Delineating and Typifying Urban Neighbourhoods: A Mixed-Methods Approach

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1. Introduction: Problems of Comparative Neighbourhood Analysis

For over a hundred years, neighbourhoods have been perceived as central elements of the urban society and community (Albers 1974). As spaces for diverse activities and encounters, they play an important role in the everyday lives of their inhabitants. They provide basic functions of life: housing, work, education, (local) supply, recreation and, last but not least, social life. Processes of social change can therefore be observed particularly well in these "dynamic micro-worlds" (Schnur 2014, 21). For more than two decades, neighbourhoods have also been gaining in importance as a level of urban development policy action, which can be seen in a multitude of small-scale funding programmes and instruments (Franke 2011; Schnur 2018, 1833).

Therefore, from a social, spatial and planning science perspective, neighbourhoods are increasingly relevant spaces for observation, research and action. At the same time, however, systematic and, above all, comparative neighbourhood analysis faces a number of practical, theoretical and methodological problems.

1.1 Spatial Monitoring at Neighbourhood Level

Since neighbourhoods are not standardised objects of spatial observation, there is often a lack of meaningful data at the small-scale level. In Germany, spatial monitoring as a legally prescribed task starts at the municipal or district level. It is thus possible to observe city-wide development trends, but not small-scale changes. Many cities and municipalities therefore set up their own small-scale monitoring, which is usually tailored to the administrative (sub)structures (usually city districts and/or subdivisions). This leads to at least three problems: firstly, the spatial outline hence follows an administrative logic, which often does not correspond to the everyday understanding of neighbourhoods. Secondly, the administrative divisions in the various cities often differ significantly from each other, from the depth of division to the average number of inhabitants. Thus, district A of municipality X can only be compared to district A of

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municipality Y to a limited extent. For this reason, the Metropole Ruhr, for instance, has attempted to set up a region-wide monitoring system (RuhrFIS), in which the 53 cities are mostly subdivided into 635 comparable districts on the basis of the local administrative division (RVR 2017, 11). Thirdly, all cities survey the number of inhabitants at the level of their small-scale subdivisions. But that is where the commonalities end: there are considerable differences between the cities in terms of the variables observed (e.g., age or nationality) as well as the possible characteristics of these variables (e.g., cohorts in the case of age, and regional groupings such as "Maghreb" or dichotomous scalings such as "national" and "foreigner" in the case of nationality). This means that comparative neighbourhood research – within a city, but also on a supra-local level – faces great methodical difficulties.

1.2 Understanding Space and Neighbourhoods

In addition, comparative neighbourhood research is complicated by the fact that there is no unified understanding of 'neighbourhood'. However, there is a clear dividing line between neighbourhood concepts based on an absolute or objective understanding of space and those based on a relational or constructivist conception. In the former perspective, neighbourhoods are conceived as clearly delimitable 'containers'; in the latter, they appear as 'social spaces' defined by the living world with open, fluid boundaries.

Absolute neighbourhood concepts usually entail quantitative research approaches. The aim is to make the social phenomena or processes taking place in the 'containers' measurable with standardized procedures or to describe them statistically, to analyse them and, possibly, to compare them.

But according to the constructivist perspective, spaces or neighbourhoods are precisely "not fixed units that precede social processes, but are themselves a result of these processes" (Kessl/Reutlinger 2010, 27). This research therefore aims to understand the individual and collective construction processes of neighbourhoods and to trace the position-dependent perceptions, interpretations and action orientations that constitute neighbourhoods from a subjective perspective. Qualitative methods are particularly suitable for this purpose. They stand for (at least semi-)open, interpretative approaches that are intended to identify overarching patterns within the diversity of subjective perspectives, for example, shared neighbourhood concepts or overlapping spaces of action. In this view, there can be no firmly defined neighbourhoods with objective, binding boundaries. Rather, neighbourhoods are characterised by fuzzy boundaries.

The social constructivist understanding of neighbourhoods is widely shared today. Nevertheless, empirical neighbourhood research and practical urban or neighbourhood planning are repeatedly faced with the task of meaningfully delimiting spaces of investigation, action or intervention for their respective purposes, i.e. ultimately defining 'containers' nonethless. After all, municipal planning must "determine places and areas in which employees are to carry out outreach work, kindergartens or roads are to be built, green spaces or playgrounds are to be created, emissions are to be limited or social division is to be countered" (Groos/Messer 2014, 10), and must justify this selection in a comprehensible way. Thus, the dilemma of "real complexity" and "necessary sim-

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plification" (Schnur 2014, 42) cannot be resolved. Schnur therefore calls for a reflected pragmatic approach (ibid.).

In what follows, we present such an approach. It is characterised by the integration of qualitative and quantitative methods. The aim of this paper is to present a transferable model of neighbourhood delineation and typification that enables comparative neighbourhood analyses within a city, but also between cities. The approach has already been successfully tested in the city of Remscheid in cooperation with the local administration.[1]

2. A Mixed Methods Approach

The delimitation and typification of observation areas is one of the classic tasks of spatial observation – from the European to the regional level. Numerous (standardised) methodological approaches have been tried and tested for this purpose (cf. Terfrüchte 2015). So far, there is no such established approach for spatial observation at the neighbourhood level.

2.1 Mixed Methods

Since our aim is to capture a multifaceted object of study, i.e. the neighbourhood, in the most complex way possible and from different perspectives, we choose a mixed methods approach (Burzan 2016, 9). We understand "mixed methods" as "the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the purpose of breadth and depth of understanding and corroboration" (Johnson et al. 2007, 123).

In doing so, we combine qualitative and quantitative instruments carefully tailored to the subject matter, i.e. along the research question of how to meaningfully delineate and typify neighbourhoods for research and planning purposes. For, as Johnson and Onwuegbuzie (2004, 17f) state: "What is most fundamental is the research question—research methods should follow research questions in a way that offers the best chance to obtain useful answers."

In this context, we assume that "all methods can only capture sections of the empirical reality of interest, have different strengths and weaknesses and can therefore complement each other" (Hense/Schork 2017, 360). For us, however, methodological plural research also means, as far as possible, always relating the data obtained from different

1 The model was developed within the framework of the joint project "MOSAIK – Model Strategies for Integrated and Culturally Sensitive Housing Stock Development" funded by the Federal Ministry of Education and Research in the "Kommunen Innovativ" programme. We would like to thank the city of Remscheid for the opportunity to use the municipal data stocks for our research. For his dedicated organisational and technical support of the MOSAIK project, we would especially like to thank Dennis Hardt very much.

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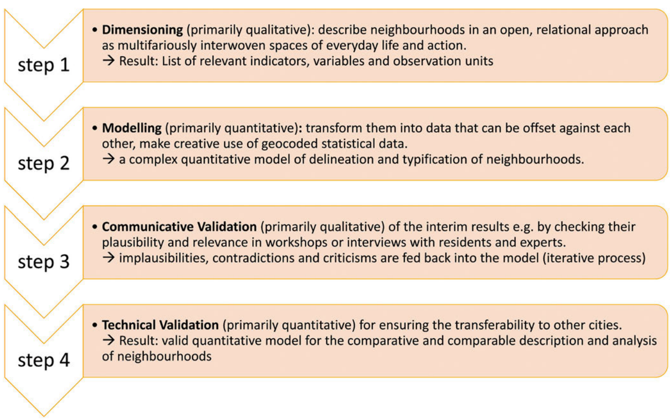
sources and with different means to each other in such a way that they not only complement each other, but can also, if possible, challenge or even contradict each other. So this is not only about combining methods, but also about integrating methods.

Thus, our research approach is "problem-centred", "pluralistic" and "oriented towards 'what works' and real-world practice". In this respect, it fully corresponds to the "pragmatist worldview" in mixed methods research, as characterised by Creswell and Plano-Clark (2018, 34ff.), among others.

2.2 Sequential Design ("Four Steps")

In model building, we proceed in qualitative and quantitative sub-steps that systematically build on each other, but should not be understood linearly (cf. Fig. 1).

Fig. 1: Sequential design in four steps



The starting point is, firstly, a qualitative, open, relational understanding of neighbourhoods as multifariously interwoven spaces of everyday life and action, which we, secondly, transform into a complex quantitative model of delineation and typification of neighbourhoods with the help of a creative use of geo-coded statistical data. Thirdly, interim results are repeatedly validated with qualitative methods, e.g., by checking their plausibility and relevance in workshops or interviews with residents and experts ("communicative validation", Flick 2014, 413ff.; Kvale 2007). It is crucial that the delimitations and typifications correspond to the everyday perception of neighbourhoods. If this is not the case, the model or its components are put to the test. Contradictions and criticisms are fed back into the model, which is corrected and improved until its results stand up to the critical scrutiny of residents and experts. At the end of this iterative, sequential procedure, there is, fourthly, a valid quantitative model that can be transferred to other cities for the comparative and comparable description and analysis of neighbourhoods, which, as its application in the city of Remscheid shows, can also provide a valuable basis for evidence-based urban and neighbourhood development.

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3. Challenges of Modelling

In our project, the delineation of neighbourhoods therefore stands at the end and not at the beginning of the research process. The attempt not to define neighbourhoods in advance, but to discover them in the statistical data from a lifeworld perspective, is associated with great challenges. For one thing, suitable material, i.e. material that is available or can be translated into data, must first be identified or collected and processed (sections 3.1 and 0). On the other hand, it is necessary to find ways of including defining neighbourhood characteristics in statistical modeling, such as everyday interactions, principle openness, and the social and functional interdependence of neighbourhoods (section 3.3). This is anything but trivial.

Therefore, the first step is to take a look at the variables and observation units that are relevant for neighbourhood delineation and typification. In the following, we will examine the question of which data are available to us at all, what significance they have and how they can be modelled.

Fig. 2 classifies the usual indicators of neighbourhood research according to whether the variables or observation units are manifest or latent.

Fig. 2: Latent and manifest variables and observation units

	observation unit: **manifest**	observation unit: **latent**
variable: **manifest**	people • age • citizenship area • morphology (e.g. size) • located infrastructures	household • size (number of people) • mean age neigbourhood • mean age • located infrastructures
variable: **latent**	people • educational background • migration background building • primarily usage • property value	household • type • Income neigbourhood • local identity • household-types

3.1 Manifest Variables and Observation Units

People

Since we consider neighbourhoods as spaces of activity and interaction for their inhabitants, we first look at the people living there and the ways they live (together), i.e. in private households. (Private households – apart from one-person households – are already aggregates of the persons belonging to the household). Persons as observation units are in principle directly observable. However, not all variables attributed to them can be observed beyond doubt. The most prominent example is probably gender, whose

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dichotomous recording as "male" and "female" has been prohibited in German civil status law since the end of 2018 (Federal Constitutional Court, 2017). The validity of the observed or observable characteristics in the context of the concept of migration background is also complex (see below).

Irrespective of this, a great deal of information about people is available, of comparatively good quality, through compulsory registration (in Germany and many other European countries), and this information can be geo-referenced via the registration address. The registration laws in each case regulate which characteristics are recorded. In Germany, these variables include the date of birth, gender, place and country of birth, nationality, and, in the case of minors, the same information on the parents, and many more (§ 3 Bundesmeldegesetz [BMG]). For individuals, monitoring (in accordance with data protection) is therefore possible at any small-scale level.

Infrastructure Facilities

Infrastructural facilities are not only important with regard to the perception of the basic functions of existence in the neighbourhood. In our approach, they play a central role as potential places for everyday encounters and interactions. Therefore, we focus on mobility infrastructure (especially public transport stops and routes, roads, footpaths and cycle paths), education and care infrastructure (especially day-care centres and schools), supply infrastructure (especially retail facilities) and health infrastructure (e.g., general practitioners and paediatricians). Basically, a distinction must be made between point infrastructures, which can be geo-referenced via addresses, and network infrastructures. While point infrastructures are destinations of everyday interconnections, network infrastructures influence the accessibility of these destinations. Just as large as the variety of relevant infrastructures is the number of institutions that hold the relevant data. Although many cities are trying to systematically compile such points of interest and make them available to third parties, there are only uniform state or national data sets for those infrastructures that are the responsibility or sovereignty of the states or the federal government. However, this does not prevent small-scale monitoring.

Buildings and Areas

In addition to population and infrastructure facilities, structural characteristics are particularly relevant for neighbourhood perception (Schnur 2018, 1832). Observation units are then essentially buildings and, if applicable, associated cadastral areas. These data are processed uniformly throughout Europe on the basis of the INSPIRE Directive (*INfrastructure for SPatial InfoRmation in Europe*). In this way, comparable statements can be made on the (dominant) land use or on the use of buildings. In addition, the official house coordinates assigned to the buildings form an excellent data basis for the georeferencing of people and infrastructure facilities.

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3.2 Latent Variables and Observation Units

In addition to the three directly observable observation units of persons, infrastructures and buildings, there are – as mentioned – also interesting variables and observation units that are latent and must first be constructed.

Private Households

In comparative neighbourhood research, private households are often considered as *the* relevant characteristic carriers. The focus then is on characteristics such as income, receipt of transfer payments, number of children and many more. However, since the municipal registration system does not recognise household membership as an obligatory survey characteristic of a person, households are not statistically observable.

Therefore, households must be modelled based on statistical information, as is done for the census, among other things. On the basis of a series of premises, married or paired persons who are registered at the same address are successively aggregated into households with biological children who are also registered there. What is easily possible with single-family and multi-family houses with traditional forms of living is more difficult with multi-generation houses and shared flats. Here it has to be determined whether it is the same household or separate ones. Insofar as households are already latent as observation units and their determination is subject to a multitude of premises, the variables aggregated at the household level always have a certain susceptibility to error.

Relocation

In social science, migration describes the (outward or inward) movement of people from a source to a destination. This includes both intra- and inter-communal migration within a nation state (internal migration) and migration across national borders (international migration) (Han 2016, 7f.).

From the perspective of municipal statistics, this means that by definition there is only internal migration within the municipality – without further differentiation. However, the (address-specific) raw data, which can be retrieved from the population registers of the municipalities, also allow intra-municipal migration to be modelled. This means that further differentiations can be made, e.g., migration within a neighbourhood, migration between neighbourhoods (within the city) or migration between the city and the surrounding area.

Migration Background

International migration is relevant for the concept of 'migration background' as defined by the Federal Statistical Office. While the destinations (i.e. the new places of residence) of migrants can usually be recorded without any problems via the registration system, this is by no means the case for origins and places of birth. There are many possible causes for incomplete and erroneous data records, ranging from incorrect recording at the registration office to unclear cases or the non-existent obligation to record the country of birth before 2015 (cf. Terfrüchte et al. 2021). The source of migration and the

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country of birth of migrants must be distinguished from their nationalities. In principle, migrants (like natives) can have any number of nationalities. They do not all have to be entered in the residents' register as long as no (new) identity card is requested. Since in Germany it is obligatory to do so only every ten years, it might be the case that, for example, non-German citizenships acquired in the meantime remain unknown to the registration system. In this respect, only the concept of "foreign national" is valid for persons who do not have German citizenship.

In addition to the fact that only those nationalities can be included in analyses that are known to the registration system, it must also be clarified whether and how the various combinations of nationalities are dealt with analytically. For example, do we ask in a survey whether a person has a Turkish or Russian passport (among others), or are German-Turks and Russian-Germans understood as a separate group precisely because of their combination of citizenships?

Official information on persons (as observation units) thus has its weaknesses, but from a pragmatic point of view it is still the most suitable, since the latent variables of interest in the research context (such as migration background) can be constructed in a reasonably plausible and transparent manner, so that there is no need to draw on already constructed variables from secondary data sources.

Small-scale Monitoring Units

The aforementioned data is often subject to restrictive data protection. If data is passed on to research institutions for scientific purposes, then there is the obligation to aggregate it in such a way that it is not possible to draw conclusions on individual persons, registration addresses, companies, etc. The data must not be passed on to third parties.

At the same time, the municipalities do not have all data that are of interest from a research perspective, such as data on purchasing power, the labour market or health care. Requesting these data from the relevant agencies is only possible for spatially delimited sub-areas. However, to define such sub-areas for the data query conflicts with our claim not to define neighbourhoods in advance, but to develop them from the available (data) material.

Due to both requirements (data protection and spatial data retrieval), we therefore form spatial units, in such a way that we can assume that the buildings and persons belonging to these units will under no circumstances belong to different neighbourhoods, and can therefore be considered 'inseparable' in the sense of belonging to a neighbourhood. We call them the 'smallest units'. They are building blocks of the neighbourhoods to be delimited and should not be confused with the neighbourhoods themselves!

Box 1: Sequential mixed methods procedure for determining the smallest units Based on observation (Step 1), it was initially building blocks that seemed suitable as the smallest units. However, we have found that there are building blocks with a heterogeneous building and settlement structure – a criterion that can itself have a neighbourhood-defining effect and can therefore also be relevant for the delimitation. Our model for the formation of smallest observation units (Step 2) therefore combines building blocks

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with settlement types. In the further course of the neighbourhood delimitation, it has become apparent that there are large units with only one or a few buildings. This can sometimes result in smallest units which are adjacent in the sense of the delineation algorithm, but the buildings within them are far away from each other (Step 3). After reviewing a few individual cases, we introduced a plausibility check which, based on the population density and the density of residential buildings, identifies such smallest units that may have an 'unsuitable' cut (Step 4); if this was the case, the smallest units were separated manually. The example shows that a method-integrated approach with qualitative validation leads to more plausible findings in the sense of the aforementioned subject adequacy.

3.3 Modelling (Dis)similarity

In this project, neighbourhoods are understood as spatially coherent settlement bodies, composed of smallest units, with usually similar building structures, which are characterized by an above-average degree of interconnectedness in everyday life (cf. Section 0). From this we deduce that, methodologically, neighbourhoods are multifunctional similarity spaces: They are similar with regard to the building structure and with regard to the (many) everyday interconnections. We therefore test the smallest units for such similarity structures.

Building and Settlement Structure Similarity

The physical-structural coherence of a settlement body can – unlike spatial-functional interrelations – be perceived directly through the senses. If one looks at a traditional block perimeter development, one will hardly assign the respective buildings and people to different neighbourhoods. If this type of housing development were to be adjoined by a dispersed single-family housing development, many people would, simply based on the clear change in the development structure, probably assume that this is where one neighbourhood ends and the next neighbourhood begins – it remains unquestioned that there may well be substantial interrelationships between these settlements. Since building structures often correspond to social structures, many cities also work with settlement types when it comes to different requirements for action in (social) urban development.[2]

Spatial-Functional Linkages (Source-Destination Linkages)

Spatial-functional interdependencies can assume very different intensities. To ensure comparability between the different spatial dimensions for neighbourhood delineation, 'pairs' of smallest units assume the value 0 if there are no linkages and the value 1 is assumed as the maximum of the linkage intensity, which is reached if all (external) linkages of a smallest unit (as an observation unit) are accounted for by the 'pair'. This is also referred to as the so-called linkage coefficient (Terfrüchte 2015, 131ff.). In contrast to

2 We also explicitly do not include data on social structure in the construction of neighbourhoods. We use such data to describe, but not to delineate the neighbourhoods.

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Fig. 3: Transforming nominal scaled variables into an interconnection-matrix

City	Type
a	A
b	A
c	A
d	B
e	B
f	B
g	C

	a	b	c	d	e	f	g
a	-	1	1	0	0	0	0
b	1	-	1	0	0	0	0
c	1	1	-	0	0	0	0
d	0	0	0	-	1	1	0
e	0	0	0	1	-	1	0
f	0	0	0	1	1	-	0
g	0	0	0	0	0	0	-

1 = max. similarity

the building and settlement structure with usually one or – when considered separately – two variable(s), there is a multitude of relevant spatial-functional linkages that are expressed via routes: to the day-care centre, to school, to the playground, to the shops, to friends, to the doctor, to an office or a public authority, etc. In the model, these routes are understood and processed as source-destination connections.

However, the modelling of source-destination linkages is only valid if the sources (i.e., the residential locations of the users) are entirely available for the respective destinations (i.e., the infrastructure facilities). In this respect, the municipalities are in possession of a multitude of valuable, but so far – if at all – insufficiently used data resources (Terfrüchte/Hardt 2021). For example, they know which children use which day-care centre or open-all-day school (through the parental contributions) and they know which children attend which school (at least for those in municipal responsibility).

In the area of outpatient medical care, it is the Association of Statutory Health Insurance Physicians (Kassenärztliche Vereinigung) that has nationwide and address-specific knowledge about source-destination relationships for the provision of general and specialist care by statutory health insurance physicians. Through the billing data, the practice locations of the treating physicians as well as the residential locations of the patients are available. The associations of SHI-accredited physicians therefore know which patients have billed which doctors, when and how often.

Methodologically, it is now a matter of offsetting the diverse interdependencies against each other as multifunctional interdependencies. In any case, the result is again an n:n matrix in which 'pairs' without spatial-functional interdependencies are given the value 0 and those with the maximum possible interdependencies are given the value 1. In our example, we have offset the various interdependencies equally and normalised them on a scale from 0 to 1.

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Neighbourhoods as Places of Encounter

If a large number of different linkage data are available, multifunctional linkage areas can be identified in the same way as central-location interdependency areas (Terfrüchte 2015, 214). The starting point is then the individual destinations with their specific catchment areas. Moreover – and this seems to be 'new territory' in spatial sciences so far – the sources (i.e. the residential locations of the users) can also be the starting point for modelling, namely for the aforementioned modelling of similarities. Based on the assumption that the destinations (schools, day-care centres, supermarkets, waiting rooms of doctors or public authorities, churches, etc.) are also potential places of encounter), it is determined which spaces show similar patterns of interconnectedness from the perspective of patients, pupils, parents of children in care, etc. The results are then used to model similarity. In practice, a link between the sources (i.e. the households/locations) is created via the respective target. An enormous advantage of this approach is that it opens up the possibility of discovering and delineating neighbourhoods in the material that do not themselves have any of the above-mentioned targets (such as social or medical infrastructure facilities).

Political-administrative Responsibility

The example of primary schools is also suitable for introducing a further perspective on spatial interdependencies. Before the abolition of primary school districts in North Rhine-Westphalia in 2006, there were clear responsibilities, i.e. depending on the place of residence (address), children were assigned to a specific primary school. The linkage was practically predetermined. The situation is analogous to other administrative or "responsibility" areas (Terfrüchte 2015, 42ff.), such as city districts or parishes. Even if offices or places of worship are not regularly visited destinations for many, from a methodological point of view they lead to a commonality, since the same church parish or district council is responsible for the inhabitants of these smallest units. These examples always boil down to the question of whether a smallest unit X has something in common with a smallest unit Y, which indicates whether they should, ceteris paribus, belong to the same neighbourhood – or not.

In the model with the n:n matrix, 'pairs' of smallest units thus take the value 1 if they belong to the same jurisdiction space; otherwise the value is 0.

4. Delineating Neighbourhoods

If neighbourhoods are thus methodically understood as similarity spaces and, in particular, the interrelationships are also included in the modelling of similarity and dissimilarity, classical cluster analytical approaches can be used not only for the typification of neighbourhoods, but also for their delimitation. In Section 3, the central challenges of modelling were presented with corresponding approaches to solving them. Now the task is to statistically delineate the neighbourhoods for comparative neighbourhood research on the basis of this data. For this purpose, tools from the GIS software ArcGIS and the statistical software SPSS are used.

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4.1 Spatially Constrained Multivariate Clustering

The ArcGIS tool "Spatially constrained multivariate cluster analysis" combines spatially neighbouring polygons (with a common boundary) into similarity spaces on the basis of any number of content-related characteristics, provided that so-called spatial constraints do not prevent this (see below). In addition, further premises can be set, for example, for the number of clusters or target values for certain characteristics (such as a minimum number of inhabitants).

In our case, the smallest units are aggregated into neighbourhoods on the basis of the existing interdependencies and the similarity in terms of building and settlement structure. The mode of operation corresponds to a cluster centre analysis (cf. Section 0), i.e. a distance model is first created on the basis of the characteristics and those smallest units (if they are spatially neighbouring) are aggregated into neighbourhoods that have the smallest distance – i.e. the greatest similarity. However, the spatial-functional linkages are available as a source-destination matrix and therefore cannot be straightforwardly used in the tool.

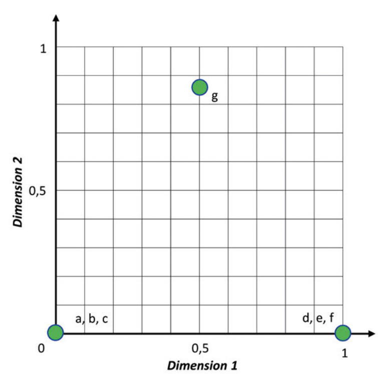
4.2 Multidimensional Scaling

The relevant interdependencies must therefore first be converted into latent characteristics (with the above-mentioned smallest units as characteristic carriers) via the interdependency intensity. The following applies: the stronger the interdependence intensity, the smaller the distance and the smaller the differences in the characteristic values of the latent characteristics. Fig. 4shows this transformation schematically. Technically, the SPSS tool "Multidimensional Scaling" is used for this.

Fig. 4: Transforming interconnection-matrices into latent variables

	a	b	c	d	e	f	g
a	0	0	0	1	1	1	1
b	0	0	0	1	1	1	1
c	0	0	0	1	1	1	1
d	1	1	1	0	0	0	1
e	1	1	1	0	0	0	1
f	1	1	1	0	0	0	1
g	1	1	1	1	1	1	0

1 = max. dissimilarity



City	dim1	dim2
a	0,00	0,00
b	0,00	0,00
c	0,00	0,00
d	1,00	0,00
e	1,00	0,00
f	1,00	0,00
g	0,50	0,87

The SPSS tool "Multidimensional Scaling" allows users to transform statistical distance measures of all observation units to each other (e.g. Euclidean, Manhattan etc.) into a multidimensional coordinate system. The individual coordinate values are then the characteristic expression of the latent dimensions.

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While classical cluster analytical methods first have to generate a distance measure based on the included characteristics and characteristic values, multidimensional scaling takes the opposite approach. The advantage for spatial delimitation based on similarity or dissimilarity is obvious: in the first step, all relevant (interdependence) characteristics can be converted into a suitable distance measure, in the second step, the individual distances are statistically linked, and in the third step, the multifunctional distance is converted into a multidimensional coordinate system for the 'spatially restricted multivariate cluster analysis'.

If we construct neighbourhoods via multifunctional similarity and model similarity as distance, the question of the appropriate distance measure inevitably arises. Widely used is the (possibly squared) Euclidean distance, which can also be interpreted as the air line between two points. The Manhattan or block distance, on the other hand, sums up the distances of the two points on the two axes. Compared to the block distance, the (squared) Euclidean distance decreases disproportionately the more similar the characteristic values of the two variables are. A scatter diagram with two variables (axes) illustrates the differences between the two distance measures (Fig. 5)

We are now dealing with different 'similarities', which are either available as a classical table with characteristics per characteristic carrier (e.g., the affiliation of smallest units to settlement types, cf. Section 0) or as interrelation matrices (cf. Section 0). Due to these different formats with their different logics, the data cannot therefore be directly 'offset' against each other. For the modelling of a multifunctional similarity, separate distance models must first be determined for all 'similarities', which are then offset to a multidimensional or multifunctional similarity. Here, the block distance offers the advantage that as much of the original information (of the respective 'similarities') as possible is retained. The multifunctional similarity can then also be represented in the Euclidean distance model.

4.3 Spatial Constraints

The modelling of similarity and dissimilarity is necessary to delineate neighbourhoods as overlapping spaces of everyday life and action for their residents and users – but it is not sufficient. At least three further rules (in the sense of premises) are necessary. Firstly, in our understanding of neighbourhoods there can be no enclaves or exclaves. As a rule, only such smallest units that have a common boundary, i.e. are spatially directly adjacent, can be combined into a neighbourhood. The cluster tool already meets this requirement (see above). Secondly, there are spatial barriers that separate even neighbouring smallest units from each other to such an extent that they cannot belong to one neighbourhood. These are in particular rivers, motorways and railway embankments. Less restrictive barriers (e.g., accessible federal roads) are taken into account in the model as ceteris paribus rules, i.e. if there are several assignment possibilities with the same similarity, those smallest units between which there is the smallest possible barrier should be aggregated. And thirdly, we assume – again ceteris paribus – that the better the pedestrian accessibility between the smallest units is, the more likely they are to belong to a neighbourhood if there are several allocation options.

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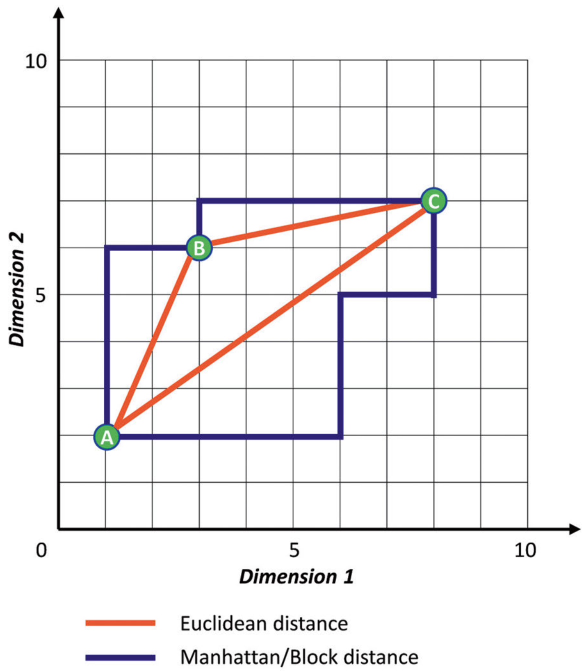
Fig. 5: Manhattan distance vs. Euclidean distance.



distance	block	euclidean	difference
$\overline{AB}$	6	$\sqrt{4^2+2^2}$ = 4,47	1,53
$\overline{BC}$	6	$\sqrt{5^2+1^2}$ = 5,10	0,90
$\overline{AC}$	12	$\sqrt{7^2+5^2}$ = 8,60	3,40
sum	**24**	**18,17**	**5,83**

These restrictions are modelled using the ArcGIS tool "Spatial Weighting Matrix". This defines which polygons may not be combined despite a common boundary and which polygons are aggregated into clusters prioritised ceteris paribus. The spatial weighting matrix thus practically forms the corrective or the correcting counterpart to the multifunctional similarity matrix.

Box 2: Sequential methodological plural approach to neighbourhood delineation The application of these rules can occasionally lead to errors, for example when the barrier effect of traffic roads is mitigated or eliminated by structures such as tunnels or bridges and is therefore not perceived as such. However, such individual cases cannot be discovered

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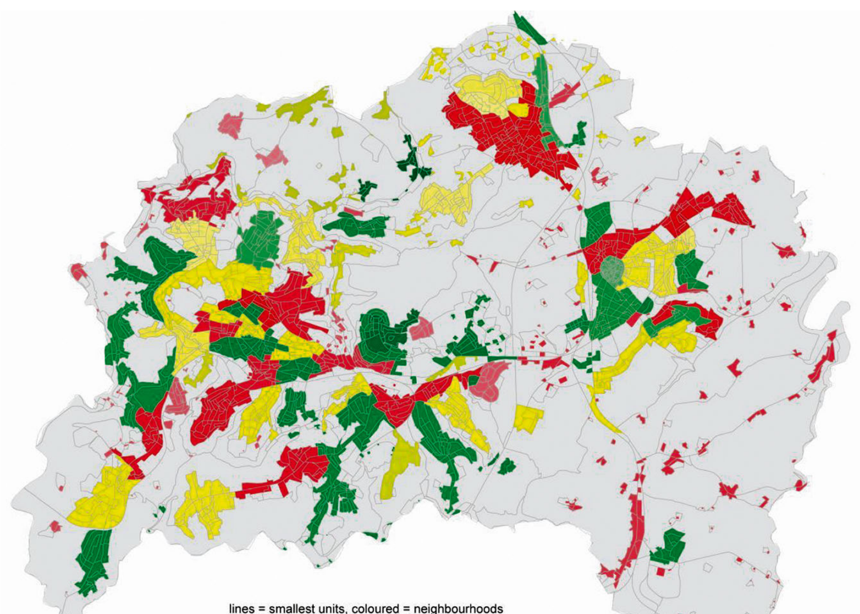
and solved via the aggregation algorithms, but only through the specific local knowledge of the residents or users of neighbourhoods. The results of the primarily quantitative delimitation methodology are therefore subjected to a qualitative plausibility check through informal conversations, surveys or expert workshops. The result of this check can be individual 'manual' corrections, but also an adjustment of the model when it comes to individual cases that can be modelled quantitatively, which are placed after the rule as an exceptional case. In our practical examples, we have found, for example, that there are smallest units that are predominantly characterised by special forms of housing such as closed inpatient care facilities or also the penal institution. In such cases, we have excluded the smallest units from the neighbourhood delimitation.

4.4 The Example of Remscheid

On the basis of 1740 building blocks and 22 settlement types, a total of 2060 'smallest units' were identified as the foundation for the investigations in Remscheid, to which a total of 23,552 addresses and 48,253 buildings can be assigned. The aggregation of the smallest units resulted in 92 neighbourhoods (Fig. 6). A list of the data sources included can be found in Terfrüchte et al. (2021, 53).

Fig. 6: Neighbourhoods and smallest units in Remscheid



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5. Multidimensional Typification of Neighbourhoods

The data monitoring at the small-scale level and the delineation of neighbourhoods based on this data already have their own value from the perspective of the planning administration, but in this article, as in our research project, they serve primarily as a basis for the typification of neighbourhoods. Only in this way is a type-related strategy development possible and the strengths of qualitative and quantitative methods intertwine in the best possible way.

5.1 About Similarity and Dissimilarity

The aim of any typification is to group observation units (here: neighbourhoods) on the basis of selected variables in such a way that the differences in variable characteristics within the groups are as small as possible, and between the groups they are as high as possible. Or, to put it more simply: the observation units are grouped according to similarity. If only one metrically scaled characteristic was considered, typification would be nothing more than class formation, i.e. the transformation of the metric scale to an ordinal scale, not on the basis of predefined class widths or a desired equal distribution, but on the basis of 'natural breaks' between different point frequencies. Within a point cloud, the characteristic carriers then do not have the same, but a similar characteristic expression (Fig. 7, left). Here we continue to speak of age or income classes and not of age or income types. Types are usually formed by at least two characteristics, which inevitably means that they can no longer be measured and ordered on a scale: by definition, they are nominally scaled.

Sometimes the characteristics included correlate very strongly with each other, which would be visible in a classic scatter plot by a clearly recognisable regression line (fig 7, right). Point clouds in the sense of observation units with similar variable characteristics are then primarily found on or near the regression line and are not arbitrarily distributed 'in space'. In such cases, it is reasonable to do a principal component analysis prior to typing. This allows one to extract a constructed (latent) variable from a large number of highly correlated (observable) variables. These latent variables can then be used for the typing.

In principle, it can be assumed that, with an increasing number of characteristics to be used for typing, the probability increases that groups of variables have a high common variance and are thus highly correlated with each other. At the same time, however, the greater the number of variables, the greater the uncertainty as to whether the variables will be appropriately aggregated into types. For this reason, typing is often carried out as cluster analysis preceded by principal component analysis.

In the Remscheid case study, we combined a total of 111 manifest characteristics into 12 latent characteristics using principal component analysis (see fig. 10).

5.2 Dimensioning and Dimension Reduction

Within the framework of dimensioning, all those characteristics that can be type-forming are operationalised – based on theory. In contrast, dimension reduction serves to

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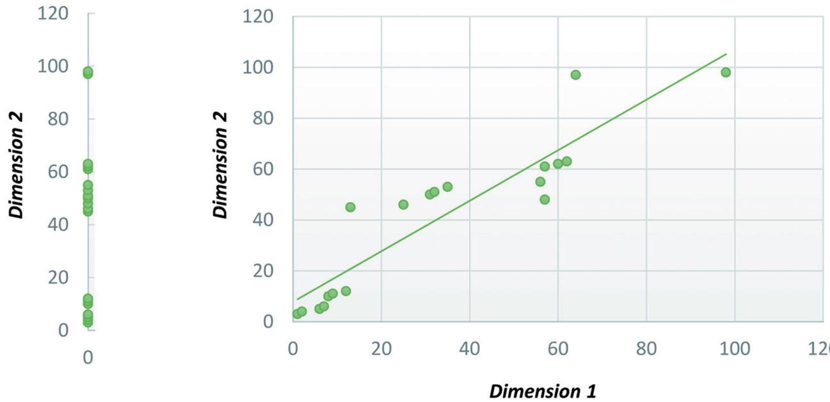
Fig. 7: Scatterplot with two dimensions and regression line



construct a few meaningful dimensions from the multitude of relevant characteristics. The essential difference between the two steps is that (quantitative) dimension reduction is based on the observed characteristics and those characteristics are combined into dimensions that show a similar spatial pattern, i.e. they are highly correlated with each other, whereas (qualitative) dimensioning is carried out independently of space, and the operationalised characteristics can, but do not have to, correlate with each other.

Basically, the point is that the characteristics of interest in terms of neighbourhood similarity are latent, i.e. not observable (e.g., socio-economic status). Only the operationalised characteristics are observable (here, e.g., unemployment, qualification level, etc.). Whether a latent characteristic "socio-economic status" can be meaningfully extracted using principal component analysis (cf. Terfrüchte, in this volume) depends on whether the characteristics correlate strongly with each other and also 'fit together' in terms of content. To stay with the example, this would be the case, for example, if neighbourhoods with high unemployment actually also have a low qualification level of the employed and a low household income. Another constellation, on the other hand, would prove problematic: for example, wage differentials between women and men lead to an increase in gross domestic product per person in employment if fewer women are in employment (cf. Terfrüchte 2019, 26), and a low female employment rate correlates with low youth unemployment. In such a case then, socio-economic status cannot be mapped on one dimension – at least not if one assumes both a high female employment rate and low youth unemployment as desirable. The statement 'The lower the female employment rate, the higher the socio-economic status' is then statistically quite expectable, but in terms of content it is not intended with regard to the dimensioning. These examples illustrate that the ability to assess the significance and thus the importance of content-related and statistical correlations is indispensable, especially in the case of constructed characteristics, in order to be able to interpret them at all and to use them for typification.

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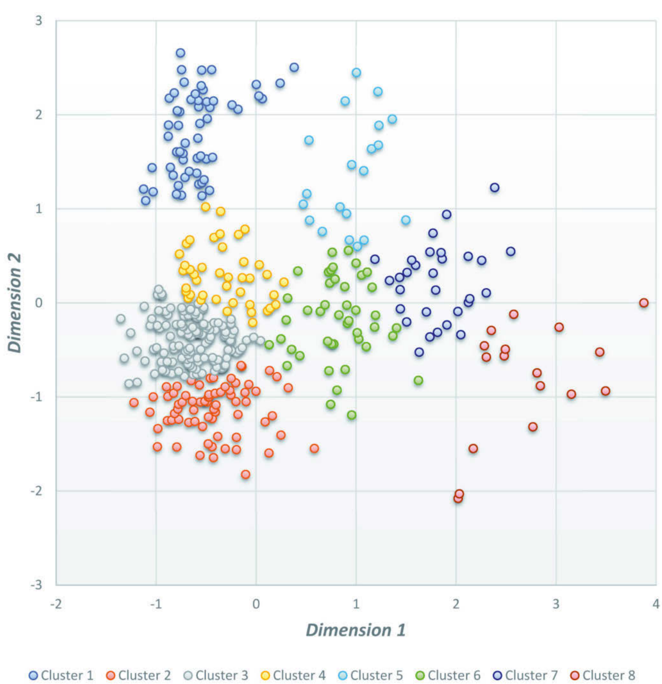
5.3 Hierarchical Cluster Analysis with the Ward Algorithm

The goal of every cluster analysis is to group characteristic carriers (here: neighbourhoods) into clusters in such a way that the neighbourhoods within a cluster are as similar as possible and the differences between the clusters are as great as possible (Bortz/Schuster 2010, 453). Depending on the cluster algorithm used, priority is then given to clusters of equal size, homogeneously populated clusters or clusters with the greatest possible differences between them. The possibilities of classifying neighbourhoods increase exponentially with the number of neighbourhoods: with five neighbourhoods there are 52 assignment possibilities, with 10 neighbourhoods 115,975 (Bortz/Schuster 2010, 458), with 15 neighbourhoods 1.4 trillion, and for the 92 quarters in the Remscheid case study (see below), the number of possibilities would have 105 digits; to find the best solution with conventional computers would be too time-consuming for any research process. Bortz and Schuster expect a duration "of several centuries" even "for samples of medium size" (ibid., 459). In this respect, it is important to reduce the number of potential solutions through certain premises.

Fig. 8: Visualised clusters in a scatterplot



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Hierarchical cluster analysis is one of the agglomerative approaches (Bortz/Schuster 2010, 459). Based on the distance model (see above), all those neighbourhoods that have the smallest distance to each other are grouped into clusters. This is illustrated in fig. 8. Now the clusters of the first stage determined in this way are successively further combined on the basis of the distances existing between them (second to n-th fusion stage) until all neighbourhoods belong to one cluster. Our goal is to form clusters that are as homogeneous as possible, which is why we use the Ward algorithm. This minimises the increase in variance in the fusion steps, so that the respective neighbourhoods will be more likely to belong to the 'right' cluster. This can sometimes lead to clusters with very few or even only one neighbourhood (cf. case study Remscheid, see below), but also to clusters with a very large number of neighbourhoods. For spatial typifications, the Ward algorithm is therefore frequently used. Which of the fusion levels is the 'best' or the 'right' one can be plausibly assumed by looking at the so-called dendogram, a special form of a tree diagram (Bortz/Schuster 2010, 464), but the final decision can only be made qualitatively. For this purpose, we examine which neighbourhoods belong to which clusters, which neighbourhoods will be added in the case of further fusion, and with regard to which included characteristics the variance will grow (with increasing merger level) or will fall (with decreasing merger level). Finally, another significant issue is how many clusters – understood as neighbourhood types – are appropriate at all.

5.4 K-means Cluster Analysis

Agglomerative clustering methods have the disadvantage that once neighbourhoods have been grouped together, they are no longer separated from each other when they pass through the further merger stages. This can lead to the similarity of individual neighbourhoods to the neighbourhoods in their own cluster being lower than the similarity to neighbourhoods in other clusters. Cluster centre analysis as a non-agglomerative procedure (Bortz/Schuster 2010, 465) offers the possibility of correcting such 'misclassifications' owed to the agglomerative procedure. For this purpose, the cluster centres (as a result of the hierarchical cluster analysis) are first determined. The cluster centre shows the arithmetic mean for each included characteristic. Thus, a typical representative is formed for each cluster. Now, starting from all neighbourhoods, it is determined to which cluster centre the smallest distance exists. As a rule, some neighbourhoods are then rearranged. The cluster centres are then determined anew and the check for correct allocation is carried out again. This iterative procedure is repeated until each neighbourhood is also assigned to the cluster to whose cluster centre it has the smallest distance, i.e. the greatest similarity.

5.5 The Example of Remscheid

Using the methodological steps presented here, four neighbourhood types could be identified for the city of Remscheid (Fig. 9).

Dynamic arrival spaces form the most populous type comprising 53 percent of the total population. The 35 neighbourhoods, most of which are located in the inner city, are characterised by a mixture of residential and commercial areas and a high residential

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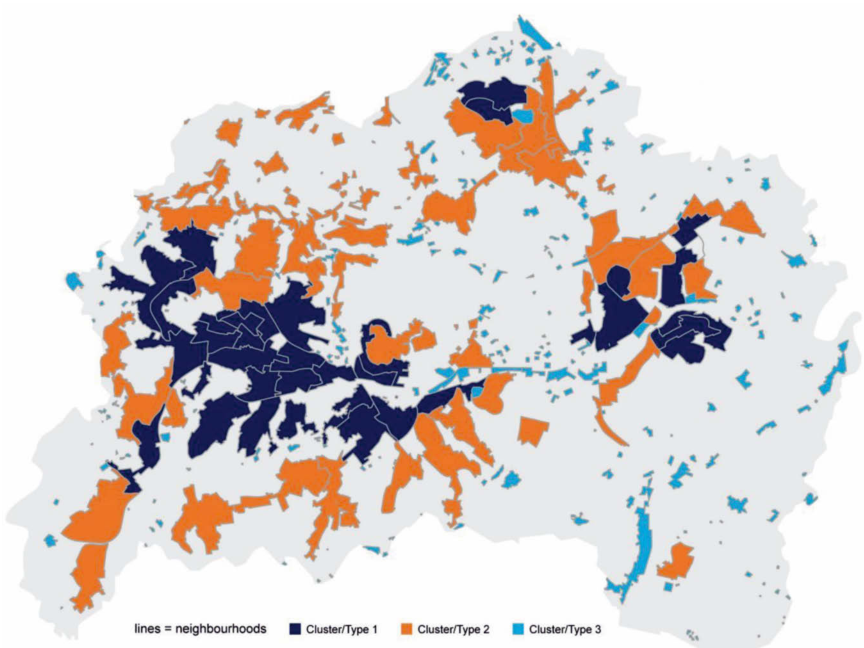
Fig. 9: Neighbourhood types in Remscheid



density compared to other cities. The neighbourhoods have a heterogeneous age structure and a marked diversity of origin. Other characteristics are high rates of people moving in and out and, in some cases, precarious living conditions.

Stable spaces to stay areas comprise 44 neighbourhoods with 42 per cent of the total urban population, which are mainly located in peri-urban areas. The lower density results from the relatively high proportion of detached and semi-detached houses. Sociodemographically, this type is characterised by a rather affluent population. The average age of the population is relatively high, which results, among other things, from a long period of residence in the new housing developments of the 1970s, 1980s and 1990s.

Four per cent of the total population live in *hybrid intermediate spaces*, distributed over twelve neighbourhoods. This neighbourhood type is characterised by a high functional mix due to a high proportion of businesses or scattered settlements characterised by agricultural use. The distances to facilities of general interest are long, and fluctuation is high in the mostly shrinking neighbourhoods.

The fourth identified type comprises only one neighbourhood in Remscheid, which is why a general description of the characteristics (typification) can only be made to a limited extent here. In terms of urban development, the neighbourhood is characterised by *high-rise residential buildings.*

Fig. 10 shows the indices used in the result of the principal component analysis with their mean value per neighbourhood type.

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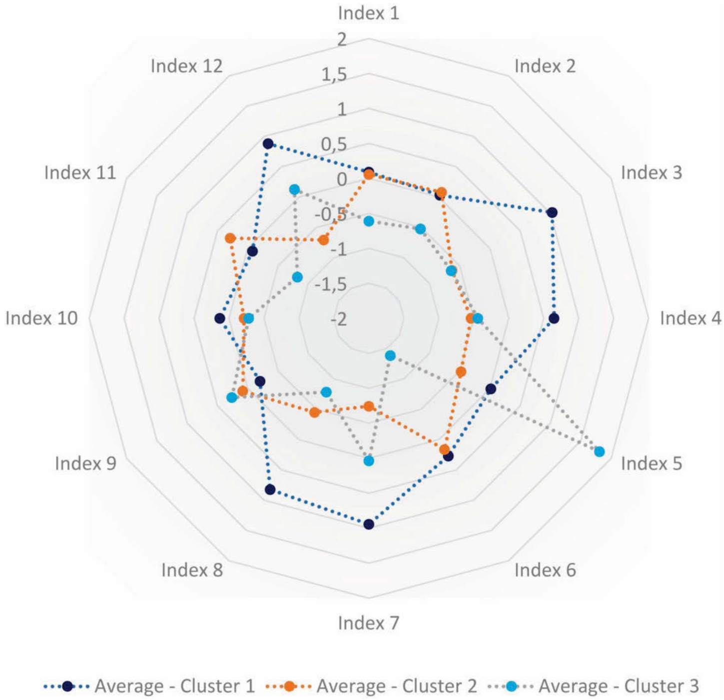
Fig. 10: 12 Indices for typification



6. Conclusion: More Evidence for Urban and Neighbourhood Development

The question of how neighbourhoods can be adequately defined and typified is a matter of concern for both comparative neighbourhood research and the practice of urban and neighbourhood development. In this context, as Groos and Messer note, "numerous well-differentiated theoretical discussions [...] have so far been contrasted by only a few good practical examples" (2014, 15). In view of this need, our contribution aims to present an approach to neighbourhood delineation and typification that, on the one hand, takes into account the complexity of neighbourhoods and, on the other hand, can well be applied in practice. Most of the required data is available to the municipalities.

This approach is innovative in several respects: As a mixed methods approach, it combines qualitative and quantitative methodological and methodological considerations and steps. By developing neighbourhoods in a theory-led manner based on the data material, it reflects the current state of theoretical discussions, which conceptualises neighbourhoods as relational social constructs or from a lifeworld, subject-centred perspective, as spaces of everyday actions, encounters and interactions emanating from the residential location. We have shown how we have translated these determinations step by step into a statistical model. As demonstrated above all by the example of functional interdependencies, we found new and original ways to give appropriate

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weight to the everyday interactions of the residents. The (interim) results were repeatedly validated through communication.

Neither the lack of administratively defined neighbourhood units nor the wholly legitimate interests of data protection fundamentally obstruct the goal of subjecting neighbourhoods, which are difficult to grasp, to well-founded quantitative analyses, and thus to meet the need, above all of the planning administration, for plausibly defined and statistically well-described small-scale intervention spaces. A small-scale division of the urban space, the creation of which is justified by comprehensible statistical operations and is also accepted and supported by the local population because it corresponds to their everyday actions, perceptions and experiences, offers all those involved in urban development a good basis for making decisions.

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