Project code: ETH-11 06-3

Title of project: Agent-based modeling of retailers and their reactions to road pricing

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Abstract and goals of the original grant application

Microscopic models of travel and land use tend to have rich descriptions of the travellers, but the other actors in the urban system are normally abstracted into market clearing mechanisms. This project aims to make a central actor, the different retailers, explicit by developing an agent, which can address the locations choice problem of a retail chain, well knowing that this is only one, if important, choice of a retailing firm. The motivation of this choice is that the evaluation of road pricing as a policy tool hinges to a substantial extent on an assessment how the local retailers will respond to such charging.
The new agent type will be integrated into the existing, IVT developed, agent-based simulation MATSim and the land use model framework UrbanSim/OPUS, which is currently adapted to Switzerland in a joint IVT/IRL effort. The traveller agents of MATSim will be extended, so that they can respond to road pricing in the scheduling choices.
The resulting modelling system will be an important first step to a much richer description of the urban system in land use transport models, while contributing to the current Swiss policy debate about road pricing. It will be also the first to integrate the supply side choices, here for retailing, into such a system.

There are three main goals for the proposed project. (I) To introduce retailers in the agent-based modelling framework MATSim, (II) to introduce road pricing to the transport micro-simulation part based on general cost functions and (III) to expand MATSim modelling capabilities by coupling it with elements of the land use model OPUS. The latter goal allows analysing both short-term transport activity and long-term land use effects. This includes shifts in both retail destination and residential location choice due to road pricing as well as shifts in the transport mode choice. Those results can feed back to the agent-based model of retailers in order to simulate their reactions to the road pricing measure.

Achievements and advances made during the course of the research project

The main contributions of the work made during this project were (I) In depth interviews of Swiss and German retailers regarding their location choice strategies integrated by an extensive literature review on retailers' location choices and their reactions to road pricing (II) The introduction of a retailer agent in the agent-based micro-simulation MATSim.

The interviews took place between January and March 2008 in Germany and Switzerland. The interviews with location planners of 11 retail companies had the goal of understanding the various methods, processes and strategies in the optic of being able to model them and integrate them in the simulation software MATSim. It was attempted to have large spectrum of different types of retail firms, which means the firms interviewed have different formats and sell different products. Since the number of interviews is relatively low, the results are not representative of the whole retail sector for any of the two countries. Nevertheless they provide a very important insight and give an idea of how much strategies and methodologies applied by the different retailers vary. Among the many findings of this part of the research here are listed some which were particularly relevant for the next part of the work:

- Retail firms are increasingly aware of the new methodologies available to find optimal location for their stores. Nevertheless, they seem skeptical that they can really substitute those traditionally used which are strongly relying on the experience of the decision maker.
- The accessibility of a site is one of the most important characteristics which are evaluated in order to pick-up a location for a store
- If it happens that a store is not performing as expected, or if its turnaround is decreasing, firms react fairly fast; the most citing 6 months as the reaction time. There are different measures which are evaluated in such cases which span from a span from a simple modification of the presentation of the goods sold in the store to a full refurbishment. Adjusting prices is also a possibility. A relocation of the store is usually considered only if the other measures do not work and the reduction of the turnaround is specific to the single store, but none of the firms considered this measure as unthinkable.
- Overall, transport related policies are something to that planners are paying attention to but are not considered as a trigger event for location strategies, at least in the short term. In particular, on the hypothesis of an introduction of road pricing respondents agreed that it would not change their location strategy. Thinkable countermeasures, however, might include

the refund of the fee for customers and the adjustments of the opening time (in case of a dynamic road pricing with time-dependent variable fees).

In the literature review was invested more time than initially expected. The reason were the difficulties finding enough firms willing to participate to the survey which clearly gave more importance to the review of existing research on the topic. Moreover, this part of the research was also propaedeutic to the choice of a suitable methodology to represent retailers' location choices in MATSim. The review generally confirmed the findings of the interviews. The most important being the fact that most of retailers use the most sophisticated techniques available for location choice only as a kind of "a posteriori" confirmation of what they already decided based on their experience and intuition. It showed also that some simple methodologies are still the most widely used. Finally, the literature on retailers' reactions to road pricing suggests that retailers in other countries are more sensitive to this policy.

The second important contribution of the work made during the course of this project is the introduction of the retailer agent in the simulation MATSim. The contribution is important because it is a fundamental first step in the direction of a fully agent-based representation of the simulated world.
In the context of this work, location choice was chosen as the only choice dimension of the retail agents because it was a necessary premise to model the reaction of retailers to road pricing. In fact, the coupling of the location choice model with road pricing, which was developed separately, eventually did not work, which is explained in the next paragraph.

The introduction of the new agent type had to conceptually fit in the existing software. In MATSim agents can perform activities in different places called facilities. In a single facility one or more activities of different types can be performed (home, leisure, education, shop, work). Each activity type of a facility has a capacity, which defines the maximum number of agents which are permitted to perform a given activity in this facility at the same time. The focus in this work was on shop facilities, interpreted as retail stores. The retailer agent is represented as the decision maker having the control on a certain number of shop facilities. According to most of definitions of agents in the artificial intelligence literature, this entity can be provided with attributes, knowledge, one or multiple objectives, a strategy to pursue the objective(s), a methodology to implement its strategy and a group of allowed choices. A retailer agent controls some of the shop facilities of the simulation scenario, which will have certain location and opening times in turn. The knowledge of a retail agent is in principle of two types: knowledge about customers and knowledge about competitors. The knowledge about customers is limited to the number of primary activities of individual agents (in the MATSim framework home, work and education activities are primary activities) happening in a determined area. However, the retail agent knows how many customers have shopped in one of his stores after each iteration. The retailer is also able to see the location of competitors' stores. The choice of a new location is made taking into account such information. The objective for a retailer agent is the maximization of the number of customers. Based on the results of the interviews and the literature review, retailer agents use a "market support" methodology. This is a simple technique but still used in practice by actual retailers. The caption area of the store is estimated along with the population in it. An inventory of potential competitors of the store in that area is also compiled. Using this information, potential locations are evaluated and the best possible are chosen.

The main idea behind the relocation process is that retailer agents try to find a constellation of shops which is more convenient for potential customers than the actual one. They will have the possibility to relocate their shops at one (or more) specific point(s) of the iterative simulation process. The available links are fixed before the simulation starts and are updated during the relocation process according to retail agents' moves. Retailers are allowed to relocate their stores sequentially, which means first retailer 1, then retailer 2, and so on until the last retailer has relocated its stores. The relocation of stores is controlled by a specific genetic algorithm. As already mentioned, this is inspired by a location methodology called market support analysis. The algorithm seeks to find, for a given retailer, the constellation with maximum accessibility for potential customers, given the initial constellation and a set of free links. More precisely, for a given, hypothetical constellation of stores a caption area with a 3 km radius is drawn. For all potential customers – the individual agents having the corresponding shop activity in their daily plan – having a primary activity within the caption area, the generalized travel cost to reach the store is computed. An average is made for each of the caption areas and those averages are summed up.

The results for a test scenario, the metro area of the Swiss city of Zurich, shown that retail agents implemented as described were are able to increase the number of their customers by relocating their

stores. Since the scenario used for the experiments is a realistic one, it seems safe to affirm that this methodology could be used in the real world by retailers in order to optimize the locations of their stores.

Reasons for not achieving the original goals

Overall the project encountered some major problems in the implementation. At the end of the 2 years the two parts described above were completed. However, due to some compatibility problems with other modules of MATSim – in particular the activity location choice of the agents, some additional details are given below – the results obtained running the model on a large scale scenario were not yet satisfactory and the retailers in the simulation were not yet able to increase the number of their customers as expected. The work continued nevertheless as unfunded project, and the expected results were obtained in the following year and the results published later (Ciari et al., 2012). Not all the original goals were achieved though. Two parts were not achieved, the integration with the land use model UrbanSim and the test of road pricing scenarios.

The part regarding the integration between UrbanSim and MATSim was indeed discarded from the project because in the time between the submittal of the proposal (Aug 2006) and the start of the project (Mar 2007) the work on the implementation of a Zurich scenario for UrbanSim – a necessary starting point for the goal discussed here and pursued by another PhD student at the institute – did not went as expected. The scenario by that time was still incomplete and the resolution was not yet the one needed for the integration with MATSim (in other words the scenario implemented had test purpose and still had a lower resolution in terms of population distribution. A final version with the necessary resolution was not achieved). At that point was clear that keeping this goal would have implied a too large work burden at the expenses of the other goals. Indeed, the work on the integration of MATSim and UrbanSim was reprised at the institute in 2010 within the EU project SustainCity (www.sustaincity.org) and this experience confirmed that the amount of work would have largely surpassed the one expected.

The whole idea of adding retailer agents in the simulation, aiming to reproduce their behavior and predict their reaction to policies, is possible because individual agents are able to react to a policy in the first place. The type of action (or reaction) the retailers are interested in is the choice of the store where the agents are going to shop. This is controlled in MATSim by the secondary location choice module. Its development was not part of this project but was rather undertaken in parallel at the institute. At the time the implementation of the retail agents was ready the secondary location choice was also functional. However, the behavior of the whole system was not as expected and retailers were not able to increase the number of customers by changing the locations of their stores. After several tests two reasons emerged for this behavior. The first was the fact that in this first version shopping activities were still undifferentiated in the simulation. The second was that the number of iterations to reach equilibrium in terms of shopping location behavior turned out to be much higher (up to ten times) than the one necessary to reach equilibrium in terms of mobility behavior. This was fixed and the results are reported in Ciari et al. 2012.

Road pricing was implemented in MATSim and was tested together with the retailer module. However, it was not possible to obtain reasonable results – i.e. to observe the expected behavior by the agents, and consequently by the retailers – when road pricing was introduced. In fact, although road pricing itself has shown to work properly (Rieser et al., 2008), it appears to have problems when coupled with secondary location choice. In fact, location choice of the agents works making an estimate of travel costs before the execution of the daily plans. For computational reasons this can be only imputed in an approximated way, which cannot include road pricing. Since location choice was implemented in parallel to the present process this was not expected when the proposal was written. The problem has not yet been solved and, therefore, the use of the location choice (and of the retailers module) with road pricing is at the moment not possible.

All in all, despite reaching only a part of the expected goals, the project was a precious experience which helped a lot understanding how the different modules of complex software like MATSim can work together. In fact, at the time this project took place MATSim was still in an early phase of its development and the lesson learned helped in avoiding the same kind of errors in successive projects. Among the goals actually reached, the model retailer location choice developed is used at the institute

and a new effort to improve it has produced its first results and (Horni et al., 2012) will be further undertaken in the next future.

List of outputs

Löchl M. (2008) Standortplanung im Detail-/Einzelhandel: Auswertung von Interviews mit Unternehmen in Deutschland und der Schweiz, *Arbeitsberichte Verkehrs- und Raumplanung*, **492**, IVT, ETH Zürich, Zürich.

Ciari, F., M. Löchl and K.W. Axhausen (2008) Location choice of retailers - an agent-based approach, paper presented at the *15th International Conference on Recent Advances in Retailing and Services Science*, Zagreb, July 2008.

Ciari, F. and K.W. Axhausen (2012) Modeling Location decisions of retailers with an agent-based approach, paper presented at the *91st Annual Meeting of the Transportation Research Board*, Washington, D.C., January 2012.

Other Literature

Rieser, M., U. Beuck, M. Balmer and K. Nagel (2008) Modeling and simulation of morning reaction to an evening toll, at *Innovations in Travel Modeling '08*, Portland, Oregon, June 2008.

Horni, A., F. Ciari and K.W. Axhausen (2012) Coupling Customers' Destination Choice and Retailers' Location Choice in MATSim, *Arbeitsberichte Verkehrs- und Raumplanung*, **808**, IVT, ETH Zürich, Zürich.