DUAL USE BICYCLE PATH NETWORK DESIGNING AND EXPLOITATION ENVIRONMENT - VELOROUTER

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ABSTRACT
One of the types of clean transport is cycling. In order to ensure the successful functioning of an integrated and intermodal urban transport system (Merkuryev, Zenina and Romanovs 2015) cycling has to be one of its natural components. Due to limited funding it is important to understand which bike path network would be more efficient and ensure the greatest possible population transfer from other types of transport to bicycles, because it is impossible to construct bike paths, racks and lease points wherever it would be desirable.

Keywords: bike path network design, occupancy simulation, multi-agent based models, VeloRouter

1. INTRODUCTION

Previous FP7-ICT-2011-7 FUPOL project No. 287119 (2011-2015) "Future Policy Modelling" (Ginters et al 2014; Aizstrauts et al 2014; Buil et al 2015) gave the opportunity to perform market research and understand the needs of potential users, interested in sustainable transport schemes development. The market analysis involves significant amount of objects. Among them would be mentioned Bikemap (http://www.bikemap.net), veloroutes.org (http://veloroutes.org), routebuilder.org (http://www.routebuilder.org) and EuroVelo (http://www.eurovelo.com/en). Similar products were Pro-Plan, Topo-Plan, Bike Node Plan (http://www.routeyou.com/route/routeplanner/overview_all/choose-the-route-planner-that-fits-your-needs), MapMyRide (http://www.mapmyride.com), CycleStreets (http://www.cyclestreets.net/about/), *plotaroute.com* (http://www.plotaroute.com), Flattest Route (http://www.flattestroute.com), Velomap.org (https://www.velomap.org), RouteLoops (http://www.routeloops.com) and several specialised route planners, for example for mountain biking BikeRouteToaster.com (http://www.bikeroutetoaster.com).
The bicycle route planner in the city of Bern Pro Velo Bern (http://www.veloroutenplaner.ch) is based on OpenStreetMap data. The proposed routes are generated automatically based on this data. The routing can be used all over Switzerland. Nevertheless, it may happen that the suggested route can't be driven all the way or that cycling is banned on certain sections. Based on the analysis implemented (Ginters et al 2013) and research mentioned above, it was concluded that existing cycling routes design and planning products mainly offer the capabilities of publishing and planning routes, but do not provide functionality necessary for municipalities to build justified bicycle path network, which is critical for sustainability of transport schema.

2. VELOROUTER CONCEPT

The multi agent-based bicycle path network and exploitation simulator (VeloRouter) is designed in the ABM/MAS Repast Symphony and uses OpenStreetMap spatial data. The product has dual applicability as it is adapted to both of audiences: the needs of municipalities and cyclists (see Figure 1).
The municipality is interested in some basic question: Is the offered cycling route map satisfactory? This is recognized by summarizing potential comments coming from "Cyclists" during the project deliberations "Requests". However the second question is: which potential cycling route sections should be built first? VeloRouter provides municipalities with bicycle path discussion and geofencing opportunities by receiving feedback from cyclists directly and by using semantic search tools on social networks. Municipality can publish ("Route Visualization") bicycle path network map intended giving possibilities to the citizens for discussing and voting "for" or "against" the project. Cyclists also can design and publish their own routes. Statistical analysis of the data ensures summarizing of viewpoints to select most suitable solution for policy crafting in the current conditions. Naturally that accuracy of the forecasting will depend on the quantity and distribution of the audience, and changes in bicycle path network already introduced.
The cyclists want to know what the occupancy of a route will be in certain meteorological conditions on a specific date, as well as if the route is suitable for the group i.e. terrain etc.? In route occupancy simulation model each agent is a cyclist or a group of cyclists that move on a chosen route considering traffic restrictions,

the quality of the route and influence of other cyclists on the occupancy. The occupancy of the route will depends also of particular time (specific hours), working days or vacations and season as well: summer or winter.

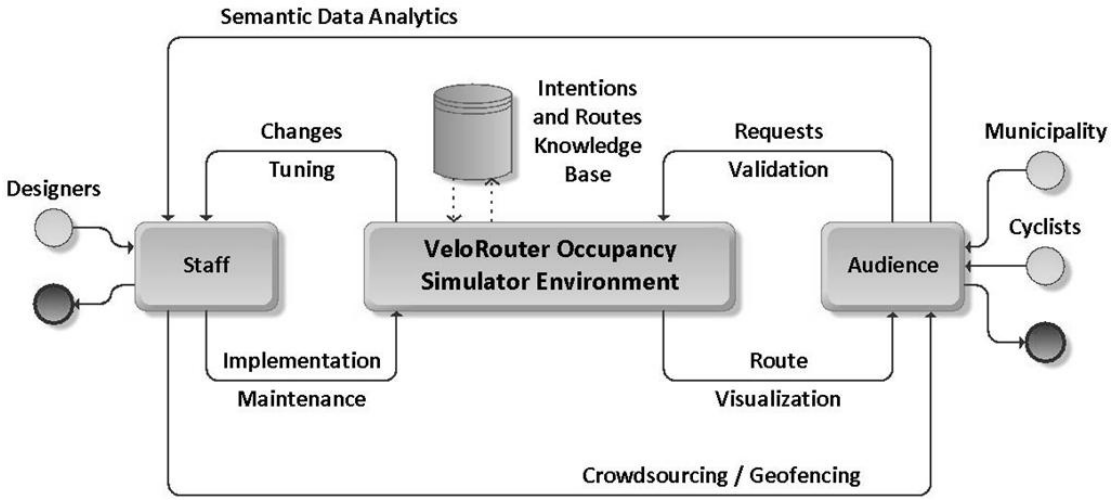

Figure 1: VeloRouter Conceptual Model

During VeloRouter usage Intentions and Routes Knowledge Base is continually and automatically updated. With each usage this improves the quality of simulated occupancy predictions. The database contains data entered by the municipality, which was gathered during interviews, voting data, information added by cyclists, as well as the planned routes of cyclists. Content is complemented by crowdsourcing data from social networks Facebook, LinkedIn etc. Semantic search methods are used also for occupancy simulation model and crafting scenarios validation.

In the conceptual model of VeloRouter there are two active informative subjects "Staff" and "Audience". "Staff" represents developers and maintainers of the VeloRouter information system. Developers design the VeloRouter Occupancy Simulator Environment, as well as are responsible for model tuning and changes management. "Staff" also supports search operations in semantic webs and processes obtained data for simulator validation. "Audience" are employees of the municipality who publish bicycle path projects ("Routes Visualization") and communicate with "Cyclists", who vote and make recommendations.

Figure 2 shows a possible Larnaca project screen. There are different types of projects. "My project" is a user created bicycle route network on the map in the allowed planning region. Simultaneously there can be multiple allowed planning regions. Project has to be published before others can view it and cast votes. It gets status "Published project". Although there is a project that everybody uses and it is called "Exploitation project" and is set by administration. In Exploitation project users can view existing road network, plan individual routes and view their terrain, view traffic restrictions, simulate occupancy as well as vote, comment and share edits of the project.
It is also possible to analyze project's statistics - see most used road sections, most commented areas and road sections of the region, vote distribution etc. Statistics is municipality's object of interest, as it offers recognition of the offered cycling scheme's acceptance as well as shows which sections of the cycling network scheme are the most important ones.

Occupancy simulation results are important also for municipality as they give an idea about possible outcome, if number of cyclists increased in specific areas or if some traffic restrictions are made.
Another one of important concepts is planning region. It is geographical area on the map within which manager of VeloRouter licence has rights to plan cycling routes. Area (region) is set during the talks of VeloRouter owners and manager of licence. Abstracting from financial factors, there is a requirement set for manager to provide full functioning. Functioning options are determined by the number of possible cyclists and size of the road network. If licence manager does not possess powerful enough resources for deployment of VeloRouter, then licence purchase can be refused or allowed planning region reduced.

A particularly important factor is provision of full occupancy simulation as it will be inconvenient if manager does not use HPC solutions. There is no problem with simulations with small number of cyclists, although analyzing real transport schemes where cyclists are over a thousand then the real-time conditions are forgettable. It isn't a problem for municipality as their simulation can be done in even a day, but user's waiting time shouldn't exceed seconds.

Figure 2: Introduction to Larnaca VeloRouter Project

Above described situation and related problems were examined while developing Skopje Bicycle Inter-modality Simulator (Ginters el al 2014), where it was found that the municipality has two fundamental questions - where to build and how to build?!

Although cyclist would not be ready to wait longer amount of time for the construction of his route. Collaboration with user has to be done in real time.

There are different types of simulation, starting with different DEVS solutions up to use of system dynamics modeling, however in situations where accurate enough situation analysis is needed, micro-simulation is unavoidable which determined the use of ABM/MAS.

3. AGENT-BASED OCCUPANCY SIMULATION MODEL

Each cyclist is an agent. For modeling purposes historical data is used, that is stored in "Intentions and Routes Knowledge Base". Municipality employees enter the data, that is obtained in interviews with potential bicycle path users in different places of the city - malls, mass events etc., as well as semantic search results in social networks and Internet environment. Database also contains cyclists' previously calculated routes and intended plans. Occupancy modeling is done for route chosen by user for travelling in specified time interval and meteorological conditions. Riding season is also taken into account (see Figure 3).

The occupancy on the route is specified as:

$$O_{\Delta t}^{AB} = (L^{AB}, Q_{\Delta t}^{AB}, T^{AB}, N_{\Delta t}^{AB}, N_{oth\Delta t}^{AB}, t_0^{AB}, \Delta t^{AB}, M_{\Delta t}^{AB}) \quad (1)$$

where,

$O_{\Delta t}^{AB}$ - occupancy on the route from the point A to B depending on the location of the agent on the route;
L^{AB} - length of the route;
$Q_{\Delta t}^{AB}$ - quality of the route with possible traffic limitations;
T^{AB} - terrain of the route;
$N_{\Delta t}^{AB}$ - number of the cyclists in the group;
$N_{oth\Delta t}^{AB}$ - other simulated cyclists on the route;
t_0^{AB} - travel start time;
Δt^{AB} - travel time;
$M_{\Delta t}^{AB}$ - meteorological conditions/season during travel time Δt^{AB}.

Since database stores all the historical data, then it is possible to determine where (in any given time) any agent will be. That means that by taking average riding speed it is possible to calculate possible number of agents in any time interval in any given route section. The smaller given time interval, wider road network and larger number of cyclists, the larger is load of computing resources. Therefore to ensure VeloRouter performance capabilities in real-time mode, there is a simulation-off option.

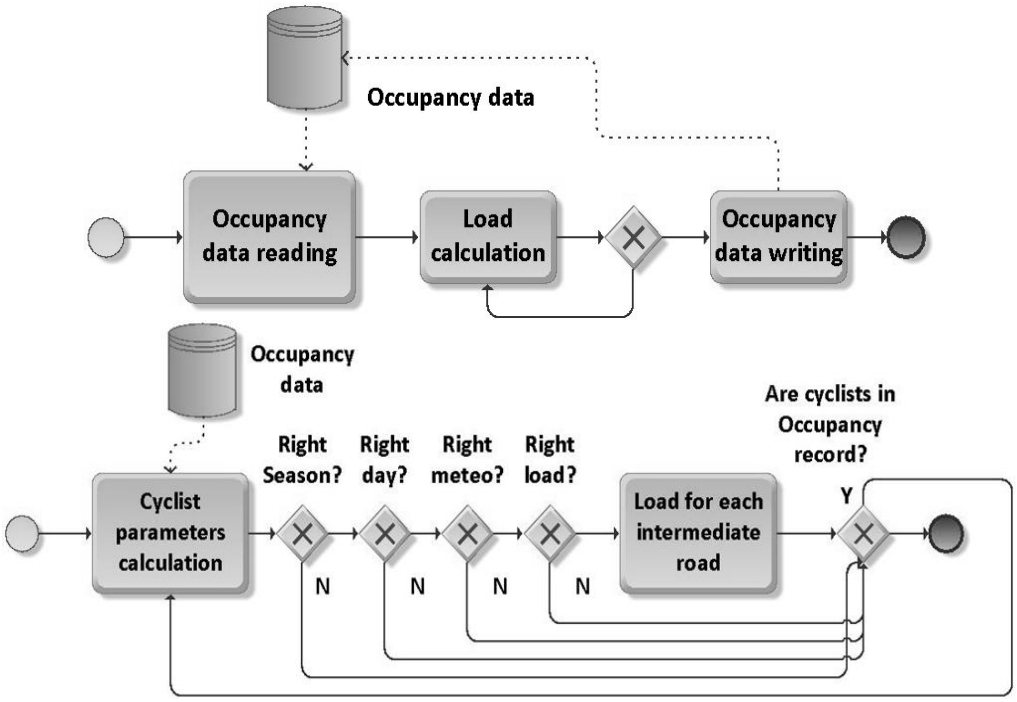

Figure 3: Occupancy Simulation BPMN2

Simulation results are visualized on the route map in form of a movie by changing the marking color indications in time of occupied route links.

4. CONCLUSIONS

VeloRouter (Ginters et al 2016) is one of the first simulators that takes into account municipality needs, performs a social function and the same time is cyclist-friendly. Software environment is designed in conformity with open source code principles. It is relatively easy adaptable for the needs of big cities and smaller ones.

Basically all cycling route designers offer route planning capabilities, however there are very few that propose route load predictions for a route on a specific date taking into account meteorological conditions and quality of the route.
VeloRouter complies with above mentioned requirements as well as provides options of publishing user designed routes, that created alternatives to municipality offered solutions. In fact, it is a municipality and user collaboration platform, that allows to reach a compromise solution during the construction of cycling scheme.

Semantic search has a significant role as it speeds up the database filling process with reliable data. In this way the quality of route occupancy modeling is being improved.
VeloRouter provides news website specific options of comments and votes that enables municipalities to make sure that their proposed transport scheme is correct. Lack of feedback is obvious road to misguided decisions.

Information statistics analysis section prepares information for region development planners as well as is useful to cyclists by showing the most popular of possible route sections.
Open-source solution gives a chance to other developers to edit the existing software and contributes to the applied model verification.

Open question is about visualization of modeling results. Currently existing cycling route planning tool methods are used, which do not allow to fully benefit from the advantages of semantic solutions. The user sees the existing situation as the result of visualization, but it is not possible to simply view similarities and influencing factors. Here the usage of semantic analytics and visualization would be preferable, offering advanced supplemented visualization solutions. It is possible to use ready-made software tools, for example SemaVis (Nazemi et al 2014; Ginters and Aizstrauts et al 2014), however the majority are commercial products that would reduce VeloRouter audience. So one of the following VeloRouter directions of development could be development of new semantic data analysis and visualization solutions.

VeloRouter route section occupancy modeling is based on use of ABM/MAS, that is useful to municipality as it shows route sections which could be reconstructed in order to increase their permeability, however, there is a series of technological problems.

Agent-based simulation (ABM/MAS) supports relatively precise load prediction so unpleasant incidents during a trip can be limited. However main ABM/MAS application bottleneck is necessity to know location of each agent on the map during simulated travel session asking for significant calculation resources if agent amount or the set of possible routes are growing. Thus make limitation for planning region size. Using Cloud and HPC solutions it is possible more or less to remove bottleneck although it is reasonable to continue the simulation algorithms enhancing.

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