Location decisions of retailers: an agent-based approach

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Abstract

The paper reports about an ongoing project, where the goal is to develop an agent-based module of location decisions of retailers which will eventually be implemented into the larger agent-based model MATSim-T. So far, this model system is basically a fast microscopic transport model, where the supply side is not explicitly modeled. The research goals of this paper are multiple. Since the envisaged retailer module will focus on location choice of retailers and in particular their possible adoption strategies facing the introduction of road pricing, a literature review on those issues and the current knowledge is summarized. Those insights of retailer location decisions described in the literature are enriched through the report of a series of in-depth interviews, which have been conducted with retailers of various product groups in Germany and Switzerland in the winter of 2008. A literature overview on agent-based descriptions of retail markets shows potentially suitable approaches of the modelling of retailers. Moreover, a short overview on MATSim-T is provided. Finally a conceptual model for the new retailer agent is proposed, discussing the main issues arising with the introduction of such types of agents in MATSim-T.

Key Words: retail planning; location choice; microsimulation

1 Introduction

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 retailers, well knowing that this is only one choice, even if probably the most important, of a retailing firm. The new agent type will be integrated into the existing agent-based simulation MATSIM-T, developed at ETH Zurich and TU Berlin. MATSim-T is a simulation toolkit which is able to deal with large scale scenarios (Balmer, 2006). It uses the concept of the Evolutionary Algorithm (EA) in order to generate consistent daily activity schedules for each individual (agent) of a population and travel times on the network. The resulting modelling system will be a first step to a much richer description of the urban system in this simulation toolkit in the future. It will be also a first effort in order to integrate the supply side choices, here for retailing, into such a system. In fact also if the initial modelling of retailers is quite simple, the agent-based approach makes the enhancing of the model to a more sophisticated one relatively easy. In the short run the main goal is to introduce this new agent for modelling the location behaviour of retailers. The shopping behaviour of individuals, in particular the location choice for the shopping, has a big impact on retailers’ behaviour and it creates a cycle indeed. In the long run we imagine thus that both retailers and individuals as consumers will have a much richer description. The work is also aimed to contribute to the current policy debate about road pricing. The evaluation of road pricing as a policy tool hinges to a substantial extent on an assessment of how the local retailers will respond to such charging. Even if road pricing is currently implemented in some cities (London, Stockholm, Singapore) the effect on spatial behaviour of retailers is not yet clear and definitely an open issue. A micro-simulation tool as presented here can be the right instrument to investigate this issue, especially when trying to analyze and compare effects in policy scenarios.

The remainder of this paper is organized in four sections. In section two an overview on retailers location choices is presented. A literature review on location strategies of retailers and on methodologies employed for the location choice of stores is enriched through the report of a series of in-depth interviews. In a subsection the available literature on effects of road pricing on the retail sector will be also discussed and hypothesis stated for later work. A literature review on agent-based approaches modelling retail markets will be the topic of section three. Section four discusses the introduction of the new retailer agent in MATSim-T. A short pres-
entation of the simulation toolkit is given in the beginning of this section. The main issues arising with the introduction of the retailer agent are discussed, and a possible approach is proposed. The last section is dedicated to conclusions and to an outlook on the future work.
2 Retailers location choices

This section is intended to provide a general overview on most important contributions on location choices of retailers, covering both the strategic and the methodological levels. The section is enriched with insights of a dozen explorative interviews, which have been conducted with German and Swiss retailers from January until March 2008 (Löchl, 2008). This allows us to get an understanding on the actual practice of location decisions of retail firms with different sizes and in various product categories. A subsection describes particularities of the Swiss retail market. Finally a short literature review on reactions of retailers to road pricing is given and based on it hypothesis are stated.

The literature argues strongly that location is the most important factor for the success of a retail store, and sometimes is also acknowledged as the only one. “Good locations are key elements for attracting customers to the outlets and sometimes can even compensate for a mediocre retail strategy mix. A good location therefore can lead to strong competitive advantage, because location is considered one of the elements of the retail marketing mix that is “unique” and thus cannot be imitated by competitors” (Zentes et al., 2007, 143). Moreover, the importance of the location has increased during the last years because of more intense competition in most of the retailing markets. This growing interest on location can also be seen in the academic literature in different disciplines such as economics, marketing, geography, land use, city planning and operation research.

The location behaviour of a retailer can be analyzed distinguishing two levels, the strategic and the methodological. Most retailers have a spatial strategy, its realization is pursued with a specific methodology. This latter may be chosen from a wide spectrum of existing methodologies, ranging from extremely simple and not very scientific, sometimes simple intuitive, to complex, computer assisted approaches.

In general, location preferences and spatial strategy of retailers are determined by the retail format. Krafft and Mantrala (2006, 193) define a retail format as “comprised of stores that offer the same, or very nearly the same, variety of product categories”. Moreover, a retail format represents a specific configuration of the retail marketing mix which is maintained consistently over time. It includes the nature of merchandise, assortment and service offered, similar promotion, pricing policy, approach to store design and visual merchandising as well as typical location (Zentes et al., 2007, 10).
Depending on the retail format, there are various location factors and preferences. Each one weighs location factors differently and involves various trade-offs. Therefore, the appropriateness of a specific site is based upon the retailer’s format and strategy and is influenced by a substantial number of factors that need to be investigated.

Table 1 Selected location factors

<table>
<thead>
<tr>
<th>Customers</th>
<th>Accessibility</th>
<th>Competition</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>numbers by demographics (e.g. population size, age profile, household size)</td>
<td>pedestrian flows</td>
<td>existing retail activity (direct/indirect competitors, anchor stores, cumulative attraction, compatibility)</td>
<td>purchase price</td>
</tr>
<tr>
<td>income level</td>
<td>pedestrian entry routes</td>
<td></td>
<td>building costs</td>
</tr>
<tr>
<td>disposable income per capita</td>
<td>road network (conditions, speeds)</td>
<td>existing retail specification (selling area, turnover estimates, trade areas, age of outlet, design, parking)</td>
<td>rent costs</td>
</tr>
<tr>
<td>employment by occupation, industry, trends</td>
<td>parking (capacity, convenience, cost, potential)</td>
<td></td>
<td>leasing terms</td>
</tr>
<tr>
<td>housing density</td>
<td>car ownership level</td>
<td></td>
<td>site preparation</td>
</tr>
<tr>
<td>housing age/type</td>
<td>public transport (types, cost, ease, potential)</td>
<td></td>
<td>building restrictions</td>
</tr>
<tr>
<td>neighbourhood classification</td>
<td>barriers such as railway tracks, rivers</td>
<td>competitive potential (outlet expansion, refurbishment, vacant sites, interception, repositioning, competitor policy)</td>
<td>development concessions</td>
</tr>
<tr>
<td>home-ownership levels</td>
<td>visibility</td>
<td></td>
<td>rate payable</td>
</tr>
<tr>
<td>building/demolition plans</td>
<td>type of location zone</td>
<td></td>
<td>refurbishment needs</td>
</tr>
<tr>
<td>main employers</td>
<td>access for staff</td>
<td></td>
<td>maintenance costs</td>
</tr>
<tr>
<td>spending patterns</td>
<td>access for delivery</td>
<td>saturation index</td>
<td>security needs</td>
</tr>
<tr>
<td>shopping patterns</td>
<td></td>
<td></td>
<td>staff availability</td>
</tr>
<tr>
<td>population growth, density and trends</td>
<td></td>
<td>proximity of key competitors, traders, brand leaders</td>
<td>labour rates</td>
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<tr>
<td>lifestyle measures</td>
<td></td>
<td></td>
<td>delivery rates</td>
</tr>
<tr>
<td>cultural/ethnic grouping</td>
<td></td>
<td></td>
<td>insurance costs</td>
</tr>
</tbody>
</table>

Sources: adapted from Zentes et al. (2007), 148; McGoldrick (2002), 240; Gilbert (2003), 293
2.1 Location choice strategies of retailers

The specific literature about location strategies of retailers is by far less abundant than the one on methodologies. As Brown (1992) observed “…academic conceptualizations of retailing location have changed little in the last thirty years. Indeed, this conceptual stasis stands in marked contrast to the dramatic methodological developments that have recently taken place.” In fact this observation can be considered valid also nowadays (Cliquet and Josselin, 2002, Rogers, 2007). Traditionally, location choices were more based on intuition and on a responsive basis to competitors but also to other stakeholders such as government, legislators, etc…- and therefore oft made with a short term horizon. More recently, many major changes in the retailing environment such as the need to justify decisions to shareholders, increased competition for retail sites, fast changing demand, the disappearance of ‘obvious’ sites, the increasing cost of location decisions and so forth brought them to a more organic approach (Clarke, 1997, Hernandez et al., 1998, Hernandez and Biasotto, 2001). Sometimes it seems that in many cases retailers attempt a sort of a posteriori validation of strategies more than a conscious path following one planned strategy of development. Naturally that does not fit, in most of the cases, larger retailers, whose expansion strategy is usually following an accurately planned and well recognizable pattern.

One systematisation of retailers’ spatial strategies is for example used in Laulajainen (1987). In his study the growth of some retail chains in Sweden and in the US is analyzed, distinguishing between contagion and hierarchical expansion. The contagion strategy consists of an expansion from areas already occupied to new areas following a vicinity principle. In that way the growth takes place from a unique central point. Wal-Mart followed such an expansion strategy in the US, where it allowed the company to exploit economies of density in distribution, training and advertising (Holmes, 2008). In contrast, when using the hierarchical expansion a retailer decides to colonize first bigger centres, disregarding the geographic vicinity from already existing own stores, and then he tries to saturate the local market expanding to increasingly smaller centres following a hierarchic path.

Neither of the interviewee in both Germany and Switzerland reported about a contagion strategy. This might be due to the fact that both countries are relatively small and each region can be delivered from a central distribution centre within a few hours. Even discount retail chains in the early market entry and expansion phase prefer to pick the most promising or available sites for new stores without regarding their current positions of stores and distribution centres.
Anyway, the aforementioned classification does not take into account the effect of the competition on spatial decisions of retailers. In fact they face two opposing incentives in the location decision.

A retailer might have an incentive to locate close to competitors in an attempt to capture more consumers, but spatial and even product differentiation is reduced and leads to greater competition in the price dimension. Therefore, a firm has an incentive to locate farther from its rivals in order to reduce price competition. This possible ambiguity is reflected in Brown (1992), who proposes a classification which is uniquely based on the behaviour of retailers versus their competitors. Three different spatial strategies of retailers are recognized: avoidance, confrontation, and predation. *Avoidance* means that the retailer seeks a site as far as possible from its competitors trying at the same time to meet some other requirement (i.e. nearby population, quantity and quality of vehicular traffic). On the contrary *confrontation* means that the retailer wants a site as near as possible to the competitors. In fact already Hotelling (1929) observed that when the demand is elastic and the good sold is not much differentiated there is an interest to place a shop in the heart of the market, instead of trying to colonize a virgin area. This approach is quite typical of the furniture market. The last, and maybe most interesting, strategy is the one of *predation*. In this case the retailer tries to fill up spaces left free by the competitors, and once installed nearby other shops of the same type tries to predate other customers with a price strategy. This strategy is often used in the clothing market.

An interesting analysis is also provided by Karande (2003). Even if it is reported only on location strategies of broad-line specialist retailers, there is an attempt to explain why a given strategy is used in a given situation, referring in particular to vicinity and distance strategies. Vicinity strategy is justified with the attractiveness for potential customers of doing “comparative shopping”. But if “darwinistic” effects prevail, the competition to get customers is the dominating factor, therefore distance strategy is the one preferred. Moreover it is observed that areas where the two different strategies are implemented are also differing. A proximity strategy tends to be adopted by retailers in areas with relatively high income, high retail expenditures, high population density, younger population and high home ownership.

The actual strategies differ by retail format and product group as the interviews revealed. Generally, clothing retailers are looking for the agglomeration in city or shopping centres, as neither of them could attract enough customers alone. Therefore, they avoid solitaire locations, but they are observing any actions by the competitors closely. Others such as sport and outdoor retailers do not generally avoid proximities to competitors, but they acknowledge
oversaturated markets in order to prevent ruinous price competition. Moreover, they are sometimes willing to locate away from the agglomeration and do not avoid solitaire locations. Grocery retailers are following a different path. They are interested in a dense network and a good market penetration. Therefore, they disregard the competitors and focus on the best locations in regard to market potential for them. Sometimes, they are looking for joint locations (i.e. supermarket and discounter) when there is minor product overlap.

Based on the interviews the preferred location types of various retailers can be roughly categorized into the following:

- Top locations with high frequencies in city centres or shopping centres,
- Semi-top locations at the inner city fringe or in subcentres as well as in less frequented shopping centres,
- Typical specialist retail warehouse locations,
- Locations close to residential areas.

The process of location selection often follows a 3 step approach with increasing spatial focus (Brown, 1992, 16, Zentes et al., 2007, 147):

1. Market selection: Interesting agglomerations, regions or municipalities are filtered based on inhabitants or purchasing power.

2. Area analysis: Within the chosen region, a potentially optimal area for the store is selected. However, this step is often neglected in practice, as anything after the market selection is driven by the site supply.

3. Site evaluation: The best available sites are examined in terms of all features that are relevant to potential store performance.

Of course, location choices are not limited to simple opening and closing of shops. In fact most of the location decisions include other activities (Ghosh and McLafferty, 1987; Davidson, Sweeney and Stampfl, 1988; Ghosh, 1990). More recently, this is also reprised in Hernandez et al. (1998). In principle location strategy is concerned with the size, type and number of outlets coupled with an assessment of intended timing and geographical spread of the chain. Basically it means to maximize aggregate returns by planning and adjusting a shop portfolio in such a way that each unit is matched closely to the market within its immediate catchment area, or is deleted if this is not possible.

In this optic, six main types of decisions can be identified, which, in descending order of risk, investment commitment, and time taken to implement are as follows:
1. **Roll-out/extension**: Increase in floor space either by the opening of new stores (by organic growth or through acquisition or extending the floor space in existing stores).

2. **Relocation**: Relocation of existing stores.

3. **Rationalization**: Closure of stores on an individual basis or selling entire of divisions.

4. **Re-fascia**: Altering the image of outlets by changing the name and appearance.

5. **Refurbishment**: Changing the retail appeal with some modification to the store.

6. **Remerchandising**: Altering the product range and merchandising of a retail location, and tailoring the offer to the local consumer.

### 2.2 Retailers’ location choice methodologies

The rising competition in most retailing markets has not only increased the interest on location issues, but has also caused major change in retailers’ approach to location choice. That is particularly true when it comes to available methodologies, much more than it is the case for strategies. The literature is reporting that many retailers are passing from really simple location choice techniques to more modern and sophisticated approaches. Even if simple “rules of thumbs” techniques keep being quite diffused and also simple intuition and experience of the retailer are still actual tools when deciding the location of new shops, the number of retailers using newer, often computer based, methodologies is internationally increasing. Apart of competition, another explanation of that is the explosion occurred in the quantity of available retail data. Moreover, most of it is of spatial nature, about 90%, pushing retailers to the adoption of GIS (Geographic Information System) systems in order to treat such geographical data. Hernandez (1998) observed:

“Although formal techniques of locational analysis have been available for over 50 years, most retailers traditionally made no use of them, relying instead on intuition guided by experience and "common sense". However, the simultaneous advent in the last 15 years of low cost computing and the increasing availability of retail related data of all types has given retailers the opportunity to take a much more rational approach to decision making.”

Among the abundant literature which in the last ten year has been produced, some good examples are Hernandez et al. (1998), Hernandez and Bennison (2001), Birkin et al. (2002) Pioch and Byrom (2004), Wood and Browne (2006), Rogers (2007). Some classic literature

A classification of location methods which separate them according to the type of analysis involved is the one proposed by Hernandez et al. (1998). Reporting on a survey of UK retailers, they include ten methods ordered in three categories:

1. **Comparative**: Rules of thumb, checklist, ratio, analogues.
2. **Predictive**: Multiple regression, discriminant analysis, cluster analysis, gravity models.

Most of these methods are described below, descriptions are adapted from Birkin et al. (2002) and Rogers (2007).

- **Rules of thumb** simply means that experience is the main instrument. Essentially subjective and intuitive guidelines or developed from knowledge of the company and sector, and tempered by “common sense”, are used.

- **Checklists** consist of a list of variables considered to have an influence on store performance and perhaps given some variable points rating.

- **Ratio and market support** methods are simple procedures which may be used when data on the existing facility is very limited. In both of them the caption area of the store is estimated along with the population in it and the relative spending potential. An inventory of potential competitors of the store in that area is also compiled.

- **Analogue methods** are still commonly used despite their simplicity, indeed they are among most popular methods since the 1930’s, and still widely used especially among retailers with limited risk related with one store’s opening. The idea is to forecast and compare the sales of stores comparing its location with the location of another store of the same retailer. This latter should have a similar location, in terms of population, geography, trade, to the one for which the forecast is desired. The data and computational requirements are small for all of these, being no more than basic facts about outlets and their sites, and the cost is low.

- **Catchment area models** are more sophisticated variant of analogues methods. The main advantage of this method is that the unique profile of a retailer is accounted for. Moreover, it is cheap and simple and might be applied even if the retailer owns only a few prototype stores. The analogies are still based on qualitative evaluations but relies more on sociode-
mographic characteristics of inhabitants of a certain area. The difficulty to account for interrelated impacts of competition, demographics and distance at a new location, traditionally the main shortcomings of analogue methods, have been successfully overcome integrating cluster analysis, decision-tree analytical frameworks and statistical modelling in this technique.

- **Rating models** are a good option when markets are very complex. In particular it is suitable when sales are highly unpredictable and based on an irregular clientele (i.e. ATM’s). The method consists on giving a rate for each of a predefined group of characteristics of the site. According to such rates the site receives a final score which can be put in relation with an expected level of sales. The method is particularly suitable for a computer based use. However it has not proved particularly successful so far.

- **Statistical models** are another popular group of methods. Their application is typical in highly segmented markets, such as restoration, clothing, books and so forth. Linear multiple regression, the most common of these methods, may be considered an analytical version of analogues methods. In fact it is assumed that sales are dependent on a group of variables which can be measured, and forecasted solving an equation of the type:

\[
Y_i = z + a_1X_1 + a_2X_2 + \ldots + a_nX_n
\]

Coefficients are calculated using already existing stores attributes and sales level. These methods have the advantage to reduce the degree of subjectivity involved in the process and the increased availability of computation power made the application of these methods easier. However, they are oft misapplied, mainly because of objective difficulties of taking into account all relevant factors. Moreover, a model produced with this method, also a good one, is a sort of a snapshot of the performance of a store of a given retailer at a given time. Thus, only a short term forecast of the sales may be imputed.

- **Cluster and factor analysis** are aimed at grouping data cases and variables together for example, segmenting a portfolio of stores into similar groups (clusters) or grouping together a range of variables which can be used to predict profitability (factors). These techniques are particularly suited to new store format development and network segmentation. However, as with the previous multivariate techniques, they require a combination of statistical expertise and business acumen, along with relatively large quantities of “good quality” data.

- **The gravity model** family regroups models having as a main assumption that spatial issues (like distance from a customer’s home) plays a key role in the attractiveness of a store. Sales are forecasted taking into account distance relationships between competing facilities and population distribution and density. They are frequently employed for evaluate aggre-
gations of stores, such as shopping malls, or extended store networks, like supermarket chains, or fuel stations chains. A crucial aspect is that a correct use of gravity models requires the availability of several different data sets. The main problem of these methods is that segments of population are not accounted for, and therefore they might be not suitable for every segmented market.

- **An expert system** is a computer program which contains the knowledge of one or more experts. That means that the system will be able to autonomously suggest solutions to the location problem dependent on a set of input data. In fact, especially in its simpler implementation, it is conceptually similar to rules of thumbs, but with the difference that decisions are more consistent and coherent from case to case. **Neural networks** work similarly. An artificial neural network is a computer program which has an initial knowledge and the capacity to “learn” if properly “trained”. Thus, again, the system is able to autonomously propose solutions. Both methods require a relatively complicated algorithm to be used (at least if compared with simple traditional methods), and are not widely diffused in practice.

After this quick overview on location methods it should be noted that, in general, techniques which are used most widely are the simpler comparative ones, requiring less expertise and incurring less cost than the more complex ones. Also the interviews revealed that a lot of location decisions, particularly those at the micro scale, are actually based on intuition and involve less sophisticated methods. These are also the ones with the greatest degree of subjectivity in their formulation, calibration and interpretation, and imply the continuing existence of decision making cultures which are opinionated and politicized. Moreover, many retailers are habitually using different methods in parallel, and not trusting just one method. Also because of that, even when the most sophisticated methods are applied experience and intuition are still essential for successful location choices.

### 2.3 Retail situation in Switzerland

The Swiss market is with 7.6 Mio. inhabitants and only 5 cities with more than 100,000 inhabitants (Basle, Berne, Geneva, Lausanne, Zurich) relatively small. Particularly for retailers which are looking for top locations in inner cities or shopping centres, there are only very few local markets with few potential spots. Therefore, the demand is focusing on a small area where rents are extremely high and expansion is restricted by the short supply of available sites. This situation explains the relatively low level of methodological sophistication reported by retailers of products with longer life spans.
The grocery retail chains are looking for locations rather close to residential areas with good accessibility. Moreover, they pursue a seamless and dense market presence. This is particularly true for the two predominant grocery retailers in Switzerland, Coop and Migros, which together have a market share of more than 46% in the food sector. The two German discounteres Aldi and Lids have recently started to expand in Switzerland. They are requiring more parking and are therefore found more often at the periphery of settlements. They also want to have a seamless market presence, although their minimum catchment areas per shop are considerably larger than those of the two leading retailers. While Coop and Migros require at least around 8000 inhabitants for a 700sqm-shop and 2000 inhabitants for smaller (convenience) shops, the discounters require a minimum of around 20,000 inhabitants for a shop. Nevertheless, those catchment area sizes are considerably lower than those in most other product groups.

2.4 Location of retailers and road pricing in the literature

Road pricing is often mentioned as an effective measure for sustainable transport in metropolitan areas. A broad body of literature about this topic is available, focusing mainly on short-term transport, economic and acceptability aspects of pricing policies. Papers focused on spatial aspects of road pricing are relatively rare, and only recently a stream of work analyzing them is starting to emerge. Probably that is also because implemented examples around the world are still few and their duration too short in order to see effects on location choices of retailers. In this sense it is not surprising that a fair number are ex-ante studies attempting to answer the question how the introduction of a road pricing measure would have influenced the land use. None of those studies is aimed to investigate effects on retail in particular.

However, there are a few ex-post analysis results available. For the London case, what can be measured by now is the level of sales, and eventually its modification, but relocation effects have not been seen yet. Impacts of the congestion charge are investigated in detail by applying econometric models in the work of Quddus et al. (2006). One of the datasets used includes weekly sales data for six stores of a retail chain in London, whereas one of the stores is located in the charged zone. The authors found a significant negative impact on sales at this store over a period of about eleven months following the introduction of the charge compared to the other five stores. However, the competition among shops and the spatial redistribution of sales could not be considered in the analysis. A second dataset covering total retail sales in central London did not show a significant downturn because of the charge. This supports sus-
picion of spatial redistribution. Therefore, no congestion charging impact could be found as a whole. Nevertheless, it is still possible that there has been some redistribution of sales from certain areas to other stores within central London (Quddus et al., 2006, 20). Similar conclusions can be found in the reports of Transport of London (2005, 2007). In the latest report, TfL concludes that “no general evidence of any clear differential impact of the central London congestion charging scheme on business activity had been found” (TfL, 2007, 95). Earlier, it has been stated that the congestion charging has not had significant effects on retail sales (TfL, 2006, 88) and that “some sectors within the charging zone have shown better performance than outside the zone. Other sectors have performed worse inside the zone than outside. These differences are all relatively small, and are not consistent between different data-sets. It is not possible to be certain what part of these differences (positive or negative) result from the congestion charge” (Transport for London, 2005, 5). Therefore, the effects of road pricing often disappear among other factors, which might have a higher influence. Overall, the impacts seem to be rather neutral so far. Nevertheless, one has to take into account that land use impacts are rather long term and the duration since the introduction is still too short to draw final conclusions, particularly since the TfL analysis is limited to long lags in the availability of published economic and business data (TfL, 2007, 95).

No effects on retail revenues for shopping malls and shops located within the toll area have been reported from Stockholm, where a road pricing scheme have been introduced in January 2006 (Daunfeldt et al., 2007). The authors are suspecting that the customers are avoiding the time-depending road pricing by changing the time when the shopping is being done. Moreover, they note that shopping behavior primarily is determined by habits that changes slowly and that therefore long-term effects have not been observed in the data, which covers the time until December 2006.

Similar conclusions can be found in cities with longer road pricing experiences. In Singapore for example, a first road pricing scheme had been introduced in the inner city in 1975. Reporting on this experience Armstrong (1986) observed that any impact that the scheme may have had on land values, land use and the environment in Singapore, has been largely eclipsed by other factors in the economy. In the case of Trondheim, there has been some research on shopping behaviour after the introduction of road pricing in 1991. A study (Avant Management A/S, 1992) found that 10% of the customers had changed their shopping behaviour by moving their shopping to other destinations or times after the introduction of the cordon pricing (cited in Tretvik, 2003, 88). Moreover, while business people located in the city centre had predicted major negative swings in trade prior to the cordon pricing, the Chamber of Commerce of Trondheim concluded from an own ex-post survey that there was hardly any
effect on trade at all. Anyway, there was a long lasting general trend of growth in areas outside and decline in areas of the cordon. Tretvik (1999) even concludes a general trend line of modest but steady growth in retail sales in real terms inside the cordon since the introduction (Tretvik, 2003, 89).

In conclusion, it seems that effects on retail are minor particularly at the aggregated level, but for some cities the introduction is too recent in order to allow a definitive word. In any case, it is always hard to separate the individual effects of road pricing from other factors and impacts at the spatial micro-level are still rather uncertain. Moreover, it is difficult to know to what extent experiences and conclusions drawn from one city can be transferred and generalised to other cities, since the effects depend to a large extent on the road pricing scheme as well as particular characteristics of a city such as its spatial structure, street network form and capacity, quality of public transport network and so on (Löchel, 2006). In that sense a micro-simulation seems to be the right instrument to assess the possible effects of a road pricing measure on a city by comparing policy alternatives.

2.5 Location of retailers and road pricing hypothesis

Eventually, it is planned in the project to test road pricing scenarios with the implemented retailer module in MATSim-T for the Greater Zurich area. The analysis will be led by the hypothesis that depending on the spatial range and fee schedule of a road pricing measure, it can have minor or major impacts on the retail sector. Therefore, focus will be not on the analysis on a general increase of transport costs due to road pricing but on spatially varying pricing schemes, such as cordon charging. High charges might encourage both transport mode shifts to public transport and destination shifts to retailers outside the charging area. Changes in route, mode and destination choice by the consumers can be expected. As a consequence, they might benefit from the reduction of density losses due to less congestion to and within the cordon. But in case retailers are relocation outside the charged area, the advantage of having an agglomeration in the inner city might diminish when retailers are spreading beyond.

More specifically, the following road pricing scenarios are going to be tested:

1. **Scenario A**: Road pricing at an inner city cordon in Zurich for private cars only, reduced charges for inhabitants inside the cordon.

2. **Scenario B**: Time depending fee schedules for the inner city of Zurich.
3. **Scenario C**: Cordon pricing for the whole City of Zurich; reduced charges for inhabitants inside the cordon.

The following hypotheses are stated with regard to the aforementioned road pricing scenarios:

**Scenario A**: The road pricing will impact retailers inside the cordon slightly, nevertheless spatial redistribution occurs. As the pricing is set higher, alternatives beyond the charging zone becomes attractive for customers living outside the cordon. In this situation retailers might increasingly prefer to establish their business outside the cordon in the long run.

**Scenario B**: With smart scheduling of fee levels over the day and over the week, road pricing effects on retail can be mitigated.

**Scenario C**: Applying the same fee levels as in Scenario A to the whole city of Zurich, impacts on retail are comparable lower as more customers are living inside the cordon and enjoying reduced charges. Consequently, agglomeration effects in the city center are stronger.

The test of these scenarios can build on current experiences with MATSim-T, as there has been efforts to simulate a time-dependent toll scheme for the City of Zurich (Rieser et al., 2007). It is observed that the micro-simulation approach does not guarantee that if a fixed point is reached the point is an optimum (in the sense of Nash: nobody can improve his situation by unilaterally doing something else), because the system is not deterministic. The iterative process might find a state that is locally stable, but there is no guarantee that running the iterations longer might not lead to completely different solutions. The system’s complexity is even increased introducing the retailer agents. That gives further support to the idea that solutions might be path-dependent. For that reason not only the relaxed state will be considered, but attention will also be paid to initial condition and to the adaptation behavior of the agents.
3 Modelling retail markets: agent-based approaches

The use of agent-based modelling in spatial issues is becoming more popular and is opening up new perspective in the understanding of retail markets. The popularity of agent-based systems in itself is a logical consequence of the increased calculation power of computers, but for the application to retail markets the availability of more and more precise data, plays a crucial role. The introduction of new data collection technologies such as EPOS (electronic point-of-sale) systems and the increasing popularity of store cards simplify the task to obtain detailed information on consumers for retailers (Nakaya et al., 2007). However, the use of the agent paradigm to describe retail markets is usually limited to the agent-based modelling of customers and not retailers. Agent-based implementations of retailers are rare so far and models were both retailers and customers are modelled as agent are even fewer.

Speaking about spatial choices in general some microscopic approaches can be found in the simulation of urban housing markets (Benenson, 1998; Bura et al., 1996), traffic flows under different land use conditions (Miller et al., 2004) and land use transformations (Parker et al., 2003). More specifically, in retail geography micro-simulation approaches were initially used to merely overcome data deficits. The first attempt of this type was probably the one of Birkin and Clarke (1988) and one recent example can be found in Nakaya et al. (2007). Such models just solve a part of the problem that we confront, the set up of a micro-population, but they use it in the context of traditional methodologies. In this sense they can actually not be called agent-based, even if agents are somehow defined and used. Since then, only in recent years fully implemented versions of retail markets models appeared. Most of them are using the agent paradigm to give a detailed representation of customer behaviour. More interesting are proper simulation experiments. The two sides of retail markets, supply and demand, are usually not both represented as agents, typically only consumers are. In this vein of work, Happendal et al. (2006) use a hybrid approach were the petrol market is represented by combining an agent-based approach for the supply side and a spatial interaction model for the consumer side. Individual petrol stations are represented as agent-objects and supplied with knowledge of their initial starting price, production costs and the prices of stations within their neighbourhood. The location of an outlet is considered as fixed and retailers are allowed to react to the sales only by adjusting their price to competitors’ prices, which are considered known. The problem of the location is not directly tackled but the model successfully reproduces consumer’s spatial choices observed in real markets and also the profitability of single retail outlets in the long term. In the market used as a case study in this paper the product sold
can be considered homogeneous, which is an advantage, but also a limitation. The lack of complex trade-offs typical of many other retail markets is of course a considerable simplification, but the representation of a composite retail market, where an entire array of products would be available to the customers, would imply a substantial modification of the model. Schenk et al. (2006) use a micro-simulation approach to model the shopping behaviour of inhabitants of an entire region of northern Sweden. Also in this case the agents of the simulation are only modelling the demand side, here at the household level. Nevertheless, the model is accurate and the supply side is modelled with a high spatial resolution. In particular it is one of the few examples were prices are taken into account in order to characterise a retail store. The family agent is described with the socio-demographic attributes of its components and by some family specific attributes such as size and income. Agents can select the stores by evaluating a bundle of attributes such as distance from home and work, location in the agglomeration, price, assortment, quality etc. The simulation is implemented using the SeSAm multi-agent simulation shell (www.simsesam.de), and the model is tested comparing the calculated with the simulated turnovers of the stores. Another example of application of multi-agent simulations to retail markets is van Leeuwen et al. (2007). A discussion about possible applications of micro-simulations in spatial analysis is followed by a small scale simulation example. However, the simulation exercise is conducted “by hand” and, again, only the consumer side, in this case at the household level, is described by agents.

In Lombardo et al. (2004), both sides of a retail market have agent-based descriptions. The multi-agent system is integrated in a GIS. The aim of the consumers is to reach the stores with minimal generalized costs. The aim of retailers is to maximize their profit. Shortcomings of this work are the summary description of both agents (basically within an agent type they are completely undifferentiated) and the simple way in which the environment is depicted (only eight macro-zones with few links connecting them in which 80.000 consumers and 12.000 retailers are allowed to evolve).

Another stream of work tries to integrate land use with transport models and has already a relatively long tradition; some older works of that kind are DRAM/EMPAL (Putman 1983) and TRANUS (De la Barra et al. 1984). Recently land use-transport models have moved from aggregate models of various types to discrete choice logit models and more recently toward disaggregated, activity based models. Recent examples are UrbanSim (Waddell 2000, 2007) ILUMASS (Wegener 1999, Beckmann et al., 2007) and the work of Arentze and Timmermans (2000, 2007). In the case of ILUMASS for example, where all actors of the different markets (land, work, retail) were represented as agents, the project ended without matching the initial objectives. The simulation tool, especially the transport module, was too heavy. A simulation of the Dortmund region, the final goal of the project, was never performed and
only small test scenarios were run. A complete report on its development, its achievements and its failure can be found in Wagner and Wegener (2007). UrbanSim applications have not experienced such problems, but a fully agent-based implementation is not yet realized and not the actual goal of the efforts. Arentze and Timmermans (2005) presented a multi-agent model of consumer behaviour which, besides the structural attributes of and the distance to the store, also includes opening hours as part of the institutional context of the shopping destination choice. Later (Arentze and Timmermans, 2007), they provide probably the only fully implemented example of an integrated land use- and transport model where both, retailers and customers, are modelled as agents. For the customers’ side the model makes use of ALBARTROSS (Arentze et al., 2000) an activity scheduling model which generates a day plan for each agent of the simulation. The supply side is made up of facilities which are classified according to different demand types and sectors. Moreover, it distinguishes among three structurally different facilities: elementary (only one activity is possible), mixed (the sum of several different elementary facilities in the same place) and higher level (several elementary facilities organized in a “higher level” structure, allowing also activities not possible in elementary facilities). For each demand sector an agent controls the development of the facilities network, with sub-agents controlling the development of a certain type of facility in the sector. The agents seek a location for the facility using a catchment area analysis. Once facilities are located the simulation allocates the demand and supply agents are allowed to rearrange their facility. A test case, where a mid-size town is simulated, shows that the model is able to reproduce reasonably well location patterns of suppliers and a sensitivity test shows that the model correctly react to modification of main parameters.
4 An agent-based model of retailers in MATSim-T

In the current implementation of MATSim-T (Multi Agent Transport Simulation Toolkit) (www.matsim.org) only individuals are modelled as agents. The other actors interacting with individuals in the system (e.g. firms, retailers, planners, developers, public authorities, etc.) have a static representation, which is the typical approach in agent-based travel demand simulations. Nevertheless, in principle all those actors can be represented as agents and be allowed to interact dynamically with the individual agents in the simulation. This is not only possible but also desirable since interactions between the different actors of the system are of dynamic nature and interdependent at various levels. In case of retail markets suppliers (retailers) and individuals (consumers) are the players of this interaction. Customers, choosing the location of their shopping activities, determine economic viability of stores and congestion in the system. Retailers, by the mean of different location strategies (in the wider sense of the term, see Hernandez, 2004), influence the location choices of the customers (Lombardo et al., 2004; Timermans and Arentze, 2007). Moreover, compared with traditional approaches, the microscopic one allows representing the heterogeneity of the decision makers in the system.

As a first step to a fully agent-based representation of the simulated world a new agent type for retailers is introduced. The main scope is to correctly reproduce the location choices of retailers and to recognize in the model system how such choices and shopping location choices of individuals are mutually interdependent. In the future, other typical choices of retailers, such as price policies are modelled. The creation of a new module - implemented in Java code - specifies all attributes and the functionality of retailer agents. In addition, the representation of the customers has to be enriched with respect to shopping. The main goal of this section is to present a conceptual model of the agent-based retailers and to discuss the issues arising with their introduction into the MATSim-T toolkit.

4.1 MATSim-T overview

So far, MATSim-T is basically a fast microscopic transport model, where the supply side is modelled as fixed constraints of the system. The core idea of MATSim-T is that each single actor of the transport system, both on the supply and the demand side, can be simulated. In the current version of MATSim-T each traveller of the real system is modelled as an individual agent in the simulation. The agents are able to take decisions, according to given informa-
tion and coherently with a predetermined goal. Another assumption is that transport is for individuals a derived necessity, in relation with the primary need of individuals to perform certain activities during the day. Therefore, for each agent a so called plan is generated. One plan contains information on activities that are planned by an agent for a certain time span, typically one day. Not only activities are listed, but it is also specified where and when those activities will be performed, and which mode of transport will be used to reach the different locations. More details can be found in Ciari et al. (2007) and Meister et al. (2008). The plans are executed simultaneously in the traffic flow simulation. Agents are able to learn. Several plans for each agent are retained, given a score, and compared. The agents keep the plans with the highest scores, while creating new plans based on their previous experiences. Note that in this decision-execution process there is interdependency since decisions are conditioned by traffic conditions and traffic conditions are definitely dependent on agents’ decisions in turn. This creates an iterative process in which the agents are learning from the simulation outcome in order to obtain better scores for their plans. The system iterates between plan generation and traffic flow simulation until a relaxed state is reached.

Among the literature on micro-simulations - increasingly abundant in recent years - a group of studies to which MATSim-T can be compared is the one based on activity-based demand generation. Several examples of implemented simulations of this kind can be found, such as (Bowman et al., 1999; Arentze et al., 2000; Vovsha et al., 2002; Bhat et al., 2005; Abraham et al., 2005). However, most of them are able to produce results like origin-destination matrices which are then used to dynamically assign the traffic to the network. An exception to that is TRANSIMS (2008), which generates individual activity plans as input to dynamic traffic assignment packages (see Axhausen and Gärling, 1992, for an older implementation of this approach). A more detailed comparison of TRANSIMS and MATSim-T can be found in Balmer et al. (2007). Another vein of agent-based modelling works where similarities with MATSim-T can be found is agent-based land use models; an example is ILUTE (Salvini and Miller, 2005).

MATSim-T’s most prominent application is a simulation of the travel behaviour of the whole Swiss population, which means to apply the agent paradigm to as many as 7.6 millions of individuals. Socio-demographic attributes, like age, gender, driving license ownership, employment, etc., are generated and assigned based on the Swiss census data (ARE & Bfs, 2001). The base network is the one of the Swiss national model (Vrtic et al., 2007) with 24,000 nodes and 60,000 links, but networks with a higher resolution are also available. With a computer equipped with 4 dual core processors (2.2 GHz frequency each) a relaxed state is obtained with ca. 100 iterations, which means about 3.2 days (around 80 hrs) of computing
time. Results are completely disaggregated and analysis can be performed at any level of resolution in space and time, and for any individual agent.

4.2 Individuals

All current agents of MATSim-T represent individuals. They are described by a group of sociodemographic attributes (age, gender, employment, driving license ownership, home location, etc.). Agents can choose the time when to leave from home, the transport mode to travel with and the route to concatenate all activities. Currently, there are five different activity types: home, work, education, shop and leisure. Note that some activities, namely home, work and education, in principle are always performed in the same facility (for a given agent), while the others (shop and leisure) might be performed at any facility where the agent is allowed to do so. The location choice for these latter activities is now modelled in a very simple way and another ongoing work, being developed parallel to this one, aims to improve it. There, the activity location choice will be optimised according to distance, time and capacity of the facility. The knowledge of an agent is limited to the plans already simulated and scored. Basically, the score of the current plan and those of a certain number of previous plans (simulated at a previous iteration) are compared. The objective of the agent is to maximise this score, where the only variable taken into account is time, with a positive value when it is spent in an activity and with a negative value when it is spent to travel. More details on the demand generation in MATSim-T and on agents are described in Ciari et al. (2007) and Balmer et al. (2008) respectively. Thus, the current description of individuals in MATSim-T is already rich, but does not take into account their consumer aspect, and it will need to be modified. First, agents will have an income and, consequently, a monthly budget for retail expenditures. Their knowledge will be also enhanced accounting for the price level of the stores and for the presence of parking facilities. The objective function will be also modified, monetary cost explicitly considered, and agents will seek for the maximum satisfaction within the budget constraint. Furthermore, the specification of activities will be also refined and, in particular, shopping activities differentiated according to predefined retail sectors.
4.3 Retailers

The scope of the model is to reproduce the location behaviour of retailers. In the model system activities may be performed in different places called facilities. Each facility is an entity with following attributes: type, location, capacity, opening time, closing time. In a single facility one or more activities of different types can be performed (leisure, shopping, work). Each activity type of a facility contains 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 here lies on shop facilities, interpreted as a retail store. Therefore the retailer agent is represented as the decision maker having the control on a certain number of shop facilities. The retailer agent does not necessarily represent an individual (i.e. the owner of the shop) but for example it might also be the board of a retail chain. This entity will be provided with at-
tributes, knowledge, one or multiple objectives, a strategy to pursue it, a methodology to implement this strategy and a group of allowed choices. So outlined, the retail agent is consistent with most of definitions of agents in the artificial intelligence literature, for example the one given by Ferber (1999), where an agent is defined as a

“real or virtual entity which is capable of acting in an environment, which can communicate directly with other agents, which is driven by a set of tendencies (in the form of individual objectives or of a satisfaction/survival function which it tries to optimize), which possesses resources of its own, which is capable of perceiving its environment (but to a limited extent), which has only a partial representation of its environment (and perhaps none at all), which possesses skills and can offer services, which may be possibly be able to reproduce itself, whose behaviour tends towards satisfying its objectives, taking account of the resources and skills available to it and depending on its perception, its representation and the communications it receives.”

In the model system all type of shops are undifferentiated. In the new representation they will be described with attributes like: type, amount of needed daily/weekly turnover per square meter, price level, jobs per shop/square meter, income per worker, facility portfolio. Each of the facilities controlled by one retailer will have some attributes in turn, such as: type, capacity, location, etc. The knowledge of a retail agent will be in principle of two types; knowledge of customers and knowledge of competitors. The model considers that the first is imperfect, the knowledge about customers will be limited to the number of individuals living in a determined area or passing through a given link of the network. However, as in Timmermans and Arentze (2007), the retail agent knows how many customers have shopped in one of his stores upon certain assumptions after each iteration. The retailer will be able to see the competitors, their positions and price levels within a predefined neighbourhood. The choice of a new location will be effectuated taking into account such information, but it will be considered that choices of retailers will be simultaneous. Another information which will be added as retailer’s knowledge is the land use regulation. Only land suitable for commercial use will be allowed as a new location. The objective for a retailer agent will be the maximisation of revenues, but we could also test other possibilities like the maximisation of the market share or simply the number of customers. The pattern the retailer intends to follow in order to meet his own objective in the long run constitutes the strategic level. Since the focus lies on the location choice, the strategic level coincides with the territorial expansion planned by the retailer. This has a meaning at the regional or at the national scale, while here simulations will be rather run at the metropolitan level, at least at an initial stage. Moreover, the interviews with German and Swiss retailers have shown that neither contagion or hierarchic expansion patterns are particularly used in practice. Therefore, at first this level will be neglected. In any
case, more general, the strategic level could also be extended to other policies such as price or advertising level. The methodological level is the way the retailer will effectuate the choice, in this case the location choice. The market support analysis will be the technique used by retailer agents. This technique is simple but still used in practice by retailers (Birkin et al., 2002; Rogers, 2007). Retailer’s choices at a first stage will be limited to the location, but other choices will be allowed in the future work, such as changing the price level or opening times.

Figure 2  Retailers agents

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Location choice methodology</th>
<th>Objective function</th>
<th>Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Market support analysis</td>
<td>Maximise revenue</td>
<td>Customer</td>
</tr>
<tr>
<td>Needed turnover</td>
<td></td>
<td>Maximise market share</td>
<td>Competitors</td>
</tr>
<tr>
<td>Price level</td>
<td></td>
<td>Maximise customers</td>
<td>Land use regulation</td>
</tr>
<tr>
<td>Jobs per shop</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Income per worker</td>
<td></td>
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<tr>
<td>Facility portfolio</td>
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</tbody>
</table>

4.4 The new retailer module in MATSim-T

The retail market model is similar to the model defined by Timmermans and Arentze (2007), not only because the model is structurally similar, but also because it is conceived to seek a stable equilibrium in the facility location/facility usage interaction, while other integrated land use-transport models are seeking a time path. The optimisation of the supply/demand side will be separated, at least in the first stage. The retailer module will be integrated in MATSim-T outside the main loop, in which the demand is optimised. More precisely, we estimate the initial demand for a given scenario and then we feed the optimisation tool with this demand. The optimised demand is put in the retail module as input and the retailer agent will
try to improve their location choice. This produces a new scenario, which is given back to the
optimisation tool in a loop which stops when either a relaxed state or a fixed number of itera-
tions is reached (Fig. 3).

Note that to implement the described cycle one does not need to overcome any particular dif-
ficulty related with the input/output formats, since both input and output are in the form of an
xml file. In fact, this characteristic of MATSim-T makes it, from a technical point of view,
particularly easy to introduce new modules.

Figure 3  Loop for the retailers module

Source: adapted from Balmer et al. (2008)
4.5 Conclusions

The model sketched provides a rich description of retailers and updates the modelling of individual agents taking into account their customer aspect. Results of the simulation are expected to reflect an equilibrium between retailers and individual agents’ choices. With the implementation of this model the interactions between the supply and demand side in the retail location should emerge from the simulation. This aspect is of particular importance, the agent-based approach gives us the possibility to describe the agent of the system at the microscopic level and to detect behaviours at the macroscopic level which would be not expected considering single agents’ actions. It is a powerful instrument in the hands of the modeller, but needs also to be used with caution. The construction of a comprehensive model of this type to describe real life events is only a part, if important, of the work. Other experiences, like the one of ILUMASS (Wagner and Wegener, 2007), tell that really complex models are not only hard to implement, but also that results are completely reliable only if the model is accurately tested at each stage of its development. This is planned for the next stage of work, where the functionality of the model will be tested implementing a really simple version of it, and running it on a small test scenario. This approach ensures that the system reacts as expected at the small scale and that there is a reasonable calibrated model for applications at a larger scale.
5 Summary and Outlook

This paper reports on an ongoing project aimed to introduce a model of retail markets in the agent-based traffic simulation toolkit MATSim-T. It will be done by introducing a new retailer module in the toolkit, representing retailers as agents. The new module’s main goal is to reproduce the location choices of retailers and recognize how such choices and shopping location choices of individuals are mutually interdependent. A review of the literature on retailers’ location choice has been presented and it is part of the theoretical background on which the new retail agent is constructed. Internationally, retailers have increasingly used more sophisticated computer based location techniques over the last two decades. But also older and simpler methodologies are far to be fallen into disuse. The literature review has been enriched with the results of a series of in-depth interviews, which have been conducted with retailers of various sizes and product groups in Germany and Switzerland in the winter of 2008. The results reveal that there is a huge variety of location strategies both between and within the different retail sectors. Moreover, location choices are heavily based on experience and intuition, particularly those decisions at the micro scale.

A model for retailers has been sketched and the main issues integrating it in MATSim have been discussed. The next stage of this work will focus on the implementation of the model and on its testing. First, an implementation will be run on a simple test scenario. Once the functionality of the model has been demonstrated we will step up to (more sophisticated and) realistic as well as larger scenarios, like the Zurich area. In later stages of the project, it is planned to run simulation tests with different possible implementations of a road pricing scheme and to evaluate the results based on the hypothesis given in this paper.
6 References


