.g., public transport stops. This would facilitate better results towards mode shift options, while the networks themselves would not need to be extended.
- Additional information, like parking space, is missing, which poses a problem because agents may change to public transport as soon as a street node meets a station, regardless of the fact that there may be no parking space given. Yet, this specific information is altogether rare, looking at open data resources of the city of Vienna. Surface parking is generally widespread but is newly regulated and time-dependent in availability. Solving this task may be challenging for a multi-modal transportation simulation. For our aims and purposes, this level of detail is not adequate.
- It is inherent to models that reality cannot be depicted sufficiently. Our sub-district commuter model may only output travel times between zones as depending on randomly selected start or end vertices. Exact distribution of commuters within these sub-districts is unknown. Therefore, we cannot produce better results than our background data allows us to, concluding that a finer-level simulation is useless.
- So far, we did not consider time schedules or passage times in public transport; neither did we enable changes within this network itself due to complex model building, big data volumes and processing time. Especially for public transport, complex travel time is relevant [11]. It combines waiting times, changing times, egress times, travel time on board, etc. Egress describes the time needed to access public transport stations, i.e., a commuter has to walk from their residence to a station, wait for a train, get on the train, travel for some time, get off the train and finally, walk from the station to their workplace.
- In this research we meet the general problem if a multi-modal shortest path algorithm may produce "optimal" results. Service quality and quantity in Vienna is high, comprising of many different routes of almost the same trip duration. As said before, representing a highly advanced simulation like that is not our major goal.

IV. Conclusion and Future Work

Our work-in-progress contribution addresses interesting up-to-date topics in the field of sustainable urban planning as concerned with future needs for de-carbonization. Automobile transportation, widely used in commuter traffic today, obviously has some advantages as compared to public transport. These are: lack of egress, changing and waiting times, little to no body energy requirements, comfort, the option to store luggage and, most of all: constant, unscheduled availability while offering high speed travel. Automobile transport is very time efficient. Even more so, its manifold toxic emissions and its sprawling effects on functional, densely organized urban structures are at opposites with the imperative of restrictive environmental policies, necessary to avoid unpredictable global climate change. Therefore, our research is not aiming at solutions to technical optimization problems but rather poses the general question of what prize cities and their inhabitants would need to pay if seriously considering a major turn towards sustainability.

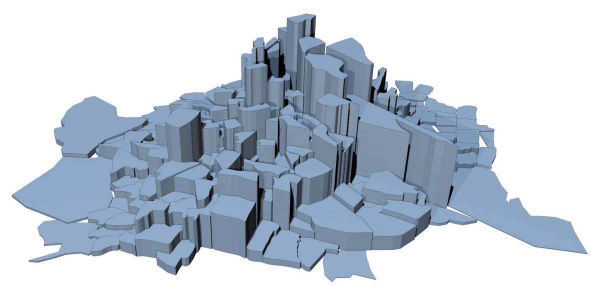

Figure 3. Utilization of the 281 zones of Vienna by automobile commuter through-traffic.

In Figure 3, the zones most frequently traversed by status quos' commuters using automobiles, are depicted by elevation. One of the main highways, passing Vienna from the middle-north to the southeast of its border, is clearly visible. The same utilization, elaborated for public transport users of our baseline model, would look quite different and, would be much more agreeable.

Our contribution offers a smooth application of the shortest-path algorithm as applied to a multi-modal transportation network under the premises of commuters switching to low-carbon transport modes. We can show a nice visual comparison of transport modes routes with regard to travel durations. Figure 4 shows an alternative path per

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public transport, found for a current route traveled by individual traffic. Accepting only mode shifts to less polluting transport modes, we highlight the solution space of de-carbonization in commuter traffic, already available today.

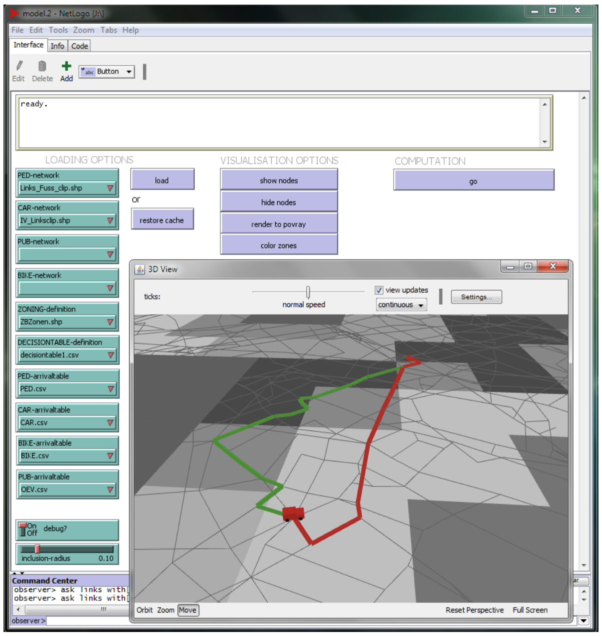

Figure 4. Utilization of the 281 zones of Vienna by automobile commuter through-traffic.

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