Urban Studies (1973), 10, 235-258

A Model for Individual Travel Behaviour

Eckhard Kutter

[*Received July 1972*]

Introduction

Urban person movement is part of the activity pattern performed by the population in an industrialised society. An analysis of urban person movement must therefore start from an analysis of human behaviour. 'Trip making behaviour can be treated as an instrumental form of activity for facilitating a person's ability to take part in a primary activity, (Chapin and Logan, 1970, p. 310). It is obvious that these primary activities or better fundamental needs[1] are satisfied within the framework of an urban activity pattern. In all industrialised cities this satisfaction of needs takes place according to similar patterns of behaviour. Trip generation methods and models are based on this regularity in human behaviour.

Criticism of current trip generation models is usually that the methodology is unfit for taking the underlying cause-effect-relationships into account: 'Most models base generation on regression analysis; such statistical formulae reflect the actual traveller's behaviour, without setting out the multiple constraints from which they are derived: economical, psychological, cultural and social' (Le Boulanger, 1971, p. 116). It is true that these regression equations provide a description of the present travel patterns, but the analysis must also include an examination of the cause-effect-relationships if the model is used in forecasting. As Lowry (1965, p. 159) has said: 'If one is able to postulate the direction of causation, knowledge of the future value of the "cause" enables one to predict the future value of the "effect"'.

There are different reasons for the unfitness of current generation models for taking the underlying cause-effect-relationships into account. These models for example base generation on an analysis of aggregated data: 'The primary basis for utilising zonally aggregated data has been the assumption that geographical proximity results in similarity of households with respect to trip making and socio-economic characteristics' (McCarthy, 1969, p. 36). McCarthy demonstrates in his study (p. 38): '... that relationships or correlations developed between variables representing aggregated data will be inaccurate, because there is a considerably larger portion of variation within zones than between zones'.

Another reason is the paralogism of a trip being an isolated event[2]. 'It appears indeed that a journey

The author is Oberingenieur at the 'Institut für Stadtbauwesen' Technical University of Braunschweig, Western Germany.

1 Chapin (1968, p. 14) differentiates 'fundamental needs (involving choices to minimise feelings of dissatisfaction) and supplemental needs (involving choices to maximise feelings of satisfaction)'.

2 For an explanation of the 'journey-concept' see Hemmens (1966, 1970), Lathrop (1970) and Kofoed (1969, 1971).

must be considered as an indivisible entity in time and space' (Le Boulanger, 1971, p. 116). It is obvious that the 'trip generator' understands a journey as an entity from starting at home till returning home. The tripmaker's decision process before starting at home comprises choice of activity, duration and also choice of the mode of transport[3]. The division of choices into 'generation', 'distribution' and 'modal-split' results in an incomplete description[4] of individual behaviour.

Criticism of generation models (based on aggregated data) also includes numerous proposals how to improve the model design. An important factor in this respect is the relevance of the individual criteria for the individual movement behaviour. The relevance of these individual criteria is being derived by deductive reasoning from the existence of a firmly established routine in an industrialised society: as certain demographic categories[5] impose typical schedules for the every-day-routine, the specific 'traffic-causes' concentrate on different groups in a given population. Furthermore the relevance of individual behaviour becomes evident by the results of the origin-destination-studies based on aggregated data[6]. A consideration of these individual criteria did not take place till today; there are only conceptual frameworks and hypotheses: 'The analysis seeks to see if respondents fall into distinct groups which show significant differences in the frequency or duration of activities' (Chapin and Logan, 1970, p. 316). 'One method, not yet available for answering such questions would seem to be 'behavioural typology'; . . . such a typology would take the form of 'behaviour patterns' (Le Boulanger, 1971, p. 114).

A logical framework for an 'individual-factor-model'

In this section hypotheses are put forward to explain cause-effect-relationships in urban person movement and to answer the following questions:

(1) Who makes the 'changes of place'[7]?

(2) What are the underlying causes for undertaking any change of place within the urban environment?

The explanation of the cause-effect-relationship becomes difficult by the fact that there is no direct relation between the causes, i.e. individual criteria of persons, and the effects, i.e. urban person movement. The individual criteria of persons determine the individual structure of role behaviour which in turn implies certain time sequences of place-related activities and the sequence of spatially distributed activities involves a sequence of movements.

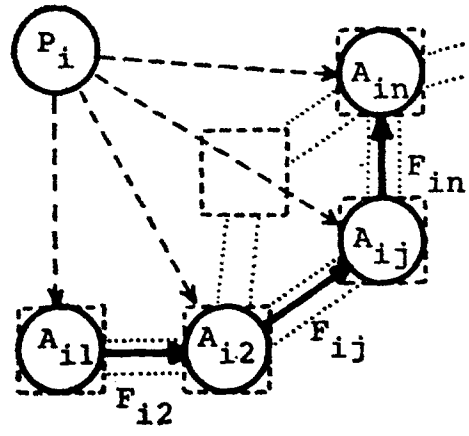


Fig. 1. An individual activity pattern.

This causality may be explained by taking into consideration the day's schedule of one individual. The individual, P_i, with his individual criteria and needs has at his disposal an urban system which is composed of the communication facilities G_k and the communication ways W_k.

In the course of one day the individual P_i carries out the activities A_{ij}, corresponding to the individual structure of his role behaviour, with the parameters of the communication facilities G_k and the parameters of time and duration of the activity itself. The spatial distribution of facilities moreover induces the changes of place F_{ij} (for $j = 2$, n) with the parameters of the activities related to these changes of place (Fig. 1).

[3] See, for example, the 'choice theory' of Chapin (1965, p. 12 f).
[4] Chapin and Hightower consider their 'activity system' as 'patterned distribution of activities in sequence, time and space' (1965, 1966).
[5] Such demographic categories are of great importance for all sorts of planning; e.g. see the study of Heidemann (1967) concerning the projection of age needs in a New Town.
[6] It seems to be impossible to take into account these individual criteria in a model or method depending on land-use-related data.
[7] The word 'trip' describes a 'one-way-movement' by any mode of transport. 'Person movement', as it is used in this study, includes all 'changes of place', even the walk to a shop or the ride on a bicycle.

(1) The individual '*activity pattern*'[8] is defined as the sum of all activities carried out by one person in the course of one day plus the movements required for these activities:

$$T_i = \sum_{j=1}^{n} A_{ij} + \sum_{j=2}^{n} F_{ij}.$$

(2) The individual '*movement pattern*' only includes the activities with relevance to distribution in space which means the movements within the scope of an activity pattern:

$$O_i = \sum_{j=2}^{n} F_{ij}.$$

on the characteristic data of the existing material system, on the other side. It is therefore desirable to describe by means of long-term observations not only the evolution of the urban society but also the changes of the environment, constructed and used by this society, and to describe the resulting behavioural system in its evolution by means of a superimposition of the two causal processes. For such an analysis, however, there is at present lack of the appropriate statistical-empirical data[10].

As a consequence, the present analysis is limited to the description of the actually existing structures of urban activity systems. In this respect the

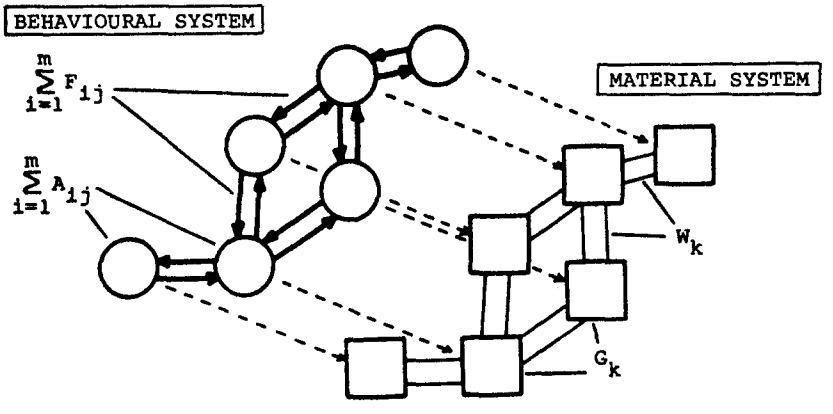


Fig. 2. Superimposition of a 'behavioural system' on a 'material system'.

(3) The '*activity system*'[9] of an urban society is defined as the sum of all individual activity patterns of the persons in this society. In this respect the activities are 'elements' and the movements 'relations' in a behavioural system':

$$\text{'activity system'} = \sum_{i=1}^{m} T_i = \sum_{i=1}^{m} \left(\sum_{j=1}^{n} A_{ij} + \sum_{j=2}^{n} F_{ij} \right).$$

Urban person movement being the sum of the individual movement patterns is caused by the superimposition of the activity system as 'behavioural system' on the urban environment as 'material system' (Fig. 2).

Regularities of urban person movement, consequently, depend on the individual criteria of the 'supporters' of the activity system, on one side, and

structure of the urban environment is at first considered as a constant value.[11]

The basic reason for the concept of an 'individual-factor-model',[12] with regard to a description of urban person movement, is the hypothesis that spatial and temporal structures of urban person movement are determined by the concurrence of individual activity patterns. Typical behaviour categories of a population may be assigned to these individual behavioural patterns[13] (Fig. 3).

Strictly speaking, the construction of such a model is based on a category analysis of urban population according to the individual movement behaviour. The nature of empirical data—time-budgets of the out-of-home-activities—requires the construction of the model in three steps:

[8] This activity pattern also includes the parameters of the sequence of activities. For an explanation of the concept of 'activity pattern' see, e.g. Chapin and Hightower, 1965, 1966.
[9] See footnote 4.
[10] Empirical data only include time budget data from 1969; there were no other data available in this study.
[11] The individual activity pattern is primarily determined by individual needs (see Kofoed, 1969).
[12] Only the characteristics of individuals should be used as 'causes' in a model based on 'cause-effect-relationships'.
[13] The relationship between 'what a person is' and 'what a person does' seems to be self-evident.

(1) *a priori* grouping of urban population according to individual characteristics of persons;
(2) detection of components of both activity patterns and movement patterns for the above defined groups of people;
(3) examination of *a priori* grouping with regard to its significance for activity patterns and movement patterns (Fig. 3).

Conditions of model construction

A priori grouping of urban population

The time-budget of a person represents a 'random pattern; individuality of time-budgets is of less interest.

(2) The social status and the role of a person are both determined by 'stages in life cycle'. There are typical criteria for the course of life cycle in a given society, which means that all persons run through the stages 'child', 'pupil', 'employed person' or 'housewife' and 'retired'.

(3) The stability of changes in the life cycle permits predictions about the future distribution of these individual-categories for a given population. This ability to predict 'causes' (of urban activity system)

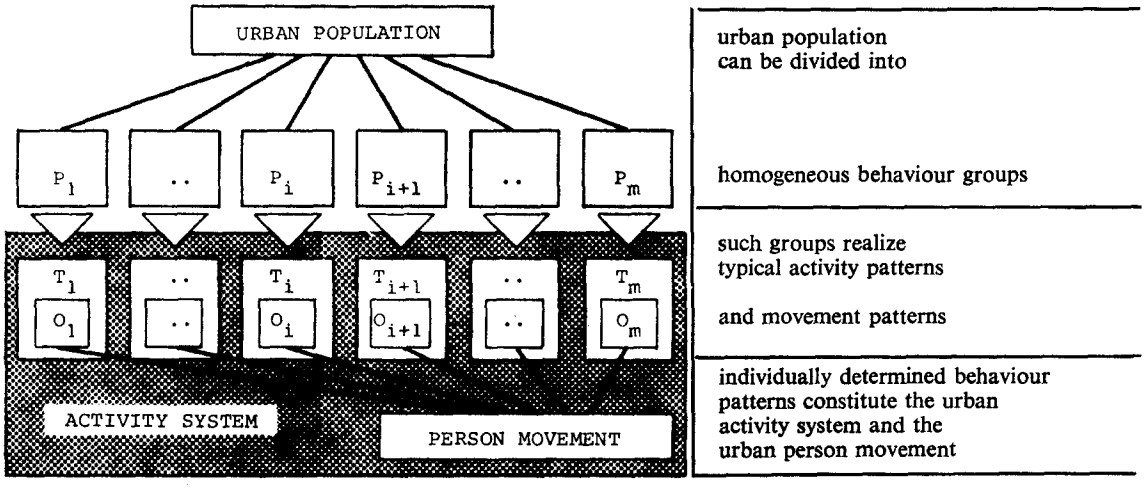


Fig. 3. Relation between the assignment of the population to homogeneous behaviour categories and the structure of the urban activity system.

sample' out of the individual behaviour[14] during longer periods. To get empirical data of some generality, individual time-budgets must be aggregated into time-budgets of groups of similar people. We have to start from the assumption that such groups perform an activity pattern within the period of one day which is similar to the activity pattern a single person belonging to this group performs during a longer period (e.g. one month).

The advantages of grouping people become evident by using such 'individual-categories' in the traffic generation analysis:

(1) The behaviour patterns of such groups usually are the aim of an analysis of the urban activity is very important with regard to forecasting, based on cause-effect-relationships.

Variables in trip generation models are partly not of the individually related type.[15] Mostly this is caused by the fact that

(1) models are derived from an analysis of aggregated data;
(2) these models usually describe the subsystem of vehicular trips out of the total movement system.

A lot of these 'structural variables' (describing traffic zones) can be reduced to individual criteria (Table 1).

Those variables, which can be reduced to criteria of a person's age and sex, are directly related to the

14 For the study of time budget and time budget technique see Sorokin and Berger (1939) and also v. Rosenbladt (1969).
15 See for example the studies of Oi and Shuldiner (1962), Wootton and Pick (1967), Wynn and Levinson (1968) and Böhme (1970).

satisfaction of fundamental needs. In comparison to this, the effect of variables like 'car ownership' or 'social status' is dubious with regard to the structure of urban activity patterns. Their relevance to the mode of transport to satisfy traffic needs is indeed apparent and may explain the significance of such variables for vehicular traffic generation models (see Böhme, 1970).

For an analysis of total person movement[16] the variables should be subdivided into two groups:

(1) Primary variables influencing the individual behaviour and the structure of individual activity patterns.
(2) Secondary variables with relevance to the mode of transport to satisfy traffic needs in an urban environment.

The individual behaviour within the main groups[17] of society is mostly determined by age and sex of a person. Individual behaviour also depends on certain stages in life cycle of the family in which the person lives (see, e.g. Chapin and Logan, 1970); typical stages in life cycle on one side, effect typical 'role behaviour' on the other side (Table 2).

In comparison to primary variables, secondary variables are related to the interaction of the family group with the other main groups of society. The analysis of this study is developed from the assumption that the following variables[18] are relevant to individual travel behaviour:

(1) Social status as depending on a classification of professions;
(2) occurrence and duration of 'work' defining the 'time ties' in a day's schedule of employed persons (see, e.g., Maw, 1970), and therefore influencing the structure of individual activity patterns;
(3) car ownership being a criterion for the economic situation of a person or family in an industrialised society; it also determines the possibilities to satisfy any traffic needs.

Table 1

Examples for the reduction of aggregated data to criteria of households and persons

Zonal averages	*Household data*	*Individual criteria*
Average household size	household size	age of persons[a]
Fertility rate[b] = $\frac{\text{children} < 5}{\text{women } 14\text{-}45}$		(age of persons)
Female labour force participation[b]	household type[c]	(age of persons)
Labour force participation	household type[c]	age of persons[a]
Social rank	occup. of head of household.	occup. of persons
Average car ownership level	household car ownership	car availability
Average household income	household income	person income
Residential density	pseudo-variable for the effects of car ownership and household size	
Distance to C.B.D.	correlated with car ownership and household size	

[a] Demographic structure influences and the structure of households and the stages in family life cycle as well as labour force participation.
[b] Oi and Shuldiner, 1962, p. 116.
[c] See Wootton and Pick, 1967.

Description of activity patterns and movement patterns

A description of daily routine in urban life which analyses the cause-effect-relationships in urban person movement should include more information than usually provided by the time-budget in sociology. In connection with this reasoning, the 'activity system' of Rosenbladt (1969, p. 68), defined as 'quantity of activities in dimensions of time and space', indicates one step forward in the given direction. The objectives of the movement analysis require an extension of the definition of 'activity

16 Only an analysis of total person movement provides an insight into the cause-effect-relationship between fundamental needs in a society and the resulting travel patterns.
17 E.g. 'family group', 'educational groups' and 'economical groups' (see Fichter, 1957).
18 There were many more variables to be tested in a pilot study; these are, however, of less interest for the objectives of this study, a category analysis of urban population with regard to the structure of activity pattern and the resulting movement pattern (see Kutter, 1972).

system' of v. Rosenbladt, because the model shall lead to a simulation of changes of place.

The extension of an 'activity model' is limited by the nature of empirical data[19]. The question arises how the activity pattern of a person can be described referring to a significant representation of movement, that the out-of-home-activities depend, to a large extent, on those external arrangements through which a society can 'minimise feelings of dissatisfaction' (see, e.g., Chapin, 1965): the time ties of 'work', 'school' and 'shopping' set the schedule for the routine of a day (Stapf and Heidmann, 1971, p. 128). As

Table 2

A priori *grouping*[a] *of urban population*[b] *according to individual and family related criteria*

			Age of persons				
			6-15	16-65 *years*			>65
Stage in family life cycle	*Female labour f. participation*	*Sex of person*	*pupils*[c]	*pupils, students*	*unemployed*	*employed*	*retired*
Single persons		m/f		6 20		10 43	22 59
Married, no children	wife employed	m				11 86	
		f				12 94	
	wife unemployed	m				13 70	23 73
		f			7 89		24 57
Married, young children <6 years	wife employed	m	1 42			14 72	
		f				15 78	
	wife unemployed	m	2 181			16 326	
		f			8 328		
Married, children >5 years	wife employed	m	3 103			17 79	
		f				18 83	
	wife unemployed	m	4 157			19 151	
		f			9 165		
Young adults, living in family		m		5 45		20 74	
		f				21 61	

[a] The study started from a more differentiated grouping of population; such grouping usually results in very small groups which have no significance for any analysis.
[b] 'Research population' as used in this study.
[c] Groups according to the roles in family and society.

on one side, but abstracting from the complex individual behaviour, on the other side.

If the quotient of persons being out of home and of all persons in a given population is defined as 'activity index', the distribution by the time of day of the activity-indices can be defined as an 'activity profile'. The reason for the striking similarity of the activity profiles of urban populations[20] is the fact regards an urban population category analysis dealing with the differences of individual activity patterns, the activities 'work', 'school', 'shopping' and 'recreation' are most interesting. These activities usually are the 'main activities' of a journey[21].

The reasoning for a description of an urban activity pattern starts from the assumption that individual activity profiles mostly derive from lo-

19 In a daily schedule the important time ties for a person are start and end of a journey. The individual trips in a multiple-leg-journey have no relevance to the 'traffic generator' and it seems possible to partly register these single trips in a day's schedule.
20 Empirical data are random samples out of three dwelling areas: 'Braunschweig—Lehndorf', 'Braunschweig—Heidberg' and 'Wolfsburg—Teichbreite' (see Kutter, 1972).
21 The advantages of the 'journey-concept' (see Hemmens, 1966, 1970) become evident in the light of the significance of empirical data. Trip schedules of three dwelling areas in this study reveal a 90% share of 'two-leg-journeys'. If this rate is correct, the journey-concept provides an exact description of travel behaviour. If in the schedules some trips are missing, the journey-concept allows to maximise the significance of description, because start and end of a journey at home are the outstanding time and place ties of a person's daily routine.

cation and duration of main activities[22] of the journeys over a day. This hypothesis is confirmed by dividing the activity profile of a population into activity profiles of single activities (Fig. 4).

The duration of activity pattern is determined by occurrence and duration of the main activities 'work', 'school', 'shopping', 'personal business' and 'recreation'.[23] About 80% of all activities are main activities in the sense of the journey-concept. The duration of the main activities represent as much as 93% of the total duration of the activity pattern.

Taking for granted the stable arrangements for the time ties of certain activities[24] the 24 hours of a day are divided into six intervals: '4 a.m. to 6 a.m.', '6 a.m. to 8 a.m.', '8 a.m. to 2 p.m.', '2 p.m. to 5 p.m.', '5 p.m. to 7 p.m.' and 'past 7 p.m.' The urban area is, according to the traditional location of activities, divided into 'dwelling area', 'CBD' and 'remaining area'. As the duration of activities is a determining factor for the requirement of the individual time potential, the 'activity model'[25] is defined as the matrix of duration of the five main activities applied to three urban zones and the six time-intervals of a day (Table 3).

The 'movement-indices'[26] for any population or any group in a population can be specified according to the definition of activity-indices. The distribution of hourly movement-indices over a day, divided into

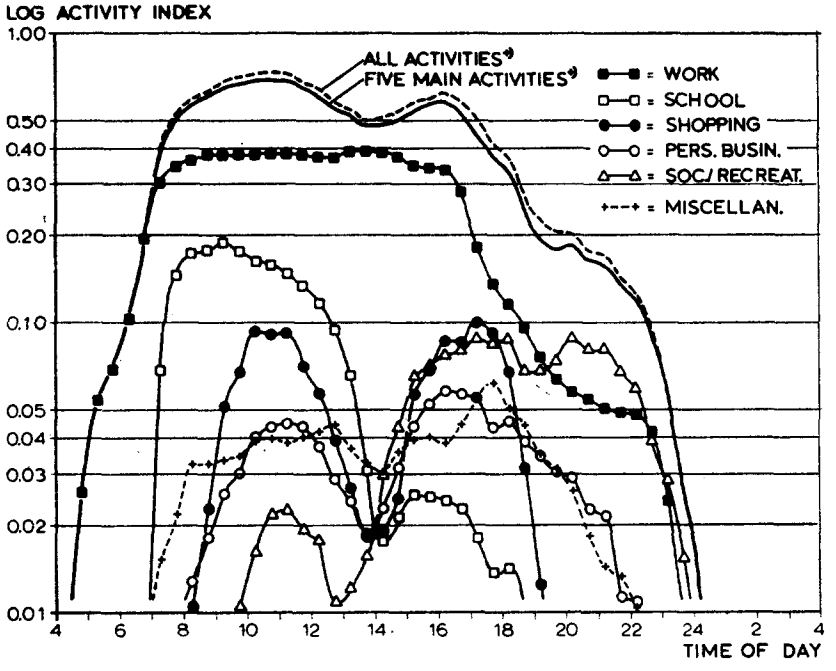
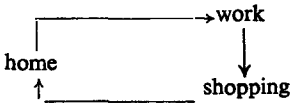


Fig. 4. Activity profile of urban population divided into the activity profiles of main activities.

22 The detection of the main activities of a journey was carried out according to the following schema:

For a given journey, e.g.



(1) the activity of the greatest 'importance', for instance 'work' in the above journey, is to be defined;
(2) if an activity figures twice or more often in a journey, the activity with the longest duration is to be chosen as main activity.

23 These activity categories include numerous more specified activities; with regard to the construction of an 'individual-factor-model' it seems to be advisable to reduce the number of activity-categories.

24 In Germany the normal working hours are from 7/8 a.m. to 4/5 p.m.; school begins at 8 a.m. and lasts to 1 p.m., etc. Other countries may have other time ties.

25 This 'activity model' is one method of describing the complex system of urban outdoor activities. There are better and more complex models of urban activity pattern. However, the advantage of this model lies in its simplicity, because it is used in a category analysis of urban population.

26 Movement-index has the meaning of 'percentage out of a population engaged in a change of place'.

starts from home and returns back home, may be interpreted as the distribution of trips[27] from home and trips back home, usually known as 'trip generation' (Fig. 5).

Fig. 5 shows that the distribution of hourly trip generation is equally influenced by the duration of the main activities 'work', 'school' and 'shopping'.

Table 3

Matrix[a] of the 'activity model'

	Activity 'work'			*Activity 'school'*			*Activity 'shopping'*		
Interval of day	*area* 1[b]	*area* 2	*area* 3	*area* 1	*area* 2	*area* 3	*area* 1	*area* 2	*area* 3
4 a.m.-6 a.m.	0	0	0·07	—	—	0	—	—	—
6 a.m.-8 a.m.	0·02	0·06	0·39	0·06	0·02	0·04	0	0	0
8 a.m.-2 p.m.	0·12	0·40	1·76	0·38	0·09	0·33	0·20	0·09	0·04
2 p.m.-5 p.m.	0·05	0·18	0·81	0·02	0	0·04	0·08	0·07	0·02
5 p.m.-7 p.m.	0·02	0·05	0·20	0	0	0·01	0·07	0·06	0·02
7 p.m.	0	0·02	0·22	0	0	0	0	0	0
Total day	0·22	0·71	3·45	0·47	0·13	0·43	0·35	0·22	0·08
		4·38			1·04			0·65	

	Activity 'personal business'			*Activity 'recreation'*			*Five main activities*[c]		
Interval of day	*area* 1	*area* 2	*area* 3	*area* 1	*area* 2	*area* 3	*area* 1	*area* 2	*area* 3
4 a.m.-6 a.m.	—	—	—	—	—	0	0	0	0·07
6 a.m.-8 a.m.	0	0	0	0	—	0	0·08	0·08	0·43
8 a.m.-2 p.m.	0·03	0·06	0·10	0·02	0·01	0·05	0·75	0·65	2·28
2 p.m.-5 p.m.	0·04	0·02	0·07	0·07	0·02	0·09	0·26	0·29	1·03
5 p.m.-7 p.m.	0·03	0·01	0·05	0·06	0·02	0·09	0·18	0·14	0·37
7 p.m.	0·02	0·01	0·05	0·07	0·07	0·16	0·09	0·10	0·43
Total day	0·13	0·11	0·26	0·23	0·12	0·38	1·36	1·26	4·61
		0·50			0·74			7·23	

[a] Duration of activities differentiated according to activity category time of day and location of activity.
[b] Area 1 = dwelling area, area 2 = CBD, area 3 = remaining urban area.
[c] Data matrix of the 'reduced activity model'.

The interval between the first leg and the last leg of a journey[28] reflects the duration of activities.

In traffic planning we are interested in temporal and spatial distribution of movement. After all the underlying motivation for a journey is of less interest with regard to forecasting in traffic planning. There is no need to take the journey-purposes into account. Corresponding to the activity model, the movement model is defined as the matrix of movement-indices, divided into start of journey and end of journey, differentiated by three urban zones and hourly intervals over a day (Table 4).

Application of the factor analysis

A priori grouping of urban population permits the detection of behaviour of individual-categories even on the basis of time-budget data. But first of all it is unclear whether the *a priori* grouping is significant with regard to the differences in human behaviour. By means of typology the following problems can be solved:

(1) Significant differences in relation to the structure of activity pattern and movement pattern are pointed out for the *a priori* defined groups in a population.

(2) In order to determine the groups in an individual-factor-model only by individual criteria, the influences deriving from location and facilities of the dwelling areas are eliminated.

The first problem may be solved by applying the 'factor-analysis' to the correlation-matrix 'between persons' (Überla, 1968). The resulting factors of such an analysis are 'type-factors' or 'person-factors'. Moreover one of the basic reasons to conceptualise an individual-factor-model is the hypothesis that individual criteria of persons are of greater relevance to the individual travel behaviour than 'location-

[27] In this chapter 'trip' is used in the sense of 'change of place'.
[28] The journey-concept allows to reduce a multiple-leg-journey to a hypothetical two-leg-journey; roughly speaking, we concentrate on start and end of a journey and on its main activity.

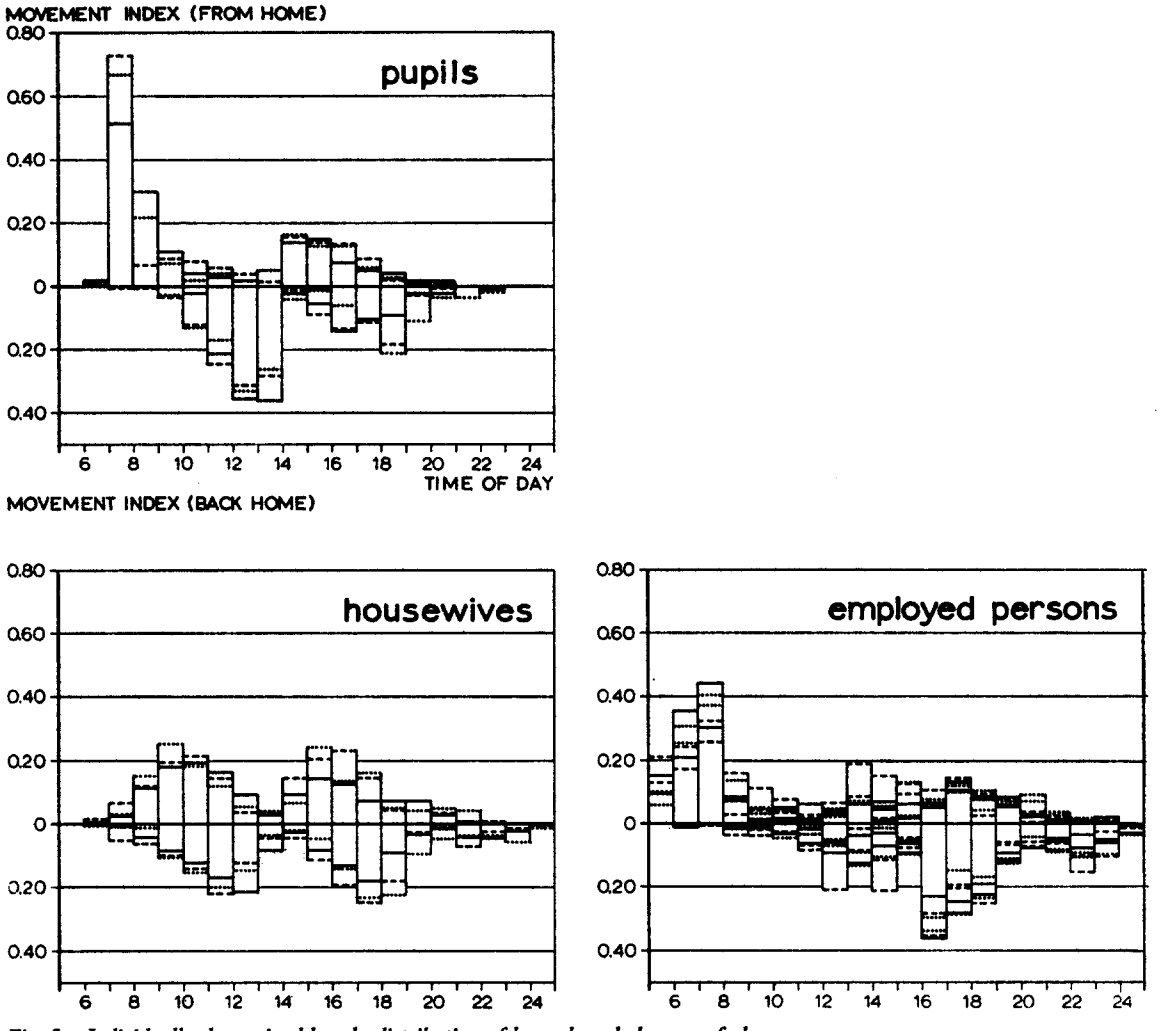


Fig. 5. Individually determined hourly distribution of home-based changes of place.

Table 4

Matrix[a] of 'movement model' for pupils

Leg of journey	*Interval of day* a.m. -6	6-7	7-8	8-9	9-	10-	11-noon	p.m. -2	-3	-4	-5	-6	-7	-8	-9	-10	-11-midn.-
From home to area 1[b]		2							2	6	8	16	4		2		
area 2		2	14			2			6	8	4	2			2		
area 3			48	24	2				6	2	8		2				
To home from area 1							2			2	12	8	12	4			2	
area 2							10	6	2			14	2					2
area 3							2 28	32		6	4	6	12	2		2		

[a] Hourly movement-indices differentiated according to direction, time of day and location of main activity.
[b] Area 1 = dwelling area, area 2 = CBD, area 3 = remaining area.

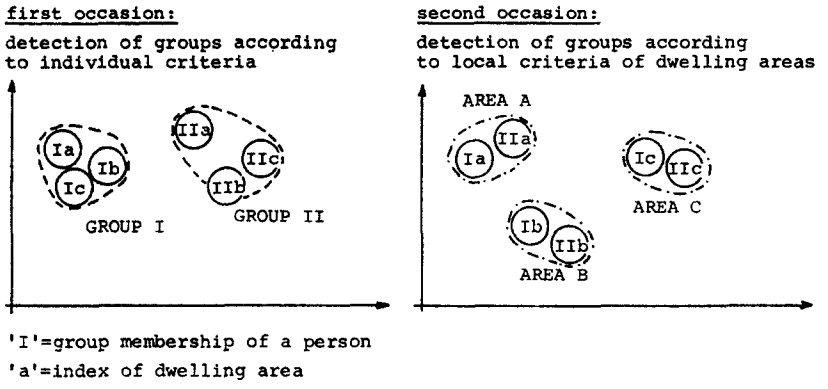


Fig. 6. Theoretical structure of factor-loadings for the grouping by individual criteria and by local criteria.

criteria'. This hypothesis might be conclusive if the similarity between persons belonging to one group but to different dwelling areas is greater than between persons living in the same area but belonging to different groups (Fig. 6).

It is desirable to apply this 'group-criterion' to an analysis of a large number of dwelling areas. A first testing of the model hypothesis may be carried out on the basis of empirical data acquired from the three surveyed dwelling areas, because there are great differences as far as demographic structure, location and area facilities are concerned.

Model calibration by means of 'behavioural typology'

Typology according to individual activity patterns

Typology according to individual activity models includes first of all a type analysis[29] of the 24 individual categories defined above. These categories were determined with regard to the individuality of

Table 5

Matrix of correlation coefficients between 24 individual categories

	1	2	3	4	5	6	7	8	9	22	23	24	12	15	18	21	10	11	13	14	16	17	19	20
1		96	97	92	45	15	−06	−07	−06	−07	−06	−04	−07	−09	−07	−09	−06	−07	−06	−07	−06	−06	−06	−05
2			98	98	52	36	−07	−09	−05	−07	−05	−02	−08	−10	−09	−11	−07	−08	−07	−08	−07	−07	−08	−06
3				98	60	34	−07	−09	−08	−08	−07	−06	−08	−09	−07	−10	−07	−07	−07	−08	−07	−07	−07	−04
4	PUPILS <16				65	51	−09	−09	−09	−10	−09	−07	−08	−10	−07	−11	−07	−08	−07	−08	−07	−07	−08	−04
5	PUPILS >15,					71	−12	−12	−13	−14	−12	−11	−04	−07	−04	−05	−02	−02	−02	−03	−02	−02	−02	10
6	STUDENTS						−08	−09	−07	−11	−12	−11	−07	−09	−05	−10	−07	−06	−06	−07	−06	−06	−07	02
7								86	84	78	58	58	−13	−10	−18	−07	−13	−12	−11	−13	−11	−12	−12	−13
8									75	65	43	66	−13	−12	−17	−06	−13	−12	−12	−13	−12	−13	−13	−14
9	HOUSEWIVES									65	54	63	−14	−13	−19	−09	−14	−13	−13	−15	−12	−14	−14	−13
22	RETIRED PERSONS										67	63	−15	−12	−16	−08	−13	−14	−13	−14	−13	−14	−14	−14
23												72	−17	−16	−20	−14	−15	−15	−15	−16	−14	−15	−15	−15
24													−16	−14	−17	−09	−14	−14	−14	−15	−13	−14	−14	−15
12														97	97	90	94	96	93	94	93	91	92	94
15	EMPLOYED WOMEN														97	90	88	90	85	89	86	84	87	87
18																86	88	89	85	88	85	83	85	89
21																	90	89	88	92	89	88	89	89
10																		99	99	99	99	99	99	98
11																			99	99	99	99	99	98
13	EMPLOYED MEN																			99	99	99	99	98
14																					99	99	99	98
16																						99	99	98
17																							99	97
19																								97
20																								

[29] Factor analysis for the matrix of correlation coefficients between persons.

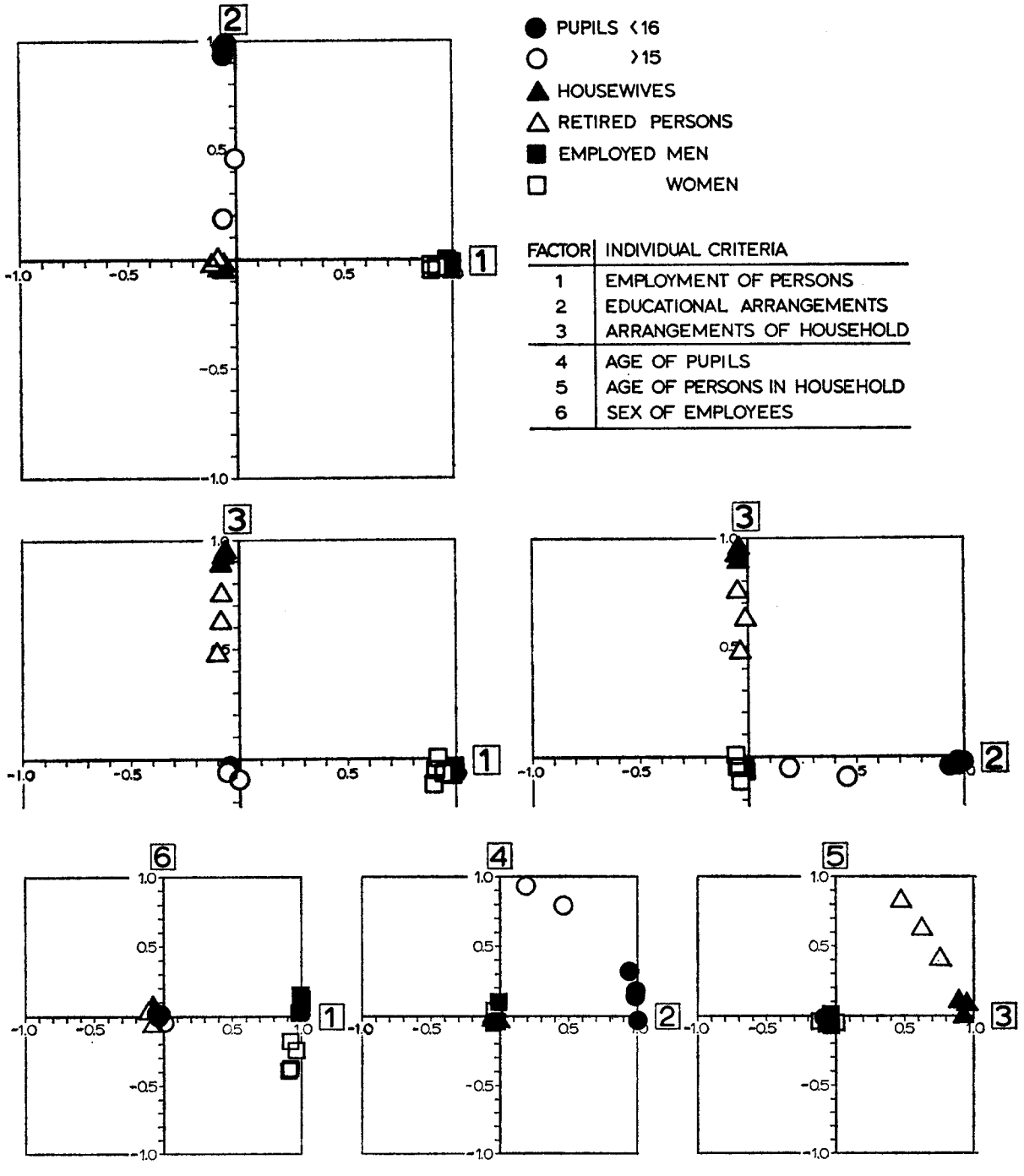


Fig. 7. Grouping of 24 individual categories of an average population (type-analysis according to the matrix of activity model).

persons and the related household-criteria (see Table 2).

At first sight, the matrix of correlation coefficients —detected from the matrix of the activity model— show a significant grouping of persons in a given population:

Positive coefficients have only been observed within the groups 'pupils', 'housewives/retired' and 'employed persons'. All correlation coefficients between these groups were negative (Table 5).

The principal-components-analysis clarifies the structure of the correlation matrix. Nevertheless an interpretation of type-factors is not possible until a rotation of the principal-components-axes has taken place (Fig. 7).

An interpretation of the resulting type-factors will be easy as the criteria of persons in the analysed sample are well known from the *a priori* grouping of population. The resulting grouping of population follows the social ties of persons in connection with arrangements at work, school and at other facilities.

The occurrence and temporal distribution of certain activities over a day's period constitute the determining factors for the activity profiles of these 'archetypes' in a population:

Group	*Determining activity*
Pupils, students	School
Housewives, retired persons	Shopping, personal business
Employed persons	Work

Social ties, such as are caused by external arrangements of the society, explain why, in comparison to individual criteria, the criteria of households are of less importance. Using activity-categories in the description of individual activity patterns requires the division of any urban population into the three groups 'pupils', 'housewives' and 'employed persons' (Fig. 8).

After all, a specification of activities is of no interest for the objectives of the analysis, a significant description of urban person movement. Such a model has to solve the problem of a significant description of temporal and spatial distribution of person movement in the sense of 'all changes of place performed by a given population'. Activity categories are therefore excluded from the matrix of activity model. 'Reduced activity model', as used in the following chapter, only includes criteria of temporal and spatial distribution of activities.

Type-analysis based on a reduced activity model also results in a significant grouping of population into 'pupils', 'housewives' and 'employed persons'. This grouping is, indeed, less significant with regard to the social ties; on the other side the exclusion of activity categories leads to a greater significance of criteria, which are of some relevance for the temporal and spatial distribution of movement: time ties, duration and location of activities (Fig. 9).

Activity-categories used for an interpretation of type-factors can be expressed by the temporal and spatial extent of activities:

Activity-category	*Duration*	*Location*
work	long	urban area
school	middle	dwelling area
shopping, personal business	short	dwelling area, CBD

A priori grouping of urban population is based on the hypothesis that individual activity systems are determined by criteria of persons and household. Typology based on the matrix of activity model substantiates this hypothesis and, over and above, results in a more distinctive grouping of population: only person-related criteria such as age, sex and employment are relevant to the structure of activity patterns. Such a modified grouping is easy to perform (Table 6).

The type-analysis of groups belonging to different dwelling areas shows that the resulting grouping is of some generality. Corresponding to the generality[30] there are similar activity profiles within the six groups belonging to different dwelling areas (Fig. 10).

Relation between activities and changes of place

In relation to the individual activity pattern a change of place is a 'means to an end'. Therefore the movement model was defined by analogy to the activity model. At first it has to be examined whether by reducing the movement circuit to the first and last leg of a journey an adequate description of the observed changes of place can be guaranteed. This hypothesis is examined by means of a type-analysis with different movement matrices of six groups as per the activity model (Fig. 11).

It is obvious that the reduction of the total movement pattern to the movement model does not mean any loss of information with regard to the grouping of population. Furthermore the extreme similarity

[30] This generality is to be seen in relation to the features of available empirical data.

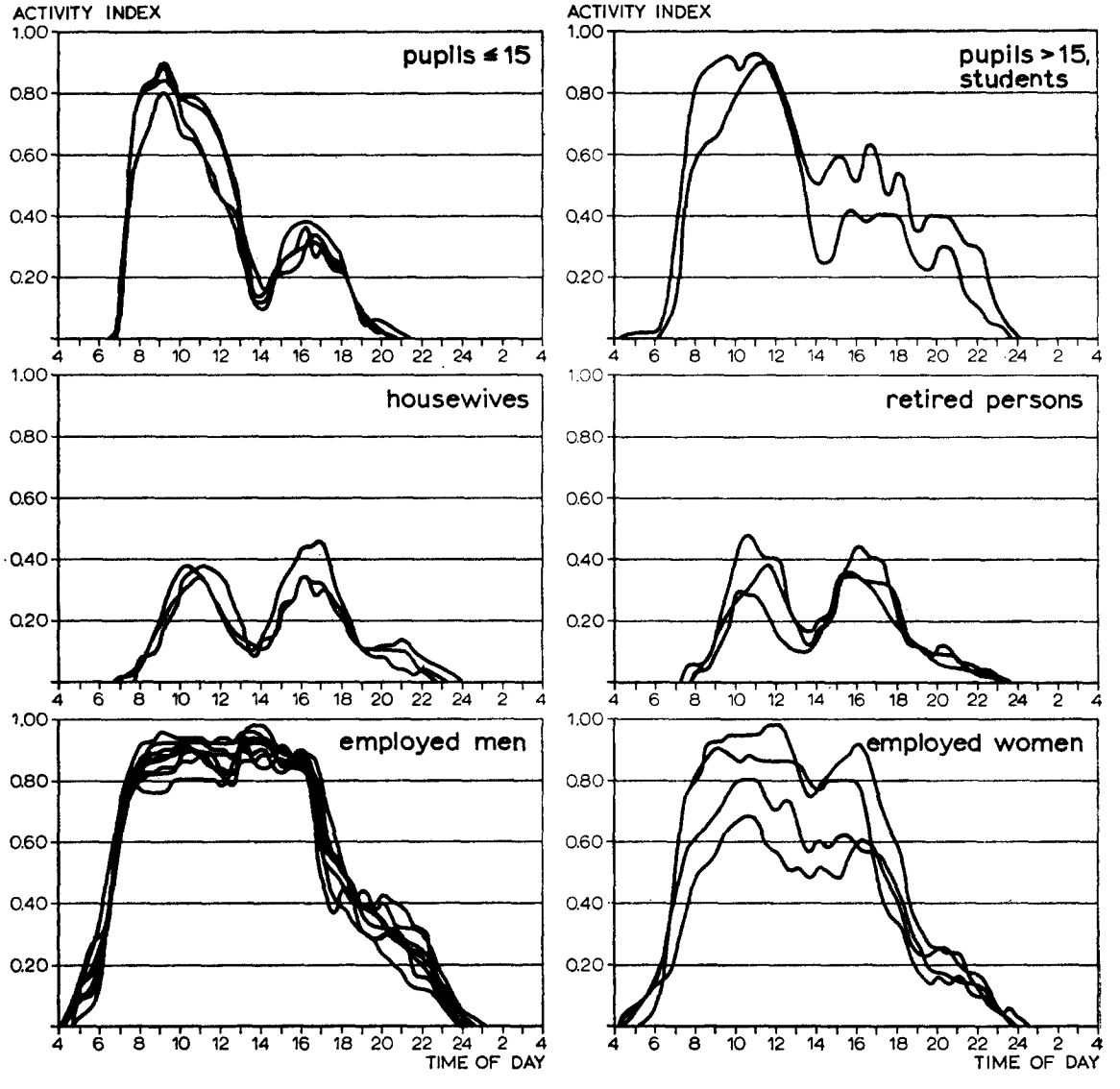


Fig. 8. *'Activity profiles' of six 'archetypes' in an average urban population.*

Table 6

Distribution of population into six individually determined groups

	Distribution of population to groups in area							
	Lehndorf		*Teichbreite*		*Heidberg*		*All areas*	
Group	*no.*	%	*no.*	%	*no.*	%	*no.*	%
Pupils < 16	83	11·1	254	23·4	146	16·5	483	17·8
Pupils > 15	19	2·5	14	1·3	12	1·4	45	1·7
Housewives	119	15·9	263	24·2	175	19·8	557	20·5
Retired persons	198	26·5	17	1·6	113	12·8	328	12·1
Employed men	213	28·5	402	37·0	299	33·8	914	33·6
Employed women	116	15·5	136	12·5	139	15·7	391	14·4
Persons in 6 groups	748	100·0	1086	100·0	884	100·0	2718	100·0
Percentage of pop. > 5	95·0		99·3		97·5		97·5	
Population > 5 years	787		1094		907		2788	

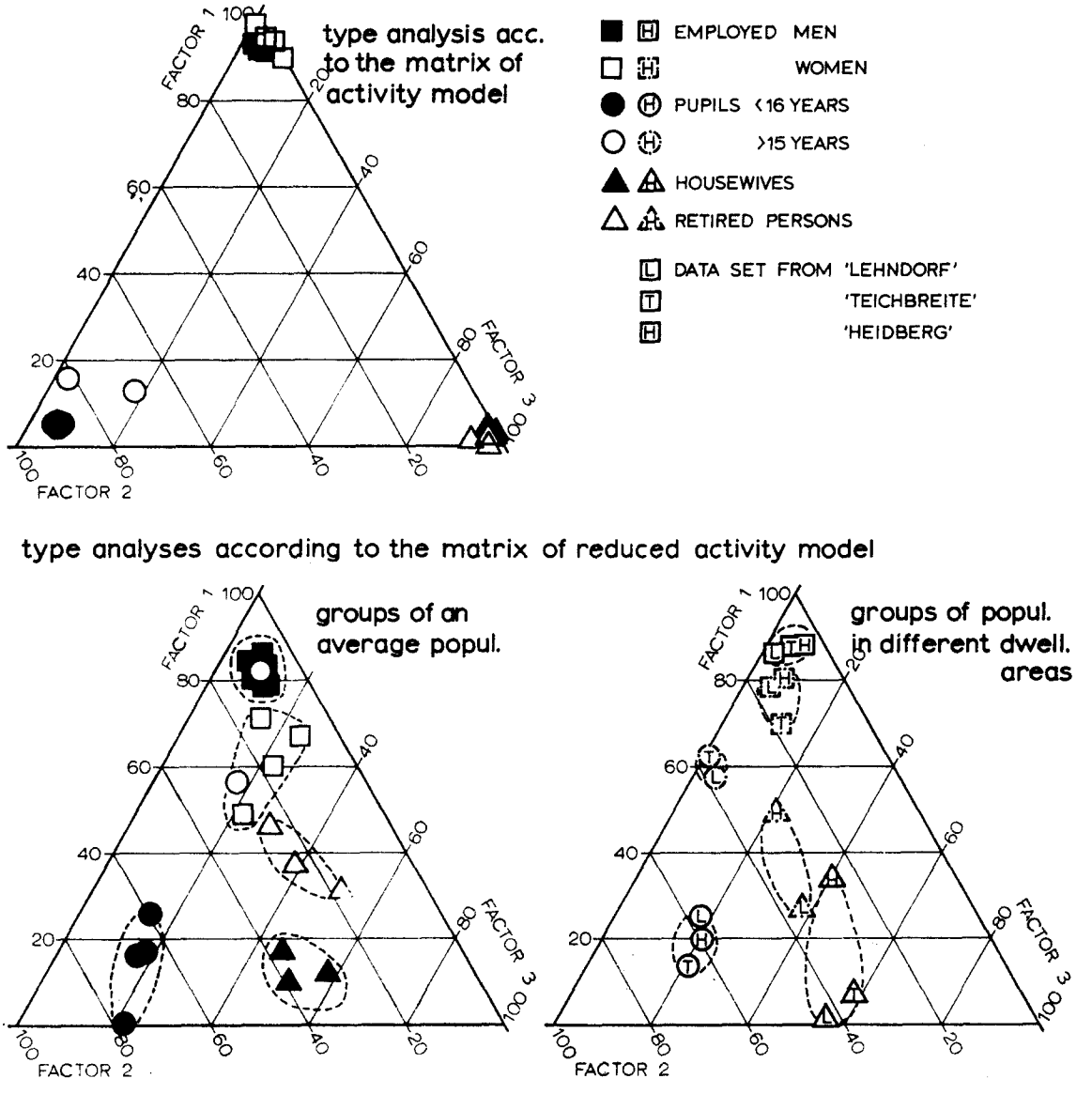


Fig. 9. Grouping of urban population according to different empirical data (three-components-systems of factor-loadings resulting from type-analyses).

between the structure of factor-loadings computed (*a*) from matrices of the activity model and (*b*) from the matrix of the movement model allows us to reason as follows:

(1) The activity pattern and the movement pattern are combined in a cause-effect-relationship. Changes of place related to 'casual' activities are 'means to an end'. They only become necessary because the facilities to satisfy fundamental needs are spatially distributed in an urban environment.

(2) The significant component of both urban activity pattern and the movement pattern seems to be the factor time; by the time of occurrence and the duration of activities the factor time will also influence the hourly distribution of changes of place. Moreover the spatial distribution of activities is of some relevance; the three urban areas used in this study must be considered in connection with the 'action spaces'[31] of certain groups of a population.

(3) Individual activity patterns, in reality, represent

[31] This 'action space' is found in numerous studies; see, e.g. Kofoed's 'field of contacts' (1969, 1971), Hurst's 'movement space' (1969a) or Horton's 'action space' (1970).

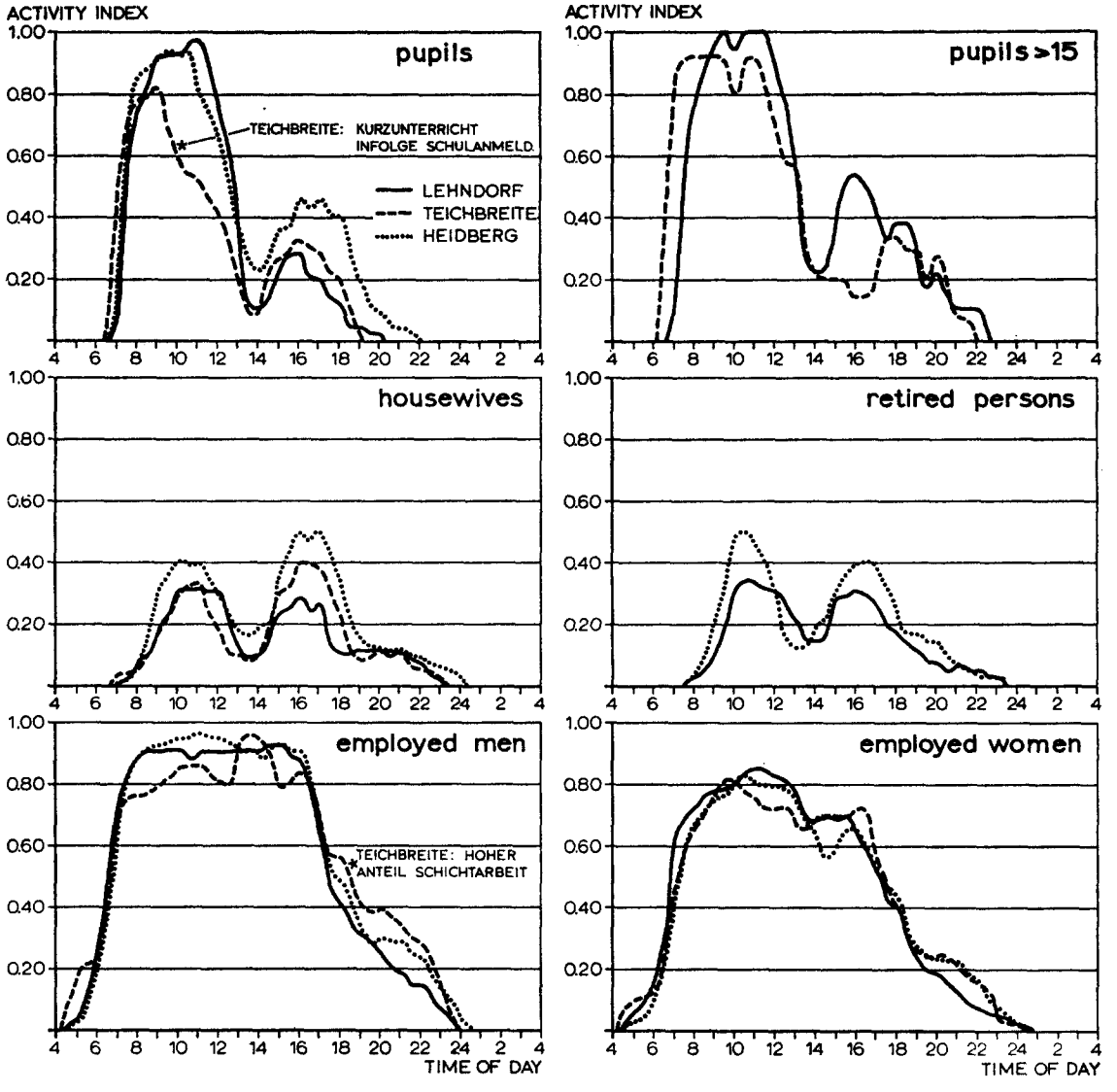


Fig. 10. *'Activity profiles' of six 'archetypes' out of different urban areas (as per a type-analysis of 18 modified groups).*

a combination of 'two-leg-journeys'—journeys to one main activity. It will therefore become easy to abstract from the complex system of movement and to describe the individual movement behaviour at the level of journey-concept. This method seems to be appropriate especially with regard to the quality of empirical data.

Typology according to individual movement behaviour

Certain activity-categories with their time and space ties are relevant to certain groups of population. Such ties also have a dominant influence on the other criteria of individual behaviour in an urban environment. More detailed grouping according to movement behaviour only seems to be possible if the exclusiveness of activities for certain groups is excluded from the data set. Logic suggests that this can be realised by means of a type-analysis within certain subgroups of population, e.g. groups of persons performing the same main activity in a day's schedule.

It seems to be advisable to start from the grouping of population according to the activity model: 'pupils', 'housewives', 'retired persons', 'employed

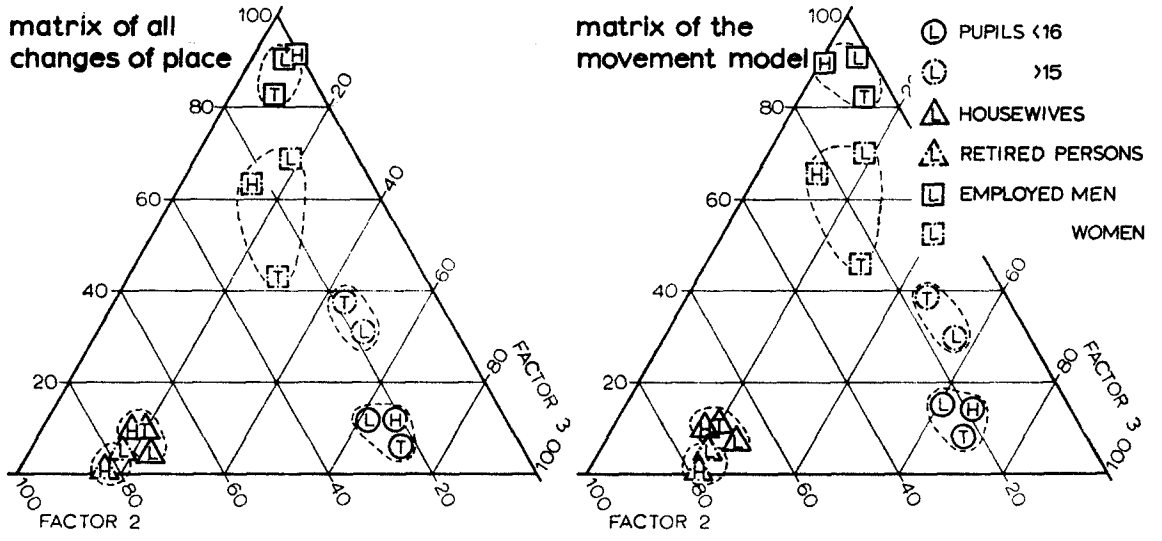


Fig. 11. *Grouping of population detected from type-analyses with different movement-criteria.*

women' and 'employed men'. Giving an example for the above defined grouping, this chapter specifies the movement behaviour of employed men.

This analysis starts from the hypothesis that individual movement patterns of employed men are influenced by the following criteria:

(1) social class[32] of a person,
(2) occurrence of working hours over a day's period,
(3) age of person (< 45 years <), and
(4) car ownership in relation to person or household.

The type-analysis of individual movement models results in the following grouping of employed men:

(*a*) persons in upper classes[33],
(*b*) persons in lower classes, working from 7/8 a.m. to 4/5 p.m.,
(*c*) persons in lower classes, working from 5/6 a.m. to 2/3 p.m.,

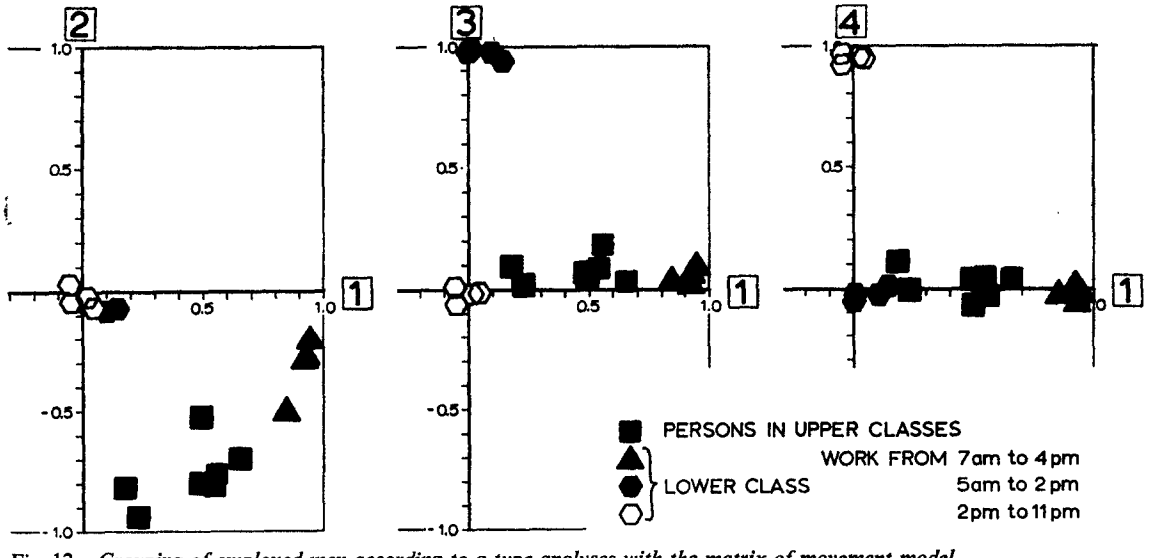


Fig. 12. *Grouping of employed men according to a type-analyses with the matrix of movement model.*

[32] This classification corresponds to Kleining's (1968) classification which is based on the occupational status of a person.
[33] Roughly speaking, 'upper class' represents white collar and higher occupations, 'lower class' represents blue collar and lower occupations (see Kutter, 1972, Anhang C).

(*d*) persons in lower classes, working from 1/2 p.m. to 10/11 p.m. (Fig. 12).

The determining factor in the structure of individual activity patterns is the occurrence of work over a day's period. The time ties of work also determine all other activities of employed persons (Maw, 1971). Great importance must be attached to the fact that car ownership in no way affect these individual movement patterns. It is true that car ownership might cause an increase in recreation trips; nevertheless it is quite clear that such an increase of trips is of less relevance to the travel patterns which are of interest to urban traffic planning.[34]

It is logical that car ownership is of great relevance to the choice of travel mode, i.e. the way in which travel needs are satisfied in a communication network. A type-analysis according to the matrix of travel modes[35] subdivides employed men into two groups, one with car available and one with car not available (Fig. 13).

It is obvious that in the study area[36] the use of cars is only determined by car availability. In smaller towns location of dwelling areas and quality of transportation network have no relevance to the choice of mode (Fig. 14).

Variables and parameters in an 'individual-factor-model'

Time budget and daily movement patterns of a person, living in an urban area, are determined by the age and the sex of this person. Therefore the activity pattern of an urban population is determined by the grouping of population according to age: 'under 6 years', '6 to 15 years', '16 to 65 years' and 'over 65 years'. This subdivision into age-groups causes the main activities of a population, e.g. 'school', 'work' and 'shopping'. It also influences the structure of the resulting movement patterns. The demographic structure of a population is a well-known instrument in planning. But it is very important that a grouping, merely found by deductive reasoning, can be substantiated on the basis of empirical data derived from urban activity patterns.

If economic and social factors which are of some relevance to the individual travel behaviour are also taken into consideration, the analysis results in a grouping of urban population into 36 individually determined groups.

Amongst the numerous criteria of model-groups, three significant characteristics should be discussed:

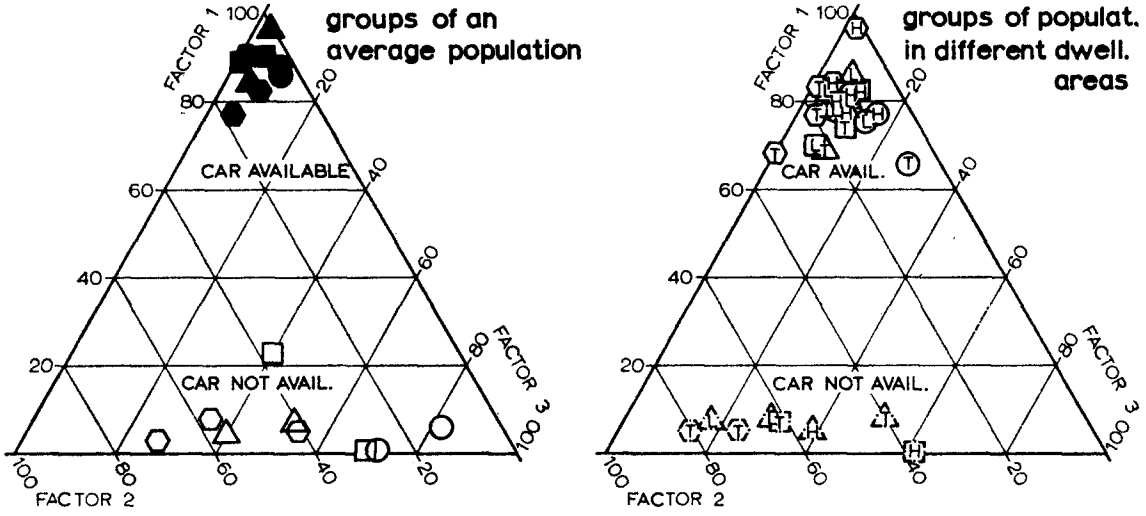


Fig. 13. *Grouping of employed men according to type-analyses with criteria of modal choice.*

[34] In the first place we are interested in travel models describing the peak period in the morning and in the afternoon; determining trip purposes in these periods are 'work', 'school' and 'shopping'.

[35] This matrix subdivides all changes of place into 'walking', 'cycling', 'car driver', 'car passenger' and 'public transport'.

[36] Braunschweig: 230,000 inhabitants; Wolfsburg: 90,000 inhabitants.

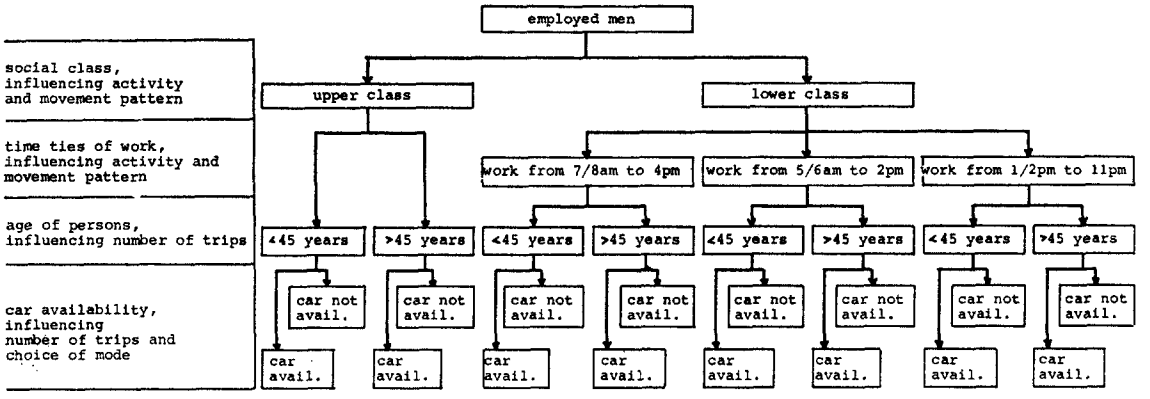


Fig. 14. *Grouping of employed men according to movement pattern, number of daily trips and choice of mode.*

(1) The total number of daily trips—known as trip production—is, to some degree, related to the age of a person and the role behaviour. If we compare the values of daily trip production for our model-groups, it becomes evident that trip production scarcely is a significant value to differentiate human behaviour in an urban environment (see Fig. 15).

(2) A significant grouping of urban population in fact results from the hourly distribution of trips from home and back home (first and last leg of the journey). According to these home-based trips, urban population can be divided into 'pupils', 'employed persons' and 'housewives' (see Fig. 16).

(3) The hourly distribution of changes of place is determined by the temporal distribution of activities over a day's period. As individual activity patterns

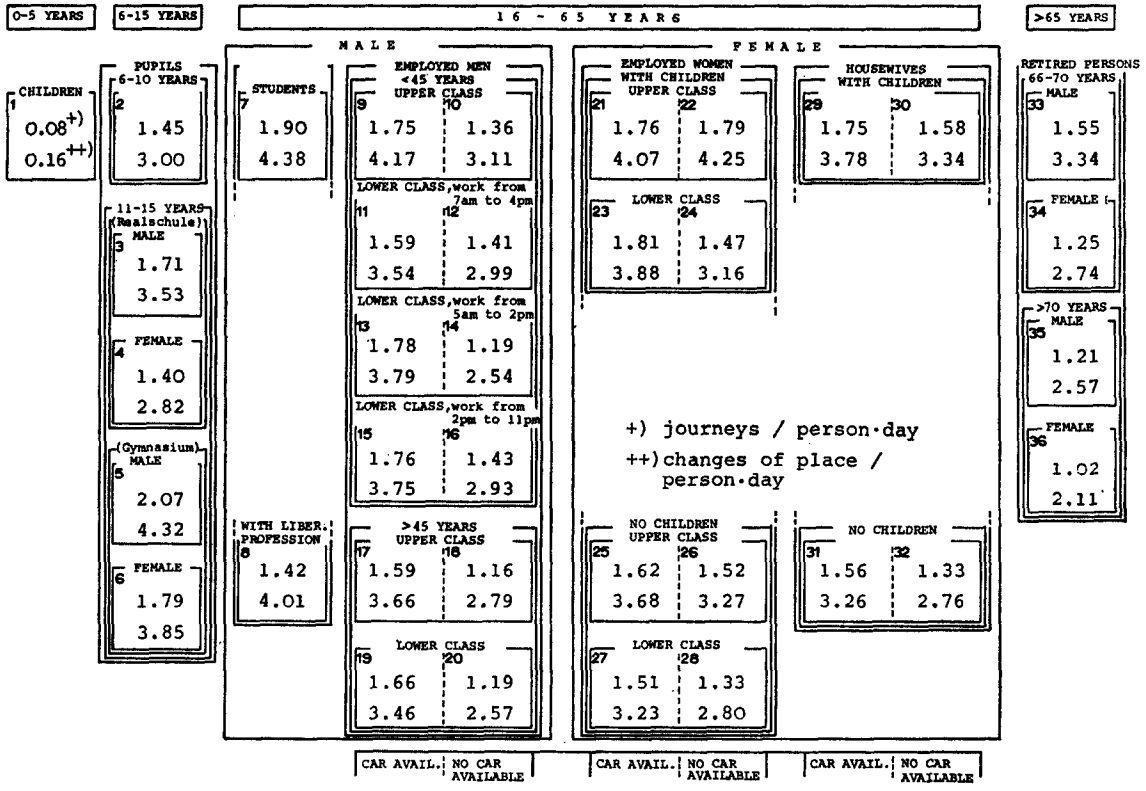


Fig. 15. *Grouping of population in an 'individual-factor-model'.*

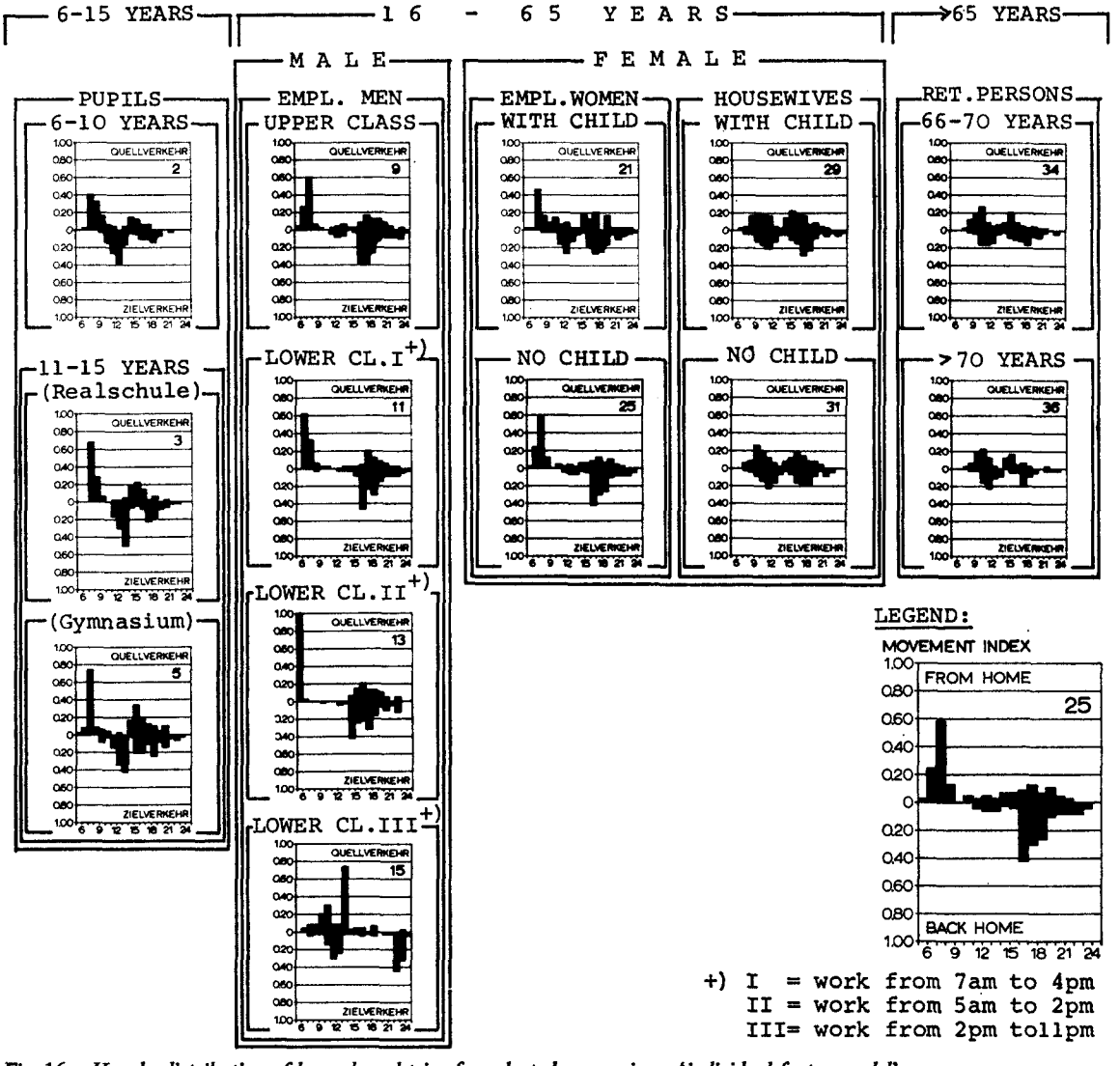


Fig. 16. *Hourly distribution of home-based trips for selected groups in an 'individual-factor-model'.*

are constituted by 'simple journeys'[37], activity profiles are indeed a significant criterion of the resulting movement models (Fig. 17).

The use of an 'individual-factor-model'

Testing of the model

The individual-factor-model is a descriptive model. '. . . . the appropriate test would be its ability to replicate the details of an existing urban pattern on the basis of limited information concerning the area in question' (Lowry, 1965, p. 164). Testing of the discussed model therefore includes the simulation of movement patterns for the studied areas.

As the model was also calibrated on the basis of empirical data of these three areas, the above defined 'testing' has no significance for any generality of the model. 'The model's structure and parameters may be so closely locked into the patterns evident in this particular area and time that its descriptive abilities may have no generality; applied to another city the model may fail miserably' (Lowry, 1965, p. 164). It seems to be possible to examine the gener-

[37] A journey related to one activity which means a two-leg-journey.

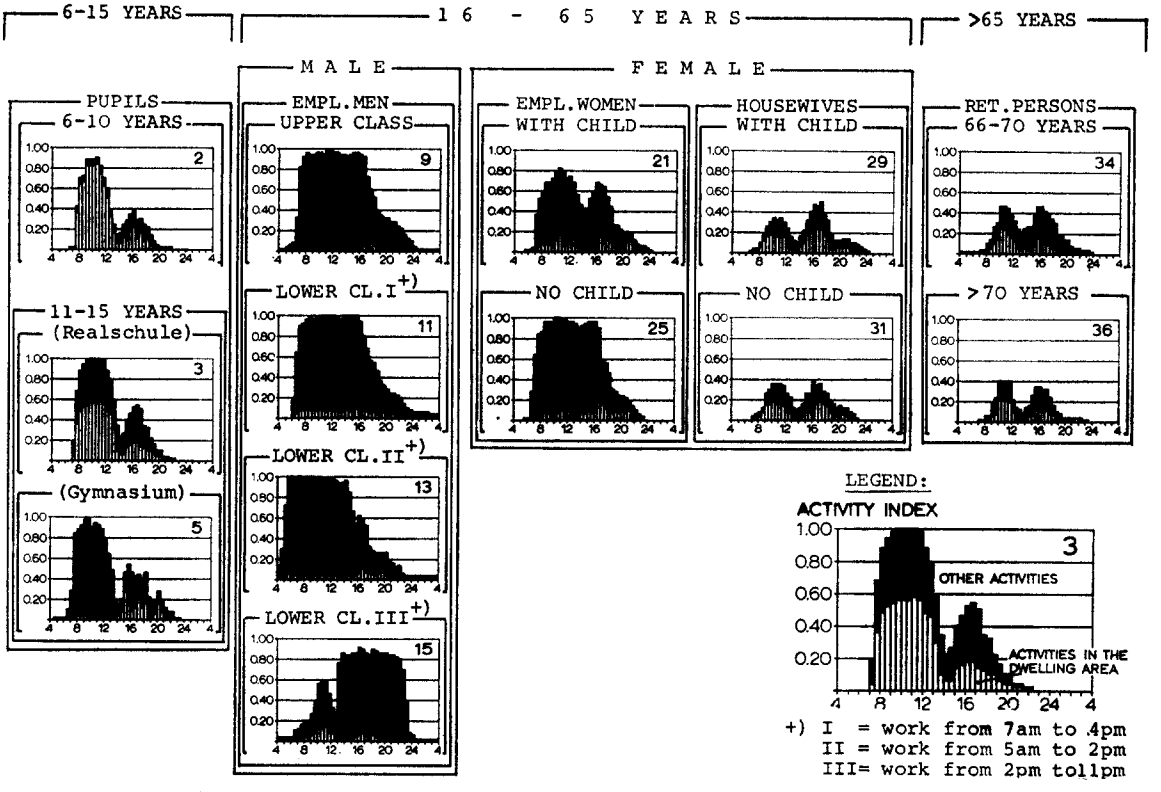


Fig. 17. Activity profiles of selected groups in an 'individual-factor-model'.

ality of the model by applying it to other populations whose travel behaviour was not used for the calibration of the model.

Data matrix for testing the model is the matrix of the first and last legs of journeys. These 'journey-legs' are subdivided into trips from home and trips back home, according to the location of the main activity (dwelling area and other places in the city) and the used mode of travel (Table 7).

Predicted values of total daily traffic[39] show a deviation of approx. 5% from the observed values. Probably the accuracy of the model could still be improved, if seasonal influences were eliminated from the data set; in summer there will always be more traffic than in winter.[39]

Root-mean-square-errors, computed for the deviation of predicted hourly values, come to less than 50%. The above mentioned deviation as a criterion of season can be explained by the deviation of hourly values in the evening. These changes of place are linked with the 'social/recreational' trips (Fig. 18).

Forecasting of changes of place according to activities in the 'dwelling area' and 'other places' results in a RMS-error of 11 and 9%. Partly this deviation is a result of the seasonal circumstances of research. On the other side, accuracy of prediction seems to be higher for changes of place resulting from activities out of the dwelling area. Daily experience shows that these activities are limited to a large extent by the above mentioned external arrangements of society, e.g. 'work-arrangements'. If we differentiate changes of place according to choice of mode, the highest accuracy will be given for the car trips.

Application to the prediction of the future

Prediction of the future, using a descriptive model, may be significant under the assumption *rebus sic stantibus* and *ceteris paribus* (Seiffert, 1971, p. 160 f). In spite of this restriction, it is also evident that any sort of planning must include a prediction of the future (Schäfers, 1970, p. 251).

[38] Total daily traffic includes all changes of place in connection with out-of-home-activities.
[39] The individual-factor-model overestimates total traffic of winter-weekdays and underestimates traffic in the summer season.

It might be essential to apply the cause-effect-relationships, resulting from inductive-empirical research, to the future, if we are aware of the 'boundary conditions' of the examined system. Boundary conditions of the individual-factor-model derive from the observed situation in the study areas. On one side, empirical data are detected on the basis of a time budget study; the analysis, on the other side, is started from a specific situation of an urban population.[40]

The disadvantages of the time-budget-method are compensated by the extreme uniformity[41] of external arrangements at work, school and shopping facilities. But we are unable to forecast any changes of boundary conditions of society in a descriptive model. Such changes are for example:

(1) Change of role behaviour, especially change of traditional destruction of roles of men and women.
(2) Increase of second cars in households which might result in an increase of mobility of housewives.[42]

These 'causes' were not observed in the study areas and therefore we cannot make any statements in relation to possible 'effects'.

In current trip generation models[43] the trip generation is based on criteria of car ownership. The

Table 7

Matrix of 'movement model' as used for testing of 'individual-factor-model'

	Changes of place from home[a]								*Changes of place back home*[a]							
	Activities in the dwelling area				*Activities at other places*				*Activities in the dwelling area*				*Activities at other places*			
Interval	*walking*	*car driver*	*car passenger*	*public transport*	*walking*	*car driver*	*car passenger*	*public transport*	*walking*	*car driver*	*car passenger*	*public transport*	*walking*	*car driver*	*car passenger*	*public transport*
4 a.m.- 6 a.m.	2	2	1	—	4	17	2	5	—	—	—	—	—	—	—	—
6 a.m.- 7 a.m.	4	3	1	—	10	45	13	35	2	—	—	—	—	1	—	—
7 a.m.- 8 a.m.	61	1	2	—	16	74	20	70	1	1	—	—	—	1	—	1
8 a.m.- 9 a.m.	45	3	2	—	3	21	9	21	4	1	—	—	—	3	—	—
9 a.m.-10 a.m.	45	2	2	1	3	10	3	20	26	1	—	—	—	—	—	—
10 a.m.-11 a.m.	43	2	—	—	2	7	2	10	53	2	—	—	—	3	—	3
11 a.m.-noon	23	—	—	—	1	4	1	8	55	—	—	—	3	10	1	15
noon-1 p.m.	10	3	1	1	—	4	1	3	58	1	2	—	4	22	3	27
1 p.m.- 2 p.m.	3	2	—	—	3	16	6	8	21	7	1	1	3	16	3	35
2 p.m.- 3 p.m.	12	1	—	—	10	16	5	11	4	—	—	—	1	5	2	14
3 p.m.- 4 p.m.	45	2	1	—	12	9	4	19	9	2	1	—	2	10	3	7
4 p.m.- 5 p.m.	31	4	1	—	10	10	1	10	32	1	1	—	12	50	16	33
5 p.m.- 6 p.m.	40	10	1	2	2	17	12	3	42	10	2	—	11	45	14	33
6 p.m.- 7 p.m.	4	3	2	—	2	19	7	3	40	6	3	1	20	48	20	23
7 p.m.- 8 p.m.	14	2	1	—	—	15	3	5	14	1	1	1	4	27	12	16
8 p.m.- 9 p.m.	7	3	1	1	1	15	10	6	12	3	2	—	5	12	5	7
9 p.m.-10 p.m.	4	1	—	—	1	6	5	2	8	2	2	1	2	14	10	6
10 p.m.-11 p.m.	1	—	—	—	—	3	1	—	10	2	1	—	3	17	11	4
11 p.m.-midn.	—	—	—	—	—	—	—	—	3	1	1	—	1	21	13	4
afr. midn.	—	—	—	—	—	—	—	—	—	—	—	—	1	6	3	3
Total day	394	44	16	5	80	308	105	239	394	41	17	4	72	311	116	231

Total extent of 'movement model' for 1,000 inhabitants of Heidberg.

These 'causes' were not observed in the study areas and therefore we cannot make any statements in relation to possible 'effects'.

In current trip generation models[43] the trip generation is based on criteria of car ownership. The

[40] One criterion of this 'situation of population' is, for example, the observed car ownership level of 0·80 cars/household; this level of car ownership has the effect that a car is only available to the head of the household. In U.S.A. we have another level of car ownership, i.e. about 1·30 cars/household.

[41] Arrangements of society may change from town to town, nevertheless we are able to postulate these special arrangements and to include them in a model.

[42] If more cars are available (>1), housewives will also use a car.

[43] Current trip generation models describe trips by any mode of transport, but do not include every change of place in an urban environment.

conceptual framework for an individual-factor-model is started from the hypothesis that car ownership is relevant to the number of trips by private car and public transport, but has only little relevance to the total number of changes of place. By means of the individual-factor-model this hypothesis can be examined on the basis of car ownership levelling at 0 car/household and 1 car/household.

The total extent of movement system will increase by 15%, if the level of car ownership increases from 0 to 1 car/household. This small increase of total movement proves that the individual travel needs must be considered as a constant value in urban societies (see Böhme, 1970) (Table 8).

Increase of movement is not equally allocated to spatial areas. During the observed period we find an enlargement of individual action space which means that there is a higher increase of outbound movement. Furthermore for these longer trips the choice of mode will change considerably. This change of choice of mode explains the overestimation of the relevance of car ownership in current generation models[44] (Table 9).

If we start from the current car ownership level (0·80 cars/household), the car trips will increase by about 30% while the total movement will only increase by about 4%.

Conclusion

Urban person movement is part of the urban activity pattern. All changes of place in an urban environment, in connection with this activity pattern, are 'means to an end'. Deductive reasoning reveals that person movement therefore is to be considered as individually determined human behaviour. The analysis in this study is developed from the hypothesis that spatial and temporal structure of urban activity pattern is determined by the concurrence of individual activity patterns.

The setting up of an 'individual-factor-model' takes place in three steps:

(1) *A priori* grouping of urban population according to individual characteristics of persons. Such grouping mainly serves to provide empirical data of

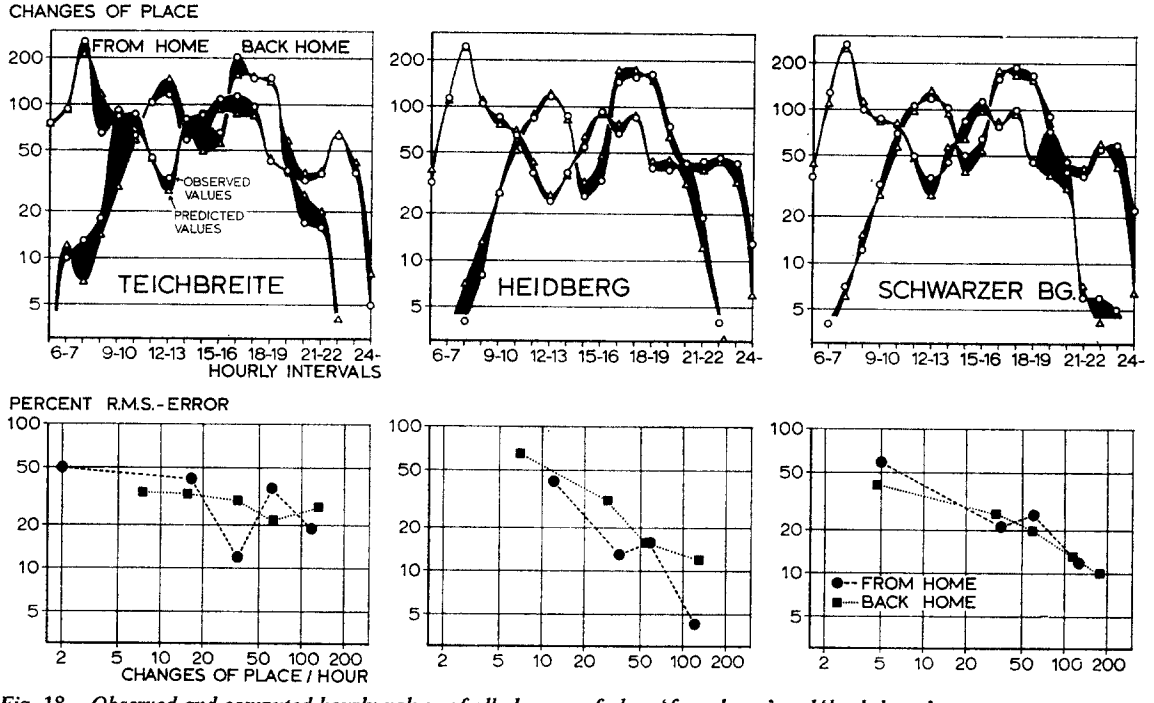


Fig. 18. *Observed and computed hourly values of all changes of place 'from home' and 'back home'.*

[44] If only the subsystem of car trips is analysed, the car ownership and the resulting car trips are combined in a cause-effect-relationship (see, e.g. Kutter, 1972, Kap. 2).

Table 8

Changes of movement pattern resulting from an increase of car ownership

	Location of main activity	Mode of transport	Changes in 'generation' in: Lehndorf interval I[a]	Lehndorf interval II[b]	Teichbreite interval I[a]	Teichbreite interval II[b]	Heidberg interval I[a]	Heidberg interval II[b]
Changes of place from home	Dwelling area	All modes	+3·5%	+10·0%	+2·0%	+10·0%	+2·6%	+6·7%
	Other places in urban area	Walking	−19·0%	−37·0%	−20·0%	−43·2%	−15·7%	−44·9%
		Car driver	+37·5%	—	+32·0%	—	+24·7%	—
		Car passenger	+23·5%	—	+11·8%	—	+10·1%	—
		Public trans.	−22·8%	−45·8%	−23·6%	−57·2%	−21·6%	−56·3%
		All modes	+4·8%	+15·1%	+5·2%	+21·8%	+3·5%	+21·7%
	Total area	All modes	+4·3%	+13·0%	+3·8%	+16·3%	+3·1%	+14·9%
Changes of place back home	Dwelling area	All modes	+3·4%	+9·5%	+2·1%	+10·6%	+2·0%	+4·5%
	Other places in urban area	Walking	−23·7%	−45·2%	−18·4%	−46·9%	−16·0%	−50·4%
		Car driver	+35·5%	—	+28·9%	—	+27·1%	—
		Car passenger	+38·8%	—	+19·1%	—	+15·5%	—
		Public trans.	−23·2%	−46·6%	−24·7%	−58·2%	−22·7%	−58·3%
		All modes	+5·6%	+15·5%	+5·4%	+22·3%	+5·3%	+21·7%
	Total area	All modes	+4·7%	+13·0%	+3·9%	+16·8%	+3·9%	+13·9%

[a] Changes between today and the car ownership level of 1 car/household.
[b] Changes between the car ownership levels of 0 car/household and 1 car/household.

some generality, even on the basis of time budget data.

(2) Detection of significant components of activity pattern and movement pattern. Hereby the observed simple structure of individual activity patterns provides a significant description of movement behaviour by means of 'journey-concept'.

(3) Examination of *a priori* grouping with regard to its significance for activity patterns and movement patterns. This analysis takes the form of 'behavioural typology'.

An analysis of empirical data shows that time budget and daily movement pattern of a person, living in an urban area, is primarily determined by age and sex of this person. The hourly distribution of changes of place depends on the temporal distribution of activities over a day's period. Moreover the 'activity profiles' are a significant criterion for the resulting movement patterns as individual activity patterns are constituted of two-leg-journeys.

The conceptualised 'individual-factor-model' is a descriptive model by nature. Contrary to current trip generation models, it takes into account the underlying cause-effect-relationships and bases trip generation on individual criteria of 'traffic generators'. Over and above, an analysis of the total changes of place results in a relatively high constancy of the total movement. Finally we are able to postulate the direction of causation and to determine the future value of the 'causes', e.g. demographic data of any given population. Therefore the 'individual-factor-model' provides a better prediction of the future.

Table 9

Changes of modal-split resulting from an increase of car ownership

	Choice of mode in percentages: Lehndorf			Teichbreite			Heidberg		
Car ownership level	*walk*	*car*	*publ.*	*walk*	*car*	*publ.*	*walk*	*car*	*publ.*
0 car/household[a]	19	20	*61*	25	14	*61*	22	12	*66*
0·80 car/household	14	*47*	39	15	*56*	29	12	*57*	31
1 car/household	10	*61*	29	12	*67*	21	10	*66*	24

[a] Households of persons in free profession are not included.

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