OPTIMAL LOCATION OF CONSUMER FACILITIES WITHIN A CITY

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1. SOME INTRODUCTORY REMARKS

The alteration of innerurban retailing and service can be divided into two phases: until the mid 1970's the areal pattern of the intraurban commercial centres undergoes some structural alteration. Supermarkets intrude into well established suburban centres or create - as well as hypermarkets - new locations on principal radial routes half-way city-centre. As a rule new planned housing areas are provided with concentrations of establishments at one or two locations with the advantage of multipurpose shopping trips including related activities like recreation or education and facilities of public transport.

Since the mid 1970's energy and economic crisis reverse the development. Urban planning policy restricts the allowances for establishing supermarkets and nearly stops hypermarkets. Instead of developing new locations the reorganization of the city centre as well as high-order subcentres gains priority.

The problem under consideration will be to look for optimal locations for intraurban commercial centres under retail operating constraints, demand requirements and general wellfare aspects. Criteria for optimal locations will be developed in modification of the theory of central places within the city (Warnes/Daniels) and stress the overall accessibility. Each different hierarchy-level has its specific route-choice assumption which also links the hierarchy levels.

Retail centres consist of several shops, areally clustered and with the possibility of multi-purpose shopping. Distances within the centre are negligible against the average distance to reach the centre.

The underlying graph for solving the nested p-median-problems has been chosen so that the nodes correspond to the distinct locations of still existing food-stores and the edges are weighted with the real distances between the nodes.

2. DEFINITION OF THE HIERARCHY

Suppose after categorizing the demand regarding to frequency and specialization one can define standard provision situations (sps) for an average household. Then these sps cause that the greater part of establishments within an agglomeration of shops could be standardized to meet the correspondent demand. The standardization could be used to establish a catalogue for describing hierarchy-levels of centres (Borcherdt).

The left column of Table 1 provides an example for a four-level-hierarchy. It must be stressed that each hierarchy-level has a structural component with necessary facilities and an additive component. The structural component cumulates with rising hierarchy-level, to some extent also the additive component.

3. THEORETICAL LOCATION CONSIDERATIONS

Top of the middle column deals with the key variables for determining the location of consumer facilities. They are used to support the location considerations on the right half of this column. Latter bear some relationship to the theoretical location principles of Warnes/Daniels statet on the left half, but there is no 1-1 correspondence.

4. OPERATIONALIZATION

The operationalization is based upon the representation of the urban road-network as a graph. Its nodes are weighted with demand values, its edges with travel costs (cf. right column of Table 1). The objective function of the nested p-median problem has components which are dependent on each other (e.g.H_3).

5. OBJECTIVE FUNCTION

The general form of the objective function will be

$$\sum_{i=1}^{4} q_i \sum_{r,s} f_i\,(P_r) g_i(d_{r,s})\, \delta_{r,s} = \min$$

with

$$q_i > 0, \quad \sum_{i=1}^{4} q_i = 1$$

f( ) demand function

g( ) travel cost function

$$\delta_{r,s} = \begin{cases} 0 & \text{if } r \text{ does not belong to the catchment area of } s \\ 1 & \text{otherwise} \end{cases}$$

Table 1 : Hierarchy, Locational Considerations and Operationalization

H i e r a r c h y	Locational Considerations	Operationalization
Catalogue of facilities according to Borchardt good/service demand AG I frequent/non-durable AG II infrequent/durable SD seldom/specialized	dependent on - shopping behaviour - operating requirement constraints - public transportation system	N : set of nodes $N \supset H_1 \supset H_2 \supset H_3 \supset H_4$ $(d_{i,j})$, $i,j \in N$: travel cost P_i, $i \in N$: demand at node i
H_1 <u>Neighbourhood</u> AG I grocery shop and 2 of (baker,butcher,bank,druggist) total of 3 - 7 shops	(Warnes/Daniels) market principle: minimize the maximal distance of population - frequent shopping - by foot - low range goods	p-Median problem on level (H_1/N)
H_2 <u>Community</u> AG I , II whole range of H_1 3 of (barber,cleaner, stationer, florist/fruits, post-office) total of 8 - 30 shops	transport principle: close to a stop of the public transportation system maximize the population covered within a service distance S, while maintaining mandatory coverage within a distance of T (T>S) - operating requirement constraints of supermarkets	MCLP with mandatory closeness on level (H_2/N)
H_3 <u>Regional</u> AG I, II, SD whole range of H_2 including additional branches of AG II (clothes, shoes, doctor, dentist etc) and SD total of 31 - 75 shops	administrative principle minimize the average distance of population aggregated at nodes of H_2 - infrequent shopping - mechanically-assisted travel	p-Median problem on level (H_3/H_2) $N \longrightarrow H_2$ $d \longrightarrow (d^*)$ $P \longrightarrow P^*$
H_4 <u>Central Area</u> AG I, II, SD whole range of H_3 and full range of SD	cf. H_3	cf. H_3

Table 2 : Innerurban centre-hierarchy - Theoretical and empircal figures

Example		Hierarchy - level			
		H_1	H_2	H_3	H_4
Theor. figures (Warnes/Dan.)	a	88	25	6	1
	c	120	32	7	1
Regensburg	a	36	14	4	1
	c	55	19	5	1
Darmstadt	a	17	27	5	1
	c	50	33	6	1
Stockport (Potter)	a	41	19	9 2	1
	c	72	31	12 3	1

a absolute
c cumulated

It must be mentioned that there has to be taken into account barriers whose impact is decreasing with rising hierarchy level.

6. RESULTS

The population of Regensburg sums up to 130 000 inhabitants, unevenly distributed on an overbounded area. As interaction barriers act the rivers Danube and Regen, highways, railway lines and the relief (NW, NE).

55 retail centres have been defined and classified according to an 4-order-hierarchy. Table 2 shows considerable differences between theoretical figures -which hold for a 4-order-hierarchy independent of population size- and empirical ones of comparable towns. Differences between the latter are due to distinctive overall accessibility, purchasing power of population and regional dynamics.

Considering Fig.1 the sites of existing centres seem to be unevenly distributed and there is no correspondence between locations of succeeding hierarchy levels as predicted by Warnes/Daniels. On the other hand the predicted connection between locations of H_2 - H_4 and the road net could be verified.

It has been tried to relocate the 55 retail centres according to the developed optimization criterium and using 111 potential locations. Results are shown in Fig.1 and can be summed up as follows:

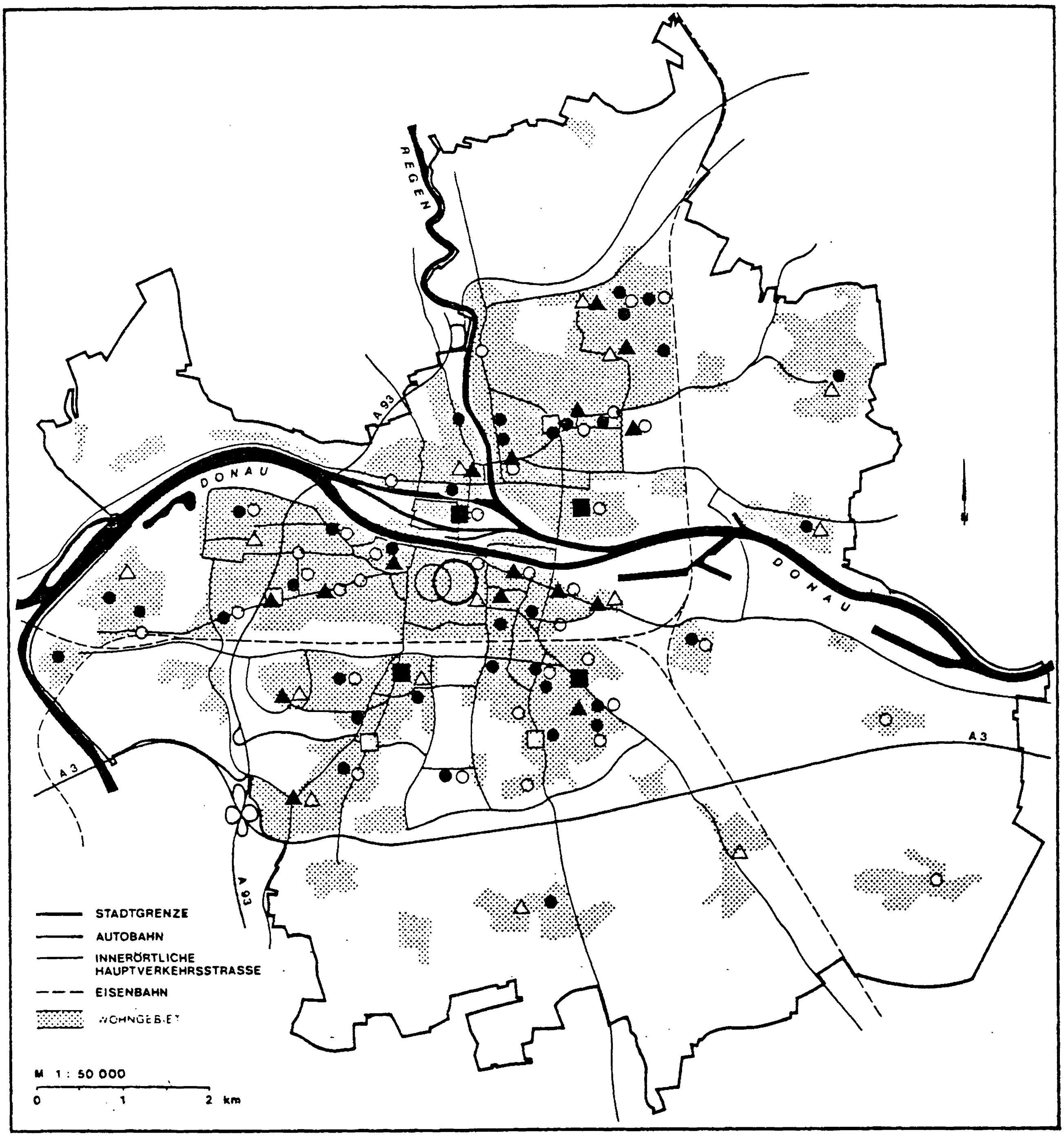
- relocated sites show no clusters
- urban fringe is revalorized, city centre devaluated, planned centres will be confirmed
- H_3 (regional) centres are relocated outwards, leaving their location at former nuclei of town development.

Comparison of existing and relocated sites could be used to derive guidelines for reorganizing the public transportation system - H_3-level - as well as developing retail centres by locating offices and institutions for adjacent activities (recreation, education, public administration) or creating pedestrian precincts, adjacent parking space and bus stops.

7. CONCLUDING REMARKS

Development of the presented locational considerations has been based upon very rigid assumptions concerning shopping behaviour. It is expected that the evaluation of a household and customer survey both held at Regensburg should reveal insights about shopping behaviour especially the transition

Figure 1 : Existing and computed location of retail centres in Regensburg 1982



Hierarchical classification of retail centres

● ○ Neighbourhood
▲ △ Community
■ □ Regional
◯ ◯ Central area

computed

existing

between centres of different hierarchical levels. This will lead to an objective function which allows minimization of travelling costs as well as maximization of alternative consumer choice.

To increase the reliability of results is seems important to calculate the minimal net of consumer facilities. But this requires planner's consensus about hierarchical service ranges.

BIBLIOGRAPHY (Selection)

BAHRENBERG, G.: A Location-Allocation Model For Maximizing Supply Dispersion Of Central Facilities. From: Bahrenberg/Streit (Eds.): German Quantitative Geography. Paderborn. 1981, pp 115 - 124.

BORCHERDT, Chr., SCHNEIDER, H.: Innerstädtische Geschäftszentren in Stuttgart. Stuttgarter Geogr.Studien 90 (1976), pp 1 - 38.

CHURCH, R.L., RE VELLE, Ch.S.: Theoretical and computational links between the p-Median, Location Set-covering, and the Maximal covering Location Problem. In: Geographical Analysis 8 (1976), pp 406 - 415.

COELHO, J.D., WILSON, A.G.: The optimum location and size of shopping centres. In: Regional Studies 10 (1976), pp 413 - 421.

DAWSON, J.A.: Commercial distribution in Europe. London 1982.

KLEIN, K.E. (Hrsg.): Innerstädtische Geschäftszentren in Darmstadt. Materialien zur Wirtschafts- und Sozialgeographie, LSt.Prof. Dr. J. Obst. Regensburg 1983.

NARULA, S.C., OGBU, U.I., SAMUELSON, H.M.: An Algorithm for the p-Median Problem. In: Operations Research 25 (1977), pp 709 - 713.

POTTER, R.B.: The multivariate functional structure of the urban retailing system: a British case study. In: Transactions 6 (1981), pp 188 - 213.

TIMMERMANS, H., VELDHUISEN, J.: Modelling Consumer Response to Changes in Spatial Structure. Some Methodological Considerations and Empirical Tests. Paper presented at Cambridge 1980.

WARNES, A.M., DANIELS, P.W.: Spatial aspects of an intrametropolitan central place hierarchy. In: Progress in Human Geography 3 (1979), pp 384 - 406.