

## **New Shopping Centres and Retail Supply Quality: A GIS based Micro-Analytical Model**

Carsten Schürmann  
Research Assistant  
Institute of Spatial Planning, University of Dortmund  
D-44221 Dortmund, Germany

### ***Abstract***

Retail supply planning processes usually look at demand sides from purchasing power perspectives, but the fact that from a customer's perspective retail supply quality is a value as such is often neglected. On the one hand this might be intentionally, on the other hand this might be due to methodological deficits on how to measure retail supply quality. The model presented in this paper shifts the perspective to pay more attention to the customer's side and, moreover, offers a quantitative way in calculating supply quality on a spatially disaggregated level.

### ***Introduction***

During the last few years great structural changes with respect to size and quality of retailing facilities took place in Europe. Similar to American examples, new shopping centres had been constructed at the urban periphery with thousands of square metres of floorspace. In many cases, only economic risks for the companies and – to some extent - effects on the labour market are calculated, but only exceptionally the improvements or deterioration of the retail supply quality from a customer's perspective are considered.

Such a customer's perspective should be also the municipalities' perspective by planning or approving new shopping centres. Until now, there have been great uncertainties by the authorising authorities about the impacts of new retailing facilities, mainly because of a

lack of easy-to-use quantitative methods for the evaluation of impacts of new shopping centres.

This paper is a contribution to overcome these methodological deficits. The approach presented here is based on a retail supply quality gravitation model developed by Bökemann (1982), which models quality of retail supply as a function of distance and floorspace of shops.

The approach developed is applied to Hombruch, which is a suburb in the south west of Dortmund with about 58,000 inhabitants and an area of some 35 km<sup>2</sup>. On a formerly industrial location area a private developer plans a new shopping mall with about 8,000 m<sup>2</sup> floorspace. Comparing this area with the current available floorspace area of about 54,000 m<sup>2</sup> for the entire district, the project increases the total floorspace area of about 115 percent.

The impacts of the new shopping centre are simulated by calculating the retail quality prior and after its realisation. Because one has to assume under market conditions that after opening a new centre some closures of existing smaller shops will occur, a retail turnover expectation model according to Lakshmanan and Hansen (1965) has been applied to define future supply, i.e. to identify those shops which will probably have to close down.

The combination of the both models leads to the following procedure:

1. Calculation of current supply quality.
2. Calculation of current sales of existing shops.
3. Calculation of future sales including existing and new shops, if necessary by using different scenarios.
4. Estimation of development of sales by comparing results of steps 2 and 3 to predict closures of shops.
5. Calculation of future retail supply quality.
6. Estimation of differences in supply quality by comparing results of steps 1 and 5 to obtain information on benefits or deteriorations.

### **Methodology**

According to Bökemann (1982), the retail supply quality is defined as the sum over all shopping centres' specific attractiveness which affect the residence areas. Shopping centres' specific attractiveness itself means the attractiveness of one single shop for one residential building.

The attractiveness depends on the distance between the shop and the residential building and on the shop's floorspace. It is assumed, that (i) the larger the floorspace the higher the attractiveness, because of a increased variety of goods in larger shops, and (ii) that the greater the distance the lower the attractiveness, because it is more time-consuming to reach the shop.

In mathematical terms, the attractiveness  $A_{ij}$  of shop  $j$  on residence  $i$  is defined as

$$(1) \quad A_{ij} = F_j^\alpha C_j f(d_{ij})$$

where  $F_j$  is the floorspace of the shop,  $\alpha$  represents an empirically derived floorspace weighting factor which takes account of the fact that there is no linear relationship between the floorspace and the benefits for the customers. This means, comparing two shops with 500 and 1,000 m<sup>2</sup>, respectively, that the benefits of the greater one are not twice but for instance 2.2 times higher. In this study it is assumed that the value of  $\alpha$  is 1.2.  $f(d_{ij})$  represents the distance decay function and  $C_j$  is the concentration index. This index reflects the fact that one single shop offers greater attractiveness to the customer if it is surrounded by other shops than if it is remotely located. Equation 2 then gives the concentration index:

$$(2) \quad C_j = \frac{\sum_k F_k f(d_{jk})}{\sum_j \sum_k F_k f(d_{jk})}$$

with  $[0 \leq C_j \leq 1], k \neq j$

The concentration index is calculated as the sum of all floorspaces of all shops  $k$  weighted by the distance from shop  $j$  over all other shops  $k$ , divided by all distances weighted by the floorspace between all shops (Schürmann 1996; 1999).

The retail supply quality  $V_i$  of residence  $i$  is then calculated as the sum of all attractivenesses over all shops  $j$ :

$$(3) \quad V_i = \sum_j A_{ij}$$

The distances could be based either on airline distances (with or without detour factor) or real network distances. If airline distances are used, mode specific delay factors should be applied to differentiate between pedestrians, cyclists, public transport users and car drivers (a detailed description of the mode specific delay factors gives Schürmann, 1996).

In this study airline distances including detour factors with mode specific delay factors based on a transport survey (EMNID 1991) are applied. The overall retail supply quality is defined as the logsum over all these modes.

The equations described above are used to model the current and future retail supply quality (see step 1 and 5 of the procedure). To calculate current and future sales of the shops, a retail turnover expectation model according to Lakshmanan and Hansen is developed.

The mathematical form of this model is expressed as follows:

$$(4) \quad S_j = \sum_i P_{ij} K_i I_i$$

where  $S_j$  represents the sales of shop  $j$ ,  $P_{ij}$  represents the share of the income which shop  $j$  gains from residence  $i$ ,  $K_i$  represent the absolute purchasing power per capita in  $i$  and finally  $I_i$  gives the number of dwellers in residential building  $i$ . In this model,  $P_{ij}$  is estimated by the attractiveness  $A$  of shop  $j$  for building  $i$  divided by the sum over all attractivenesses.

$$(5) \quad P_{ij} = \frac{A_{ij}}{\sum_j A_{ij}}$$

The Dortmund-specific purchasing power is based on surveys by GfK (1996) with some slight modifications (Kruse 1996). A value of about 9,700 DM per capita per year is assumed.

### ***Implementation***

This model is implemented by using a GIS based micro-analytical model. Unlike other approaches, which consider entire districts or blocks as the smallest spatial unit both on the supply side (retailing facilities) and on the demand side (residential areas) (Bökemann 1983, Kagermeier 1991), this approach incorporates a spatially disaggregate database in which every residential building serves as an origin and every single shop serves as a destination in the distance function.

Both the residential buildings and the shops are given with their location (x-/y-coordinates) in the GIS database. Additionally, information on floorspace and on branch are assigned to the shops, while the number of dwellers is assigned to the residences. As stated above, airline distances are used. No network information are employed at the moment. Beyond that, for the retail turnover expectation model only information on the purchasing power per capita are required additionally.

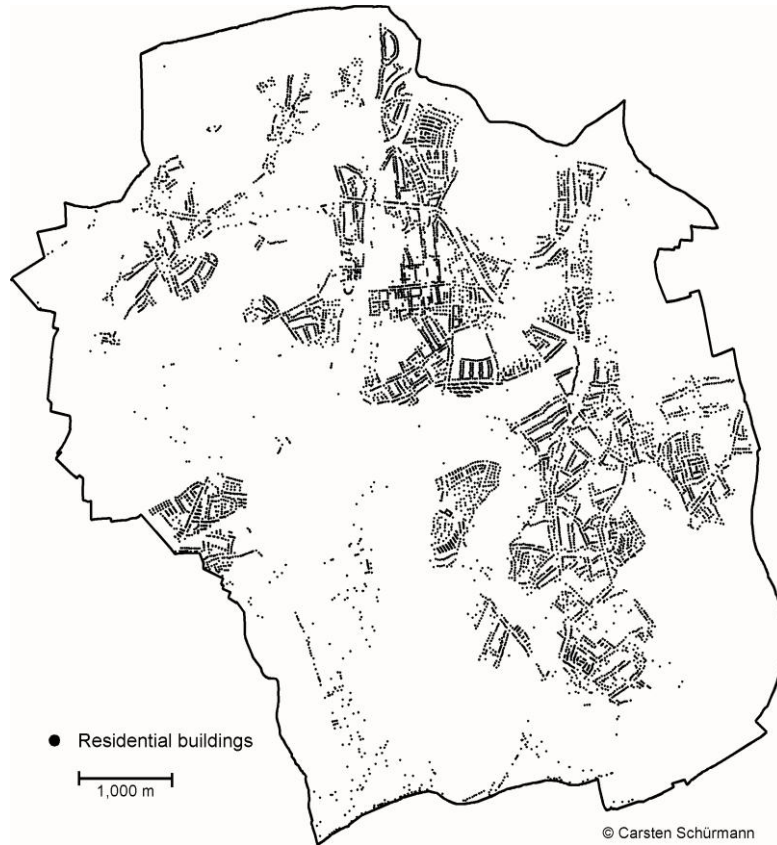
The database necessary to run the retail supply quality model in its simplest form is rather small. All data is available from the municipality's statistical offices and needs not to be gathered elsewhere. Table 1 summarises the data requirements (including potential refinement data in italics).

*Table 1. GIS database.*

Data fields	Information
Supply side	Location (x-/y-coordinates) Floorspace <i>Branch</i> <i>Branch-specific floorspace productivities</i>
Residential buildings	Location (x-/y-coordinates) <i>Number of dwellings</i>
Population	Number of dwellers per building Purchasing power index <i>Socio-demographic indices (age, sex, etc.)</i> <i>Car-ownership</i>
Transport networks	Mode specific delay factors <i>Road network</i> <i>Public transport network</i>

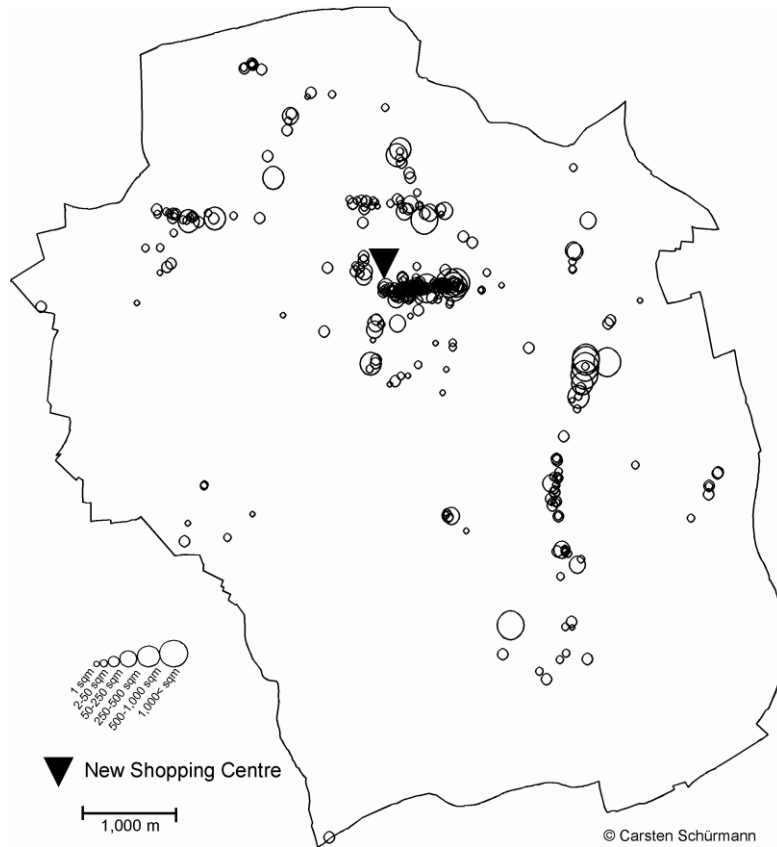
### ***Case Study of Dortmund***

Figures 1 and 2 illustrate the GIS database. Each dot in Figure 1 represents one residential building. Figure 2 displays the distribution of retail facilities within Hombruch. Most of the shops are located in the district's centre along the pedestrian mall. Additionally, two more significant locations are visible. First, in the north-west; second in the eastern part along an important north-south orientated arterial road.



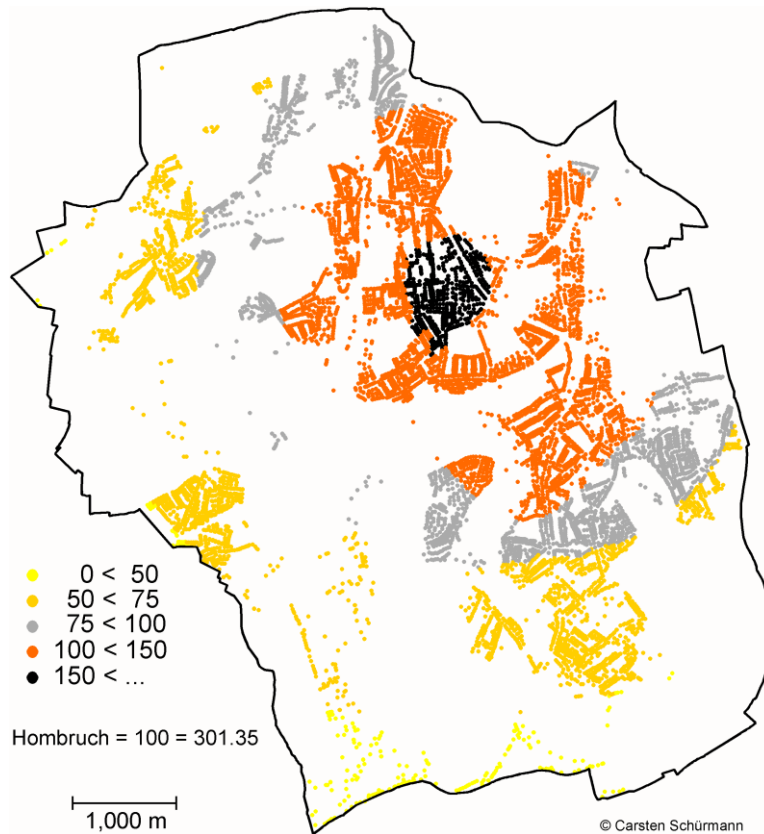
*Figure 1. Residential buildings in Dortmund-Hombruch.*

Figure 3 shows the standardised retail supply quality over all modes prior to the opening of the new shopping centre as an example of the outcomes of the model application. It can be seen that residential buildings in the centre of the district show the highest values with more than 175 percent of the average. In general, the more you turn to the periphery, the lower are the values the buildings obtain.



*Figure 2. Retail facilities in Dortmund-Hombruch.*





*Figure 3. Current retail supply quality over all modes.*

Because Figure 3 illustrates the results for dwellings only, but beyond the consideration of buildings the affected people are of interest, Table 2 summarises the outcomes for all transport modes on a more aggregate level. It is obvious, that the greatest differences in the distribution over all classes occur for pedestrians. Although 31,270 people, i.e. 57 percent of all inhabitants, experience a retail supply quality below the average, the class with more than 175 times average shows the greatest scorings with 13,475 people (23 percent). Summarising, there are great disparities in retail supply quality for

pedestrians. Considering the other modes, these disparities decrease the faster the mode is. For cyclists, the overall structure looks quite similar to the pedestrians' structure, but with slightly higher scorings in medium classes. For public transport, the lowest and the highest classes are not scored at all. Similarly, for cars the two lowest classes are empty.

*Table 2. Inhabitants per class prior to opening of the new centre.*

Classes	Transport modes								All modes (logsum)	
	Walking		Cycling		Publ. transp.		Cars			
	abs.	%	abs.	%	abs.	%	abs.	%	abs.	%
< 25	9,713	16.6	3,803	6.5	0	0.0	0	0.0	0	0.0
25 < 50	12,756	21.8	10,243	17.5	376	0.6	0	0.0	952	1.6
50 < 75	5,851	10.0	9,287	15.9	7,964	13.6	8,343	14.3	12,617	21.6
75 < 100	2,950	5.0	5,289	9.1	14,554	24.9	17,210	29.5	13,017	22.3
100 < 125	7,569	13.0	6,042	10.3	31,797	54.4	24,117	41.3	14,643	25.1
125 < 150	4,412	7.5	7,549	12.9	3,706	6.3	8,727	14.9	12,224	20.9
150 < 175	1,671	2.9	3,927	6.7	0	0.0	0	0.0	4,944	8.5
175 <	13,475	23.1	12,257	21.0	0	0.0	0	0.0	0	0.0
3	58,397	100	58,397	100	58,397	100	58,397	100	58,397	100
Mean	109.55		210.21		465.74		419.91		321.44	

Parallel to decreasing disparities, the average increases from about 109 for pedestrians to about 420 for cars. Considering the totals, i.e. the logsum, the highest scorings are obtained by medium classes.

The analysis of the development of sales has been performed by applying four scenarios. The base assumption for all the scenarios is, that the new shopping centre will operate profitably because of its specific, up-to-date production factors. The other assumptions behind the scenarios are as follows:

- Scenario 1: Constant overall sales with increasing number of shops.
- Scenario 2: Constant overall sales with increasing number of shops with increasing purchasing power binding shares.

- Scenario 3: Growing overall sales (caused by new inhabitants) with increasing number of shops.
- Scenario 4: Growing overall sales (caused by new inhabitants) with increasing number of shops with increasing purchasing power binding shares.

The common results of all scenarios is, that for about 30 shops decreasing sales of more than 25 percent can be predicted. It is assumed, that these shops will close down sooner or later. Figure 4 shows future retail supply quality after running the model once more.

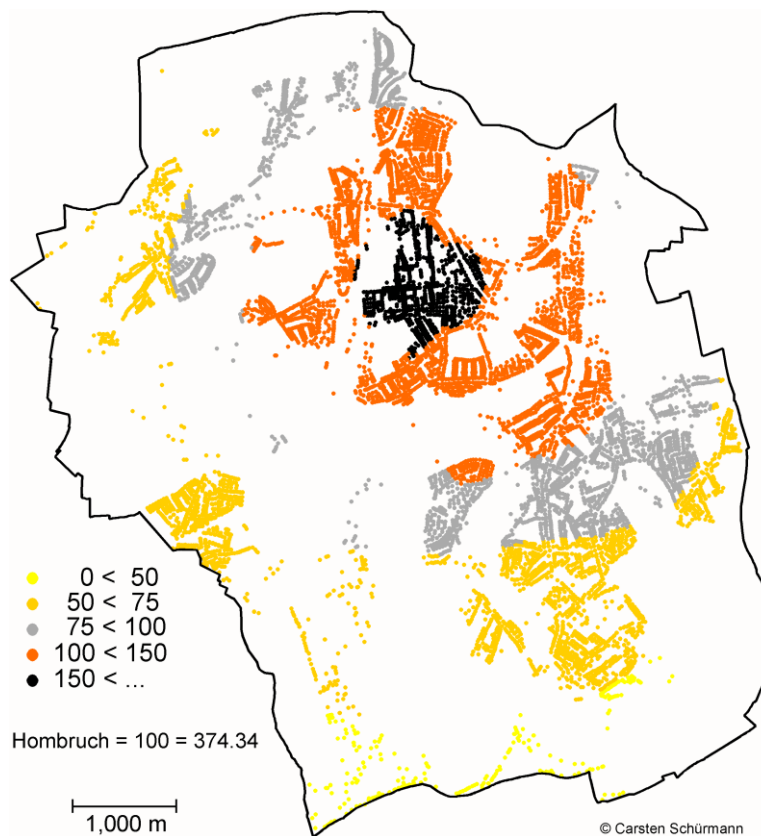


Figure 4: Future retail supply quality over all modes.

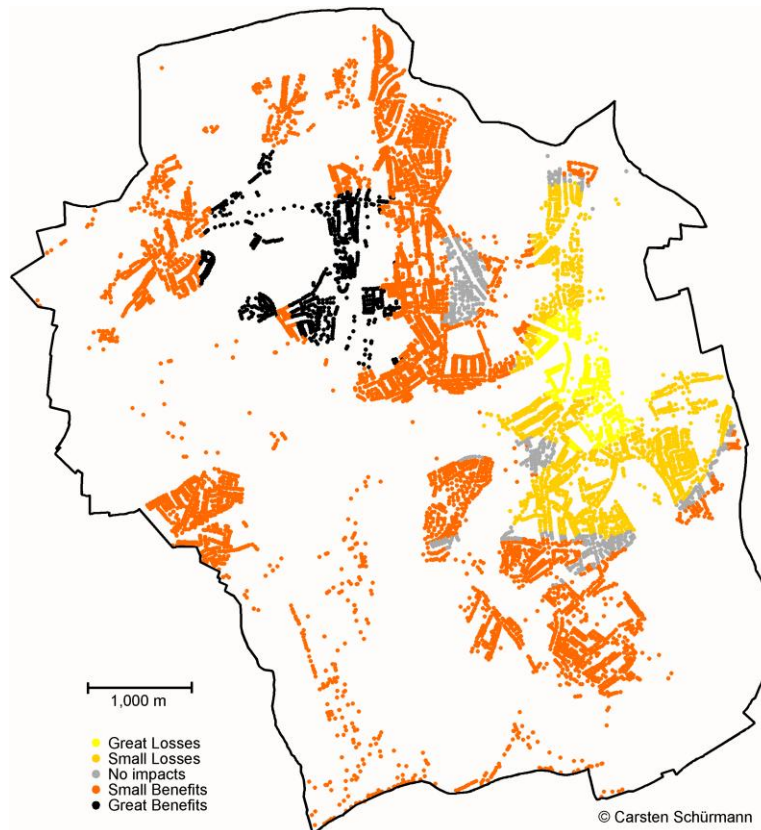
As a first result, the overall average retail supply quality increased after opening of the new shopping centre (Table 3). The observation of decreasing disparities due to faster mode speeds is also true. However, in detail the number of pedestrians with a retail quality below the average stays almost the same, the number of public transport users below the average increased just as the total number of inhabitants with a quality below the average level. This means, the shopping centre has no real equalising impacts, which might be a political goal under aspects of justice.

*Table 3. Inhabitants per class after opening of the new centre.*

Classes	Transport modes								<i>All modes (logsum)</i>	
	Walking		Cycling		Publ. transp.		Cars			
	abs.	%	abs.	%	abs.	%	abs.	%	abs.	%
< 25	8,729	14.9	4,232	7.2	0	0.0	0	0.0	0	0.0
25 < 50	14,352	24.6	10,184	17.4	697	1.2	0	0.0	1,087	1.9
50 < 75	5,512	9.4	9,287	15.9	5,089	8.7	6,053	10.4	12,637	21.6
75 < 100	2,574	4.4	5,397	9.2	15,672	26.8	19,646	33.6	14,282	24.5
100 < 125	5,885	10.1	2,932	5.0	34,746	59.5	21,859	37.4	12,005	20.6
125 < 150	4,735	8.1	9,664	16.5	2,193	3.8	10,839	18.6	11,048	18.9
150 < 175	2,242	3.8	5,331	9.1	0	0.0	0	0.0	7,338	12.6
175 <	14,368	24.6	11,370	19.5	0	0.0	0	0.0	0	0.0
3	58,397	100	58,397	100	58,397	100	58,397	100	58,397	100
Mean	134.90		259.96		579.99		522.52		362.70	

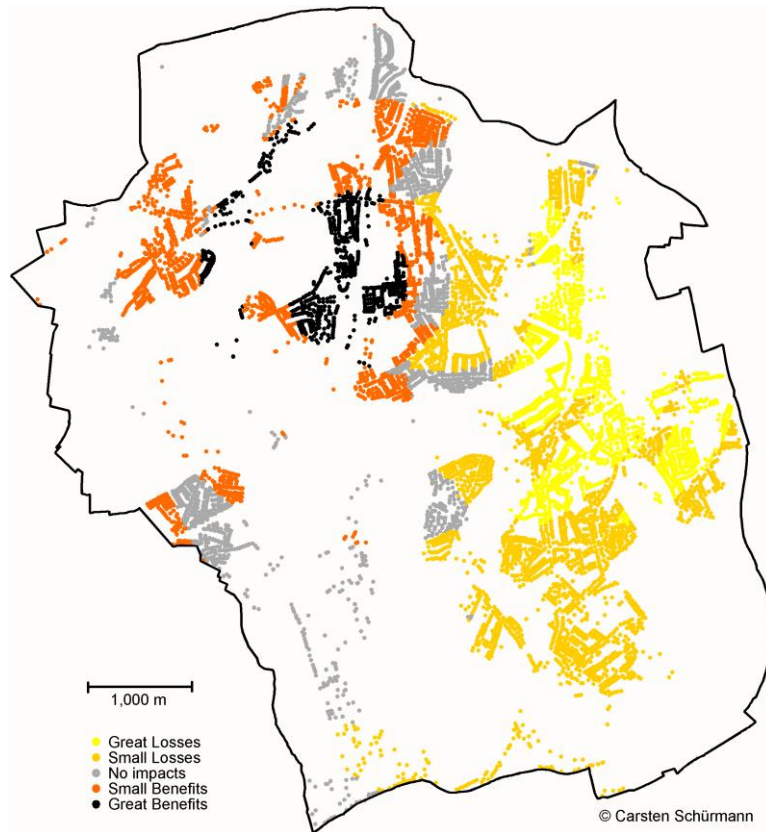
What does this general conclusion mean for the spatial distribution? Which residential areas benefit and which deteriorate? Figure 5 illustrates the changes for the residential sides in absolute values for walking.

As suggested, only very few buildings deteriorate, mainly in the south-east of the district. This is not very surprisingly as the overall average increased. For comparisons, if relative changes (all modes) are taken into consideration (Figure 6), it becomes clear, that the whole eastern part of Hombruch deteriorates, while the western part gains profits, although there are some closures of smaller shops.



*Figure 5. Absolute differences of retail supply quality for walking.*

As Table 3 shows, the general level (average) of the supply quality is increasing for all modes. This observation in combination with higher scorings in classes above the average suggests general improvements of supply quality. Taken Figure 5 into account, this observation must be qualified in the sense, that indeed there are residential areas, i.e. numbers of inhabitants, which experience absolute losses in retail supply quality for walking or cycling. Moreover, relative losses in supply quality for all modes (Figure 6) can be observed for almost half the district.



*Figure 6. Relative changes in retail supply quality over all modes.*

### ***Conclusions***

The theoretical base for estimating retail supply quality presented in this paper is well established (Bökemann, 1982), but until now for various reasons the model has not been implemented on a spatially disaggregate level. However, now the distribution of GIS technology over the municipalities and GIS techniques themselves reached a level where methodological procedures are indispensable - also in

the field of retail quality. The progress in GIS techniques allows the development of disaggregate, easy-to-use applications to estimate the impacts of new shopping centres on a house-by-house basis, which can be applied by the municipalities themselves. This leads to greater independence of municipalities from developer companies in the question of how to appraise the impacts of new retail facilities.

In the past, retail trade concepts considered customers or residential areas only from the perspective of purchasing power, and neglected the fact that from a customer's view retail supply quality is a value as such. This method shows a way to combine both perspectives. It allows the identification of residential areas with a low level of retail supply quality, makes plain the spatial pattern of purchasing power as well as the purchasing power flows and finally give hints on location, size and branch of new retailing facilities.

The advantage of this method is that the retail supply quality for every residential building, i.e. for every inhabitant, can be modelled separately, i.e. that the consequences of market changes can be estimated on an individual base. Moreover, this advantage has even more importance if this model is integrated into disaggregated micro-simulation models, for instance in simulating shopping trips in a wider context of daily trip modelling.

Briefly, the advantages of this new analytical model are:

- *Disaggregation:* Applying a micro-analytical model on a house-by-house basis.
- *Database:* Only a modest database is required. However, the method is open for further refinements. The required database is usually maintained by the municipalities themselves.
- *Application:* The model is applicable either for all shops over all branches (as it is presented here) or for shops of one specific branch only.
- *Retail quality:* It is easy to identify those residential buildings, which have retail qualities below a pre-defined, minimum level.
- *Service quality:* It is also possible to use this approach to estimate service supply qualities as well.

- *Implementation*: The model can either be implemented on each commercial GIS software or with self-written programs. Implementation in commercial GIS software is rather in line with the municipality's abilities, whereas self-written programs could have importance from a scientific perspective.
- *GIS*: The model is characterised by an open structure, which requires only modest demands on the GIS with respect to calculating distances and shortest-path-algorithms.
- *Scenarios*: The model answers 'What, if ...' questions by running possible future scenarios. This easily enables comparisons between different alternatives of retail development.

### ***Refinements***

Possible future refinements to the micro-analytical model as presented here concern aspects of retail probabilities, distance decay functions, branch-specific weightings of the floorspace, differentiating between socio-economic groups and the enlargement to a real micro-simulation model.

#### *1. Retail probabilities:*

Turning around the approach, the probability from residential building  $i$  to buy in shop  $j$  can easily be calculated. In a simple way, this probability is defined as attractiveness  $A$  of shop  $j$  to building  $i$  divided by the sum over all attractiveness' over all shops.

$$(6) \quad P_{ij} = \frac{A_j}{\sum_j A_j}$$

This probability can then be used to model the catchment area of one shop on a house-by-house basis. If all residences with a retail probability of greater than zero are taken into consideration, and all these probabilities multiplied with the number of dwellers of each building are summed up, the maximum possible catchment area  $D$  of shop  $j$  is estimated.



$$(7) \quad D_j = \sum_i P_{ij} I_i$$

Figure 7 shows one example of a probability distribution from one shop for pedestrians.

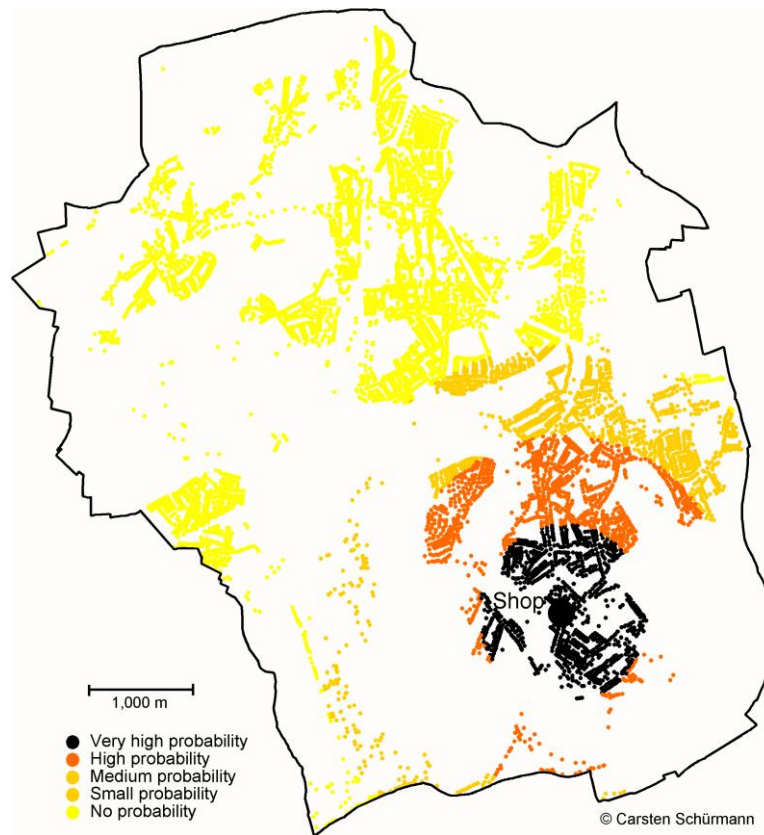


Figure 7. Purchasing probability for a sample shop.

## 2. Distance decay function

The distance calculation should be based on real road and public transport networks to obtain a more realistic view of the retail supply quality.

3. *Branch-specific floorspace weighting*

As presented here, the floorspace is not branch-specific weighted, although it is obvious that the meaning of the same floorspace area for food-shops is totally different from the one for furniture shops. This enhancement can be implemented by adding a new factor into Equation 1 when estimating the attractiveness of a shop. This factor  $\omega_b$  should reflect the branch-specific floorspace weightings, so that Equation 1 is supplemented as follows:

$$(8) \quad A_{ij} = \omega_b F_j^\alpha C_j f(d_{ij})$$

This supplementation requires further information of branch-specific floorspace productivities.

4. *Socio-economic groups*

Differentiating between socio-economic groups is another enhancement to get a more realistic picture. That requires information on age, sex and marital status (Table 1) for each residential building, which are, however, available from the official municipalities statistics. This means, not only the impacts on all inhabitants as a whole are calculated (as presented here in Tables 2 and 3), but the impacts on each socio-economic group separately. In particular this is recommended for the estimation of the catchment areas of shops (Equation 6), which strongly depend on the socio-economic structure of a district.

5. *Environmental impacts*

Only small enhancements are required to estimate environmental impacts of new shopping centres. As one outcome the model determines the retailing probabilities from a residential building to a certain shops. This means the traffic flows between residential buildings and shops can be calculated and above this, using assumption on vehicle types, fuel consumption and car emissions, environmental impacts on people (noise, air pollution) can then be estimated.

6. *Micro-simulation model*

The model as presented here can be seen as a micro-analytical model. However, this analytical model is the basis for developing a real micro-simulation model, because some behavioristical assumptions are included as well (e.g. purchasing probabilities).

On the one hand, these refinements partly enlarge the GIS database (see italics in Table 1), on the other hand they lead to more reasonable, realistic and detailed information about the retail supply quality. In any case, in spite of these enhancements, all the data necessary are available at the official statistics of the municipalities, and so the model is still easy to apply.

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