



## Normative and functional catchment areas of kindergartens: a case study of network optimization in the Banská Bystrica Region, Slovakia

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### Abstract

*The article compares two approaches to delimiting pre-primary catchment areas: a functional approach based on naturally emerging commuting patterns identified using a modified CURDS regionalization procedure, and a normative approach that allocates children to the nearest municipality with available kindergarten capacity. Using the case of the Banská Bystrica Region in Slovakia, the aim is to assess the extent to which these approaches capture actual attendance relationships and address the problem of insufficient and unevenly distributed kindergarten capacity. The results reveal a significant discrepancy between the normative and functional organization of pre-primary education. The normative model produces spatially fragmented catchment areas and, even under relatively generous assumptions, fails to accommodate a substantial number of children. This indicates that the problem lies not only in insufficient capacity, but also in its pronounced territorial mismatch with demand. In contrast, the functional regionalization identifies spatially more extensive yet internally more complex regions that reflect actual attendance patterns. The findings suggest that neither approach alone provides a sufficient solution. While the normative model proves empirically ineffective, the functional model more accurately captures real attendance patterns but simultaneously reveals and partly reproduces existing inequalities in access. The article therefore argues that a combination of both approaches is necessary for a more rational, efficient, and spatially just optimization of the kindergarten network.*

### Key words:

pre-primary education,  
catchment areas,  
functional regions,  
CURDS algorithm,  
normative approach,  
spatial accessibility,  
educational planning

## 1 INTRODUCTION

The spatial accessibility of educational facilities is among the key determinants of children's participation in pre-primary education and significantly influences parental decision-making in the choice of kindergarten (Križan et al., 2025). The importance of this factor is particularly pronounced for socially disadvantaged population groups, for whom poorer transport accessibility may constitute a substantial barrier to access to pre-primary education (Polačková et al., 2023). A greater distance between the place of residence and the kindergarten increases both the household financial and time costs, which may subsequently affect not only children's participation in pre-primary education, but also the ability of parents – especially women – to participate in the labour market (Van Ham & Mulder, 2005; Compton & Pollak, 2014; McLean et al., 2017).

Ensuring equitable access to education is supported in many countries by a system of school attendance zones, which spatially localise the right to education while also regulating the distribution of pupils on the basis of the principle of geographical proximity between the place of residence and the school (Kim & Kwon, 2020; Sulistyosari et al., 2023; Asson, 2024).

This system, also known as school catchment areas, consists of administratively delimited territories that assign pupils to schools according to their place of permanent residence. Historically, this approach was systematically introduced in the United States in 1954 with the aim of eliminating racial segregation and ensuring equal access to primary education for all pupils (Reardon et al., 2012). Unlike compulsory school education, however, systems of early childhood education and care (ECEC) only rarely make use of strictly defined catchment areas (Bennett, 2008).

Administratively defined catchment areas should ideally reflect the capacity of facilities and the principles of equitable access to education. In practice, however, these normative regions do not always correspond to the actual spatial flows of the population, especially commuting to work (McLean et al., 2017). Increasing mobility, changes in daily activities, the discrepancy between official permanent residence and actual place of residence, as well as parental preferences, may all lead to situations in which administratively defined school zones fail to reflect adequately the real flows associated with attendance at educational facilities (Richards, 2014;

Bernelius & Vilkkama, 2019), pointing to a potential mismatch between formally established school zones and the actual functional organisation of educational accessibility. Although there are examples of quite strict zoning for childcare (Felfe & Lalive, 2014), contemporary approaches increasingly replace administrative zones with accessibility models and market mechanisms (Breunig et al., 2011; Compton & Pollak, 2014; Fransen et al., 2015; Xu et al., 2018; Langford & Higgs, 2019; Chen et al., 2020; Vandenbroeck, 2020).

International research therefore increasingly emphasises the need to analyse the spatial organisation of educational systems on the basis of empirically observed flows (Kawabata, 2009; Costa et al., 2010; Farfan-Portet et al., 2011; Bernelius & Vilkkama, 2019; Kim & Wang, 2019; Chen et al., 2020; Sulistyosari & Wardana, 2023). Approaches based on the analysis of functional regions have long been used primarily in the delimitation of labour commuting regions (e.g. Coombes et al., 1986; Casado-Díaz, 2000; Papps & Newell, 2002; Coombes, 2010; Drobne, 2017; Bezák, 2010; Mitchell & Watts, 2010; Klapka et al., 2013; Halás et al., 2014), while similar methodological approaches are gradually being applied to the analysis of service accessibility and public infrastructure (Karlsson & Olsson, 2015; Kraft et al., 2022; Liu et al., 2024). In the field of education, however, the application of these approaches remains less explored.

The situation in Slovakia is distinctive in this regard. Unlike primary schools, there is no unified nationwide system of officially defined kindergarten catchment areas. In practice, catchment areas are determined through generally binding municipal ordinances and usually follow the normative principle of assigning children to the nearest municipality with available capacity (Švecová et al., 2025). In legislative terms, a catchment kindergarten is explicitly defined only for children for whom pre-primary education is compulsory, that is, typically for children one year before entry to primary school (§ 59b of Act No. 245/2008). In all other cases, the catchment system remains less formalised and depends to a considerable extent on the decisions of individual local authorities.

In this context, there is a need for a better understanding of the actual spatial patterns of children's attendance at kindergartens, which may not correspond to normatively defined catchment areas. The announced approach of the *Ministry of Education, Research, Development and Youth of the Slovak Republic* (hereafter the *Ministry of Education*) to the setting of school attendance zones is based on administrative and normative criteria and does not reflect empirically observed mobility patterns or parental preferences. A deeper analysis of these patterns could therefore contribute to more effective and equitable planning of the capacity and accessibility of pre-primary education.

An important, though so far only limitedly used, source of information consists of detailed data on children's attendance at kindergartens recorded by the *Centre of Scientific and Technical Information of the Slovak Republic* (CVTI). These data make it possible to analyse spatial flows between children's place of residence and the location of the kindergartens they attend, and thus to identify natural attendance regions.

The primary aim of the article is to present two different ways of delimiting pre-primary catchment areas: an approach based on naturally emerging attendance patterns grounded in the concept of functional regions, and an approach based on the

administrative allocation of children to the nearest municipality with spare capacity. In particular, the article develops and applies a model for delimiting pre-primary catchment areas based on a modified regionalisation procedure derived from the CURDS algorithm, originally developed for the delineation of functional regions using commuting-to-work flows. The article examines the extent to which a regionalisation approach grounded in naturally emerging attendance patterns can be applied to the context of pre-primary education and compares its outcomes with those of a normative approach. The article focuses on comparing these approaches in terms of their ability to reflect actual attendance relationships and to respond effectively to the problem of insufficient and unevenly distributed kindergarten capacities in the model area of the Banská Bystrica Self-Governing Region. Particular attention is paid to the methodological challenges associated with the analysis of pre-primary attendance flows, which are characterised by relatively low volumes and limited spatial variability. At the same time, the article highlights the limitations of the normative approach based solely on the rule of the nearest available capacity, as presented by the Ministry of Education within the planned optimisation of the kindergarten network in Slovakia.

The ambition of the article is to demonstrate that, for the rational optimisation of the kindergarten network, a combination of normative and functional approaches may be necessary, especially in the context of persisting capacity shortages in selected regions following the introduction of compulsory pre-primary education for younger age groups (four- and three-year-old children from 2027 and 2028 onwards).

## 2 THEORETICAL BACKGROUND

Children's attendance at kindergartens represents a specific type of daily mobility that differs in many respects from commuting to work or to higher levels of education. Unlike older pupils, the mobility of pre-school children is mediated by adults – most often parents or grandparents – and is closely intertwined with their daily activities, above all work-related travel (Fransen et al. 2015; Chen et al. 2020). Attendance at kindergarten therefore often does not constitute an independent movement, but rather forms part of more complex daily household trajectories (Schwanen & Ettema, 2009; Rišová, 2025).

In spatial terms, attendance at kindergartens is strongly local in character. Although explicit studies focusing on kindergartens are relatively rare, insights may be drawn analogically from research on attendance at primary schools. As Tonev et al. (2017) note, attendance at primary schools is characterised by short distances and a strong connection to the place of residence. The same character may be assumed for pre-primary education, where the demands for proximity are even more pronounced given the age of the children. Both empirical and normative approaches emphasise the principle of spatial proximity as a key determinant of accessibility. According to Costa et al. (2010), a kindergarten should be accessible on foot within approximately 15 minutes, or within 20 minutes by public transport, ideally along parents' everyday travel routes. This emphasis on short distances is also supported by the fact that children are most often accompanied on foot or by car and only exceptionally undertake longer journeys. These specificities are of fundamental

importance for the delimitation of catchment regions, since they indicate a system with low spatial dispersion and high sensitivity to local conditions.

In international research on service accessibility, including pre-primary facilities, two main methodological approaches predominate: distance-based accessibility models and models that take into account the interaction between supply and demand. Traditional approaches often draw on gravity models (Geurs & van Wee, 2004; Handy & Niemeier, 1997) or on the two-step floating catchment area (2SFCA) method, which works with a defined travel catchment and considers both facility capacity and competition among users (Luo & Wang, 2003; Kim & Wang, 2019). The advantage of these approaches lies in their ability to capture not only geographical proximity, but also capacity availability and the potential overloading of facilities. In recent years, these models have also been applied to the analysis of accessibility to pre-primary facilities (Fransen et al., 2015; Langford et al., 2018). The studies indicate that access to services is unevenly distributed and that spatial segregation may significantly affect the actual range of choice available when selecting a facility (Lee & Lubienski, 2017). From the policy perspective, however, a simpler normative principle often prevails: assigning a child to the nearest facility with available capacity. Besides minimising distance as the main criterion, this approach implicitly assumes homogeneous household behaviour and, above all, the absence of complex daily mobility linkages. It therefore fails to capture the complexity of household decision-making, which is influenced by commuting patterns, preferences and the quality of facilities.

An alternative to normative approaches is the analysis of functional regions, which is based on empirically observed flows between the place of residence and the place of pre-primary attendance. Functional regions are generally understood as spatial units defined by the intensity of interactions between places rather than by administrative boundaries. The concept of functional regions and the methods derived from it (e.g. the CURDS regional algorithm, Coombes 2010) provide an effective tool for identifying attendance regions. This approach has traditionally been based primarily on the analysis of commuting to work, which constitutes the most numerous regular daily flow of the population.

In the literature, functional regionalisation based on labour commuting has been widely used to delimit labour market areas and other forms of functional territorial organisation. These approaches are grounded in the assumption that regular daily flows reveal the actual spatial integration of settlements more accurately than administrative boundaries. Methodologically, they usually combine measures of interaction intensity with criteria of regional self-containment, and have been applied in a variety of national contexts, including the delimitation of travel-to-work areas and local labour market areas (Coombes et al., 1986; Casado-Díaz, 2000; Mitchell & Watts, 2010). More recently, similar methodological approaches have also been applied to the analysis of service accessibility and public infrastructure (Karlsson & Olsson, 2015; Kraft et al., 2022; Liu et al., 2024), demonstrating their potential beyond the traditional field of labour-market studies. In Slovakia, functional regional taxonomy based on commuting-to-work data was developed primarily by Bezák (2000), and later further elaborated by the research group led by Halás (Halás et al., 2014; Halás & Klapka, 2020).

From this perspective, kindergarten attendance

flows may also be interpreted as a form of functional interaction between municipalities, making functional regionalisation a potentially suitable framework for identifying naturally emerging catchment areas. School attendance as one of the inputs into regional taxonomy was used, for example, by Tonev et al. (2017), yet the separate use of these data for delimiting school catchment areas remains exceptional. The main reason lies in their specific character – low spatial variability and a strong local embeddedness. It is precisely this localness that explains why the literature more often contains case studies or flow modelling than comprehensive delimitations of functional regions (Keserü, 2013; Müller et al., 2008; Delamater et al., 2016). Nevertheless, the use of functional regions in this field has considerable potential. It makes it possible to identify actual attendance patterns, capture inter-municipal linkages, and partly reflect household preferences as well as capacity constraints.

### 3 THE CURRENT STATE OF DELIMITING PRE-PRIMARY CATCHMENT AREAS IN SLOVAKIA

At present, municipalities determine the catchment areas of pre-primary facilities through generally binding ordinances (§ 8a of Act 596/2003). If a catchment kindergarten (a kindergarten established by a municipality/town in the municipality where the child has permanent residence) does not have the capacity, the municipality is obliged to secure the child's admission to another kindergarten of which it is the founder, or to a kindergarten with available capacity that is closest to the child's place of permanent residence or has the best public transport accessibility from the child's place of permanent residence (§59b of Act 596/2003). A catchment kindergarten is designated only for children for whom pre-primary education is compulsory (one year before entry to primary school). Currently, only kindergartens established by a municipality or town qualify as catchment kindergartens. 'Catchment assignment' does not yet apply to church kindergartens, private kindergartens, or kindergartens established by regional school administration offices. This situation, however, may change from 2028 in connection with the planned funding reform promoted by the Ministry of Education. Eligibility for the full normative per-pupil contribution from the state budget is to be conditional upon the abolition of tuition fees and the inclusion of private and church kindergartens in the system of school attendance zones (by admitting children from their catchment area). This may significantly affect not only their operation, but also the overall arrangement of the kindergarten network.

### 4 STUDY AREA, DATA AND METHODS

#### Study area

The Banská Bystrica self-governing region, located in central Slovakia, was selected as an appropriate study area because it represents a space with a markedly differentiated socio-economic environment. It includes a wide spectrum of settlements – from stable and relatively unproblematic localities to peripheral and problem-affected municipalities characterised by high unemployment, social deprivation and the accumulation of multiple developmental disadvantages. This internal heterogeneity makes it possible to analyse the problem under investigation across diverse territorial and social conditions.

### Data on attendance and the capacity of pre-primary facilities

The analysis is based on data on the actual attendance of children at kindergartens provided by the Centre of Scientific and Technical Information (hereafter CVTI) for the year 2023. In interpreting these data, it is necessary to take into account that they are derived from the child's place of permanent residence, which does not always correspond to the child's actual place of residence. The discrepancy between the official and the real place of residence may relate not only to an unupdated permanent address, but also to the intentional registration of a child in a district/municipality with a preferred kindergarten, or in a facility better prepared to meet the child's specific needs. As a result, the database contained unrealistic commuting flows over long distances, which probably reflected administrative rather than real spatial linkages. For this reason, the database was additionally adjusted. In order to reduce distortions, flows exceeding 20 km were removed from the analysis (775 flows were removed)<sup>1</sup>. Special kindergartens were also excluded from the data, because, owing to their specialised character, they serve children over a substantially wider spatial radius than standard pre-primary facilities.

For the construction of normative regions, capacity data on kindergartens from the CVTI database for 2023 were used. These data also have certain limitations, since the reported capacity of a kindergarten does not always represent a strict upper limit and may in practice be slightly exceeded. This fact is related to the legislative framework, which under certain conditions allows the maximum number of children in a class to be increased above the standard limit (by up to 3 children).

### Construction of normative pre-primary catchment areas

The construction of normative pre-primary catchment areas is based on three data sources: (1) kindergarten capacity aggregated to the municipal level, (2) the number of pre-school children (aged 3–6) by municipality of residence (Statistical Office of the Slovak Republic; 21,664 children in total), and (3) a matrix of inter-municipal road distances (Google Maps)<sup>2</sup>.

In the first step, the capacity deficit for each municipality was calculated as the difference between the number of preschool-aged children in the municipality and the capacity of kindergartens. Municipalities in which the deficit exceeded the set threshold of 44 children<sup>3</sup> were excluded from the optimisation process and interpreted as municipalities requiring a substantial expansion of capacity. Since this threshold approximately corresponds to the capacity of two standard kindergarten classes, deficits above this level were treated as requiring a more substantial intervention, typically a new kindergarten. In these municipalities, children were regarded as placed up to the level of the existing capacity, while the remainder were classified as unplaced children (635 children). Without this step, the number of unplaced children in the model would have been even higher, and the optimisation results would have indicated an even more pronounced extent of the capacity deficit.

For the municipalities entering the optimisation, a network of admissible linkages was created between the municipality of residence and the destination municipality with available capacity. Only those linkages that met two conditions were included

in the network: the destination municipality had kindergarten capacity and the distance between municipalities did not exceed the set limit (road distance). This limit was set arbitrarily, reflecting the relatively high sensitivity of children (and parents) to commuting distance. Two variants were examined, using travel thresholds of 10 km and 20 km. The lower threshold was intended to represent a commuting distance that may still be considered practicable for pre-primary children and their accompanying adults under everyday conditions. The 20 km threshold, by contrast, should be interpreted as a theoretical upper bound rather than as a realistic assumption about daily commuting to kindergarten. It was included to test the model under a deliberately generous accessibility parameter and to demonstrate that, even under such favourable assumptions, not all children could be accommodated within the existing spatial distribution of kindergarten capacities.

The allocation of children itself proceeded in two phases. In the first phase, children were placed in a kindergarten in their home municipality up to the level of the available local capacity. In the second phase, the remaining unplaced children were gradually assigned to the nearest available municipalities with spare capacity. The order of municipalities in this phase was tested in two variants: in the first, municipalities with the smallest number of remaining unplaced children were prioritised (variant A); in the second, municipalities with the largest number of remaining unplaced children were prioritised (variant B). After each step, both the number of remaining children and the spare capacity in destination municipalities were updated. This procedure was repeated until either demand or capacity was exhausted. In this way, a dominant destination municipality was determined for each municipality, that is, the municipality to which the largest number of assigned children was directed. This information was used to construct catchment regions.

### Construction of functional pre-primary catchment areas

Construction of functional pre-primary catchment areas were delimited on the basis of data on the actual attendance of children at kindergartens (17,203 children registered in 2023 in regular full-time attendance, of whom 13,169 attend a kindergarten in their municipality of residence and 4,034 commute). The methodological procedure was based on the internationally applied CURDS regionalisation algorithm (Coombes et al., 1986; Coombes, 2010). This algorithm is a multi-stage aggregation method consisting of several iterative procedures. Within these, the flow matrix is updated after each individual join of spatial units (municipalities at the beginning of the procedure). The aggregation principle is as follows: the municipality, or later the proto-region, that attains the lowest level of self-containment is assigned with the municipality/proto-region with which it maximises the intensity of interaction.

Self-containment expresses the ratio between internal flows (in our case, children residing in and attending kindergarten within the same municipality, or within the same proto-region) and the number of all outgoing and incoming flows from/to the given municipality/proto-region, including internal flows. This is the so-called total self-containment, which comprehensively expresses the self-containment of a region with respect to both flow directions of movement across the regional boundary (Halás et al., 2015).

Given that the system of pre-primary attendance is characterised predominantly by a one-directional type of functional linkage, in which flows from children's place of residence to the municipality where the kindergarten is located are decisive, it was not appropriate to apply the standard concept of total self-containment. Moreover, under the conditions of pre-primary attendance, many municipalities do not function as independent destination nodes, but are functionally linked to local or regional centres. For this reason, a modified unidirectional self-containment was used; this better captures the asymmetric nature of these linkages and allows more convincing identification of naturally formed catchment regions. The modified unidirectional self-containment (1) is therefore expressed as follows:

$$\frac{T_{jj}}{\sum_k T_{jk}} \quad (1)$$

where  $T_{jj}$  = the internal (intra-regional) flow of municipality/region  $j$ , and  $T_{jk}$  = the outgoing flow from municipality/region  $j$  to municipality/region  $k$ . Self-containment defined in this way takes values from 0 to 1. This modification of the interaction measure is also reflected in the construction of the functional regions themselves.

Interaction intensity (2), expressed by Smart's interaction measure (Smart, 1974):

$$\frac{T_{ij}^2}{\sum_k T_{ik} \cdot \sum_k T_{kj}} + \frac{T_{ji}^2}{\sum_k T_{jk} \cdot \sum_k T_{ki}} \quad (2)$$

is among the most frequently used interaction measures and at the same time represents the mathematically most appropriate method for converting two-dimensional (and thus also interaction) statistical data into relative form, as well as for their symmetrisation (Halás et al., 2014).  $T_{ij}$  denotes the flow from origin municipality/region  $i$  to destination municipality/region  $j$ . The index  $k$  denotes any municipality/region to which flows from origin  $i$  /destination  $j$  are directed or from which they originate. However, it is evident from the formulation of Smart's interaction measure that it favours two-sided interactions between municipalities over one-sided (albeit strong) linkages with a local centre (e.g. a larger town). It is therefore suitable for identifying mutual intra-regional linkages that may be considered decisive in proposals for administrative division, or for the meaningful construction of the subregional level (municipalities). For data on pre-primary attendance, however, it was necessary to modify this measure. For this type of low-volume pre-primary commuting flow, very small flows in different directions constitute a much larger proportion than in the case of far more numerous commuting-to-work flows. Moreover, these small flows are temporally unstable. It is therefore not appropriate to assign them the weight they would receive under Smart's interaction measure calculated from data referring to a single point in time. If it were retained in its original form, it would unduly favour even very weak two-sided flows at the expense of more numerous one-sided linkages. As a consequence, for example, a reciprocal unit linkage ( $1 \leftrightarrow 1$ ) would attain a higher value than a stronger one-sided flow ( $4 \rightarrow 0$ ). A modified Smart interaction measure (3) was therefore used, employing only the first part of the original expression.

$$\frac{T_{ij}^2}{\sum_k T_{ik} \cdot \sum_k T_{kj}} \quad (3)$$

It is important to bear in mind that, at individual steps of the algorithm, the number of municipalities within a region changes, and this may affect the state of the region at the moment when a municipality is assigned. The algorithm also does not define a requirement for spatial contiguity among the proto-regions being merged.

The final number of functional regions is the result of applying the self-containment criterion. For self-containment, we set the threshold at 0.75. This threshold was established arbitrarily as a meaningful limit derived from the share of outgoing children relative to the number of children attending kindergarten in the municipality of residence. Given the maximum class size of 22 children, the threshold corresponds to five outgoing children.

## 5 RESULTS

### Normative pre-primary catchment areas

All tested variants of the normative optimisation model produced a consistent and, from the perspective of spatial equity, problematic result. In the Banská Bystrica Region in 2023, approximately 2,200 to 2,600 children of pre-school age remained unplaced (depending on the variant), having failed within the model to find a kindergarten with spare capacity within 10 km or 20 km, respectively, of their place of permanent residence (Tab. 1). Of this number, 635 children formed a separate group for whom the model no longer sought spare capacities in surrounding municipalities, but instead assumed the need to create new capacities directly in the municipality of residence. These were municipalities in which the deficit exceeded 44 places and which were therefore excluded from the optimisation process (marked in Fig. 1 as 'need for capacity expansion'). The fact that a similar scale of unplaced children persisted across all tested variants indicates the systemic character of the problem.

The individual model variants nevertheless differed in the degree of allocation success. Unsurprisingly, more favourable results were obtained in the variant with the larger travel threshold of 20 km, which allowed a greater number of children to be placed than the more restrictive variant with a 10 km limit. Such a solution, however, must be assessed critically in terms of its real feasibility. Especially in socially and economically weaker regions, the costs of daily transport may be a major limiting factor, and therefore even a seemingly more efficient solution may in practice be inaccessible to households. The results also indicate that the sequence of child allocation itself has some effect on optimisation success. Better results are provided by the procedure in which smaller numbers of unplaced children are redistributed first and larger numbers only afterwards (Fig. 1). In the opposite case, the available spare capacity is rapidly exhausted by allocation from several larger source municipalities with a marked deficit, which subsequently results in a larger number of municipalities in which even smaller numbers of children cannot be placed. This indicates that the optimisation results are sensitive not only to the total volume of spare capacity and the spatial thresholds of accessibility, but also to the selected sequence of the allocation process.

Tab. 1. Summary indicators of the optimised redistribution of children aged 3–6 to kindergartens in the Banská Bystrica Region (N = 21,664)

| 100% = 21,664                                         | Travel threshold 10 km |           | Travel threshold 20 km |           |
|-------------------------------------------------------|------------------------|-----------|------------------------|-----------|
|                                                       | Variant A              | Variant B | Variant A              | Variant B |
| Number of placed children                             | 19,067                 | 19,034    | 19,445                 | 19,438    |
| Number of unplaced children                           | 2,597                  | 2,630     | 2,219                  | 2,226     |
| Number of municipalities with unplaced children       | 172                    | 254       | 103                    | 207       |
| Average distance of inter-municipal child travel (km) | 6.07                   | 5.96      | 9.21                   | 9.84      |

Data sources: Statistical Office of the Slovak Republic (2025), CVTI (2023), authors' calculations.

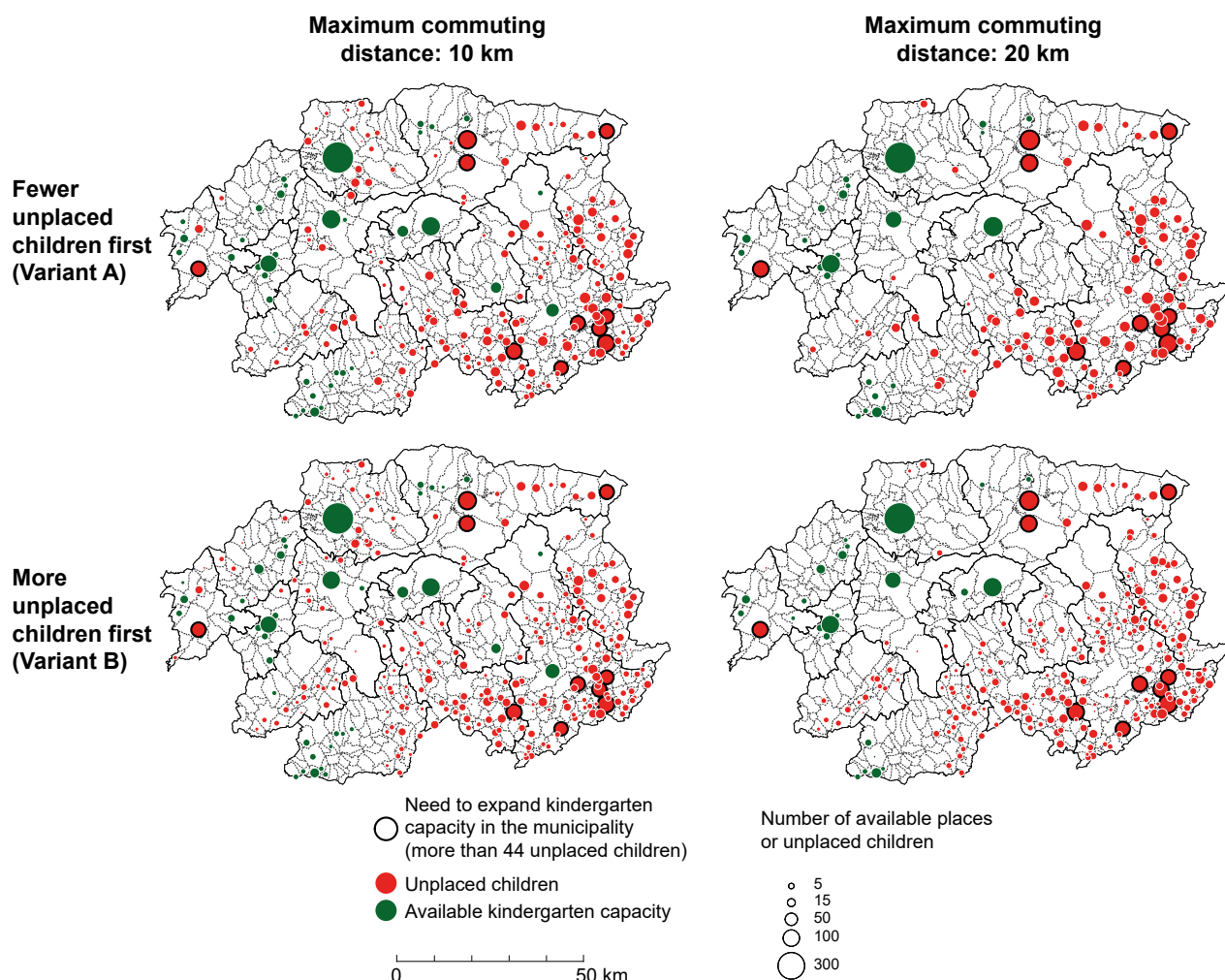


Fig. 1. Number of unplaced children and spare kindergarten capacity under different model settings for the construction of normative pre-primary catchment areas

Data sources: Statistical Office of the Slovak Republic (2025), CVTI (2023), authors' calculations

The analysis reveals a marked spatial polarisation between the demand for, and supply of, capacities (Fig. 1). A high number of unplaced children is concentrated particularly in the eastern part of the region. By contrast, spare kindergarten capacities are located predominantly in the western part of the region, especially in larger urban centres such as Banská Bystrica, Zvolen, Hriňová and Banská Štiavnica.

The resulting deficit is not caused solely by an absolute lack of capacity. Of the total of approximately 2,200 unplaced children, roughly 1,000 places are still available in the region; however, these capacities are located in unsuitable parts of the region and do not spatially correspond to actual demand. The problem therefore lies not only in missing capacities, but also in the pronounced mismatch between the location of vacant kindergarten places and the spatial distribution of children requiring placement.

From a spatial perspective, it is also clear that the lack of capacity is concentrated in municipalities with a higher share of the Roma population. At present, these municipalities are characterised by lower rates of children's enrolment in pre-primary education (Švecová et al., 2025), which may lead to an underestimation of the actual demand for pre-primary education. If compulsory pre-primary attendance is consistently introduced also for four- and three-year-old children, however, a substantial increase in demand can be expected, which could transform the existing capacity deficit into an even more serious and systemically difficult problem to resolve.

The results of the above optimisation can be interpreted not only through summary indicators, but also in the form of normative regions of pre-primary attendance. These were constructed on the basis of identifying the dominant destination municipality, that is, the municipality to which the largest number of

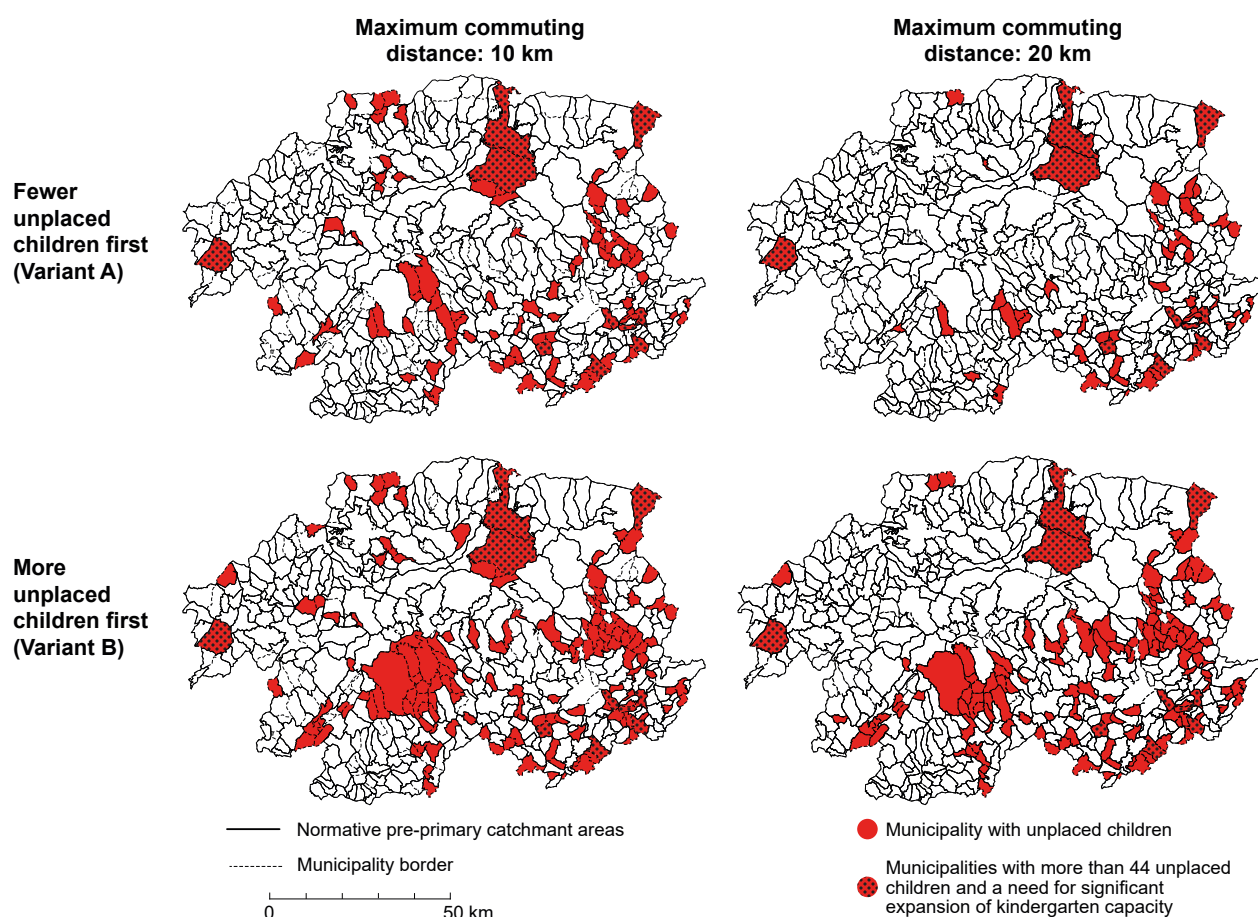


Fig. 2. Normative pre-primary catchment areas

Data sources: Statistical Office of the Slovak Republic (2025), CVTI (2023), authors' calculations

allocated children from individual origin municipalities was directed. The regions delimited in this way represent potential pre-primary catchment areas based on the principle of assigning children to the nearest municipality with available spare capacity.

The resulting spatial structure is relatively fragmented (Fig. 2). This character is, however, to a considerable extent natural, since a large share of municipalities have their own kindergarten and are able to ensure the placement of children in the municipality of residence without the need to use the capacities of neighbouring municipalities. Alongside this fragmented structure, however, larger, more or less spatially contiguous regions are also formed in which municipalities are unable to place their children either in the home municipality or in the accessible hinterland of surrounding municipalities. These areas represent regions of unplaced children, that is, municipalities which, within the model, were unable to attach to any modelled catchment region of pre-primary attendance. Their identification is analytically important because it points to territories with a cumulative capacity deficit.

The regions of unplaced children thus delimited (Fig. 2 – red municipalities) also provide a suitable starting point for consideration of the location of new kindergarten capacities. From the perspective of regional planning, it appears rational to concentrate new capacities primarily in larger municipalities with favourable transport accessibility and the potential to serve the wider hinterland of surrounding settlements. At the same time, it becomes clear that the model initially proposed at the start of the procedure – building new kindergartens in municipalities with a deficit exceeding 44 children – needs to be flexibly extended in practice. Depending on the spatial context and attendance

linkages, it may be appropriate to consider either facilities with a larger number of classes, which would also serve children from surrounding municipalities, or a more finely differentiated model that takes into account the need to establish new kindergartens already in municipalities with a deficit exceeding approximately 22 children.

Normative regions of pre-primary attendance therefore represent not only a descriptive output of the model, but also a practical basis for proposing territorially differentiated interventions in the public infrastructure of pre-primary education. At the same time, however, this is a relatively artificially constructed system, based on the normative principle of allocating children to the nearest municipality with spare capacity. For a better understanding of actual spatial linkages and attendance flows, it is therefore necessary to complement this perspective with an analysis of functional, that is, naturally formed, regions of pre-primary attendance.

#### Functional pre-primary catchment areas

At the specified minimum level of self-containment within the regionalisation procedure, 160 functional regions were formed. The average weighted travel distance covered by commuting children is 8.3 km. The results of functional regionalisation produce substantially larger and spatially more complex regions than those generated by the construction of normative catchment areas (Fig. 3). Whereas normative regions were based on the principle of allocating children to the nearest municipality with spare capacity, functional regions capture empirically observed linkages between children's place of residence and the location of the kindergartens they attend. The resulting spatial

structure therefore reflects naturally formed attendance relationships more accurately. At the same time, the functional regionalisation highlights the extent of capacity shortages in the region, as 2,469 children remained unplaced in 2023 despite being assigned to functional regions, indicating that existing attendance linkages alone are insufficient to overcome the mismatch between the spatial distribution of demand and available kindergarten capacity.

This difference is most pronounced in the hinterlands of larger towns (Banská Bystrica, Zvolen and Lučenec). Functional regions in their surroundings are distinctly more extensive than their normative counterparts. This suggests that parents are probably willing to travel longer distances with their children, especially when kindergarten attendance forms part of their daily mobility chains, above all on the route to work. Selective parental preferences in the choice of facility are also likely to play an important role. Larger towns offer a wider spectrum of kindergartens with different profiles or supplementary activities, which may lead to the crossing of normative catchment boundaries. In interpreting these results, however, it is also necessary to take into account the limitations of the input data, which may affect the size of the identified functional regions (see the next chapter).

The functional division also reflects broader spatial circumstances, above all relief and transport accessibility. More favourable conditions for the emergence of more extensive and differentiated functional linkages can be observed particularly in the area along the middle course of the Hron River, especially within the Žiar and Zvolen basins. It is here that the transport network and relief conditions create favourable preconditions for more intensive inter-municipal linkages and a broader hinterland of pre-primary attendance centres. By contrast, in the eastern part of the study area, especially in the areas of Gemer and Malohont, larger functional

structures emerge only to a limited extent. This pattern is related not only to the peripheral location and poorer transport accessibility, but also to the weaker everyday mobility of the population, which is conditioned by the broader socio-economic context of these territories.

Functional pre-primary catchment areas thus reveal that the actual spatial organisation of travel to kindergartens is shaped not only by the availability of capacity, but also by the quality of transport connections, physical-geographical conditions, the social differentiation of the territory and probably also by parents' daily mobility strategies. Compared with normative regions, they therefore provide a richer picture of natural catchment linkages and, at the same time, demonstrate more convincingly that normative school attendance zones may fail to capture adequately the actual functional organisation of pre-primary attendance.

## 6 DISCUSSION

Both approaches to modelling catchment areas – the normative and the functional – provide relevant insights into the organisation of pre-primary attendance; each of them, however, is burdened by several limitations that must be taken into account in interpreting the results.

The proposed normative optimisation model has several limitations that need to be considered when interpreting the results. First, it works exclusively with the capacities of facilities recorded in the official Network of Schools and Educational Establishments and does not take into account the capacities of off-network facilities or special kindergartens. The number of places available in the model is therefore slightly underestimated. Another limitation concerns the timeliness of the data. The capacity of pre-primary facilities changes over time, especially in the context of increasing kindergarten capacity from EU structural

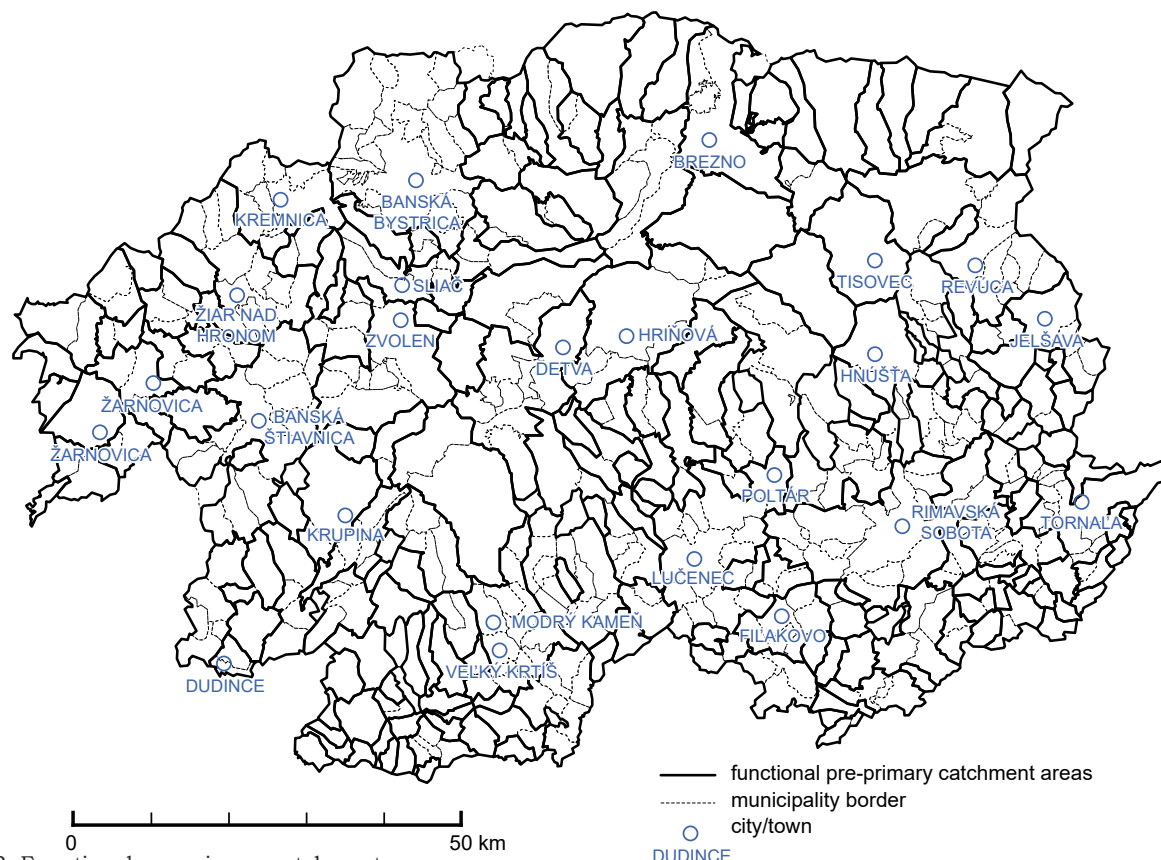


Fig. 3. Functional pre-primary catchment areas

Data source: CVTI (2023), authors' calculations

funds. In the study region alone, the number of places increased by 696 between 2023 and 2025 (although the number of kindergartens declined from 383 to 378). Another limitation lies in the very logic of allocating children on the basis of minimum distance. The nearest municipality with spare capacity may not represent a realistically accessible solution, since adequate transport connections – especially public transport – may not exist between municipalities. The model thus implicitly assumes ideal mobility conditions that may not be met in practice. Finally, the travel thresholds used (10 and 20 km, respectively) are relatively generous values. Under real conditions, parents may not be willing or able to ensure children's daily travel over such distances. This concerns socially weaker and peripheral regions in particular, where the financial costs of transport or limited transport service provision may constitute a major obstacle. More generally, actual kindergarten attendance patterns cannot be reduced to the principle of the shortest distance, but also reflect broader household mobility strategies, language preferences and local spatial conditions (Švecová et al., 2025).

The model results should therefore be interpreted more as an optimistic optimisation scenario than as a realistically achievable arrangement. In this study, both key parameters were deliberately set at relatively permissive upper-bound values: the maximum travel threshold was set at 20 km, while the municipal capacity-deficit threshold was set at 44 places, corresponding approximately to two standard kindergarten classes. If the aim were to develop an operational proposal for the practical optimisation of the kindergarten network, such a task would require systematic sensitivity testing across a broader range of parameter values, particularly lower travel-distance thresholds and lower thresholds for the municipal capacity deficit.

A limitation of the functional catchment area model is the reliability of the data on children's attendance. In practice, situations often occur in which a child's parents have different permanent residences, enabling them to place the child in different school attendance zones. As a result, the child's permanent residence need not be identical with the actual place of residence. A similar limitation may arise when the type of study is incorrectly recorded in the database. For example, a child may be registered in a kindergarten while in reality receiving individual education at home. This may affect the size of the resulting functional regions, since precisely such situations may be the cause of some flows over relatively longer distances.

The discussion of the results therefore inevitably leads to the question of the extent to which the two model variants fulfil the principle of spatial efficiency and the principle of spatial equity (Bezák 1996, 1997). The former expresses the relationship between location, spatial arrangement and the economic efficiency of service provision. From this point of view, larger facilities located in larger settlements, where there is a sufficiently robust demographic potential and where economies of scale can be applied to a greater extent, are usually more efficient. The limitations of such an approach, however, lie not only in financing operation, but also in the availability of teaching and specialist staff. The modelling results show that the normative approach based on the administrative allocation of children to the nearest municipality with spare capacity does not appear capable of fulfilling the assumptions of efficiency even when additional intervention measures are considered. Despite the hypothetical establishment of kindergartens in municipalities with a marked capacity deficit (more than 44 places, corresponding

approximately to two kindergarten classes), a large number of children (more than 2,000) remain unplaced in the study area, even when a greater travel distance (up to 20 km) is assumed. The spatial structure of the thus defined regions is highly fragmented and leads to the formation of isolated 'regions of unplaced children', that is, territories unable to be incorporated into any hinterland of an accessible kindergarten. From the perspective of spatial efficiency, this is a paradoxical result: although the model formally follows the optimisation criterion of the nearest available capacity, in practice it generates an unused potential of existing facilities while simultaneously revealing pronounced spatial mismatches between supply and demand.

The second principle represents the application of a broader understanding of social justice to space and expresses the requirement for such an organisation of the network of pre-primary facilities as would satisfy the needs of the population regardless of the size or location of the municipality. In the case of pre-primary education, this principle has a particular status. Unlike other types of public amenities, in the case of accessibility to pre-primary facilities the principle of spatial equity should carry greater weight than purely economic or rationalisation considerations. The reason lies primarily in the fact that pre-school children are more sensitive to the length and organisation of daily travel. Social and practical aspects of attendance also play an important role. These concern in particular the support of inclusion and integration of children from different social environments, children with disabilities, or children from ethnically differentiated environments, as well as the everyday organisational possibilities of households. The findings of this study therefore contribute to the broader debate on the spatial organisation of educational services and the relationship between normative and functional approaches to public-service planning. Similar to studies focusing on school catchment areas and childcare accessibility (Bernelius & Vilkama, 2019; Kim & Wang, 2019; Langford et al., 2019), our results demonstrate that administratively defined service areas based solely on the principle of geographical proximity may fail to adequately reflect actual attendance patterns and household mobility strategies. The identified discrepancy between normative and functional catchment areas confirms that educational accessibility cannot be understood solely as a function of geographical distance and available capacity, but is also shaped by everyday mobility patterns, parental preferences, transport accessibility, and broader socio-spatial conditions. This interpretative framework is also supported by findings on the factors influencing the choice of kindergarten, according to which accessibility is among the decisive criteria for parents, while its significance also varies according to the socio-economic status of the household and the type of municipality of residence (Križan et al., 2025). In this context, the approach based on functional regions provides a more convincing picture of the actual organisation of pre-primary attendance. By applying the modified CURDS algorithm functional regions were identified that are spatially more extensive but internally more complex than normatively delimited catchment areas. These regions reflect not only the distribution of capacities, but also the quality of transport infrastructure, physical-geographical barriers, the socio-spatial differentiation of the territory, and very probably also parents' everyday mobility strategies. They thus point to real functional linkages within which existing capacities are used more efficiently, albeit often at the cost of longer travel distances. At the same time, however, these findings also raise the question of spatial equity. Although functional regions better capture the actual behaviour of actors in space,

they also implicitly reveal inequalities in accessibility that result from unequal household capacities to organise attendance. In other words, what appears “functionally efficient” is not necessarily “socially just”.

Beyond the implications for educational planning, the study also contributes to the methodological literature on functional regionalisation. While approaches derived from the CURDS algorithm have been widely employed for the delineation of labour-market areas and functional urban regions (Coombes, 2010; Halás et al., 2014), the modified regionalisation procedure proposed in this article demonstrates that such methods can be successfully adapted to analyse low-volume and spatially constrained service flows, such as pre-primary attendance, provided that the regionalisation criteria are adjusted to the specific nature of the interactions under study.

The results also support broader arguments in the literature that planning educational and childcare infrastructure requires balancing spatial efficiency with spatial equity. Normative allocation mechanisms may promote formal equality of access, while functional approaches more accurately reflect actual behaviour and service use. The comparison of both approaches suggests that neither of them, taken separately, is capable of satisfactorily fulfilling both principles. The normative model fails primarily in terms of empirical feasibility and leads to pronounced accessibility deficits, whereas the functional model reflects the reality of attendance patterns more accurately but at the same time reproduces existing spatial and social inequalities. From this perspective, their combination appears to be the most appropriate solution, as it would make it possible to take into account natural catchment linkages while also normatively correcting extreme manifestations of inaccessibility in order to strengthen the principle of spatial equity in the network of pre-primary facilities.

The policy relevance of these findings becomes particularly evident when viewed in the context of ongoing demographic and institutional changes in Slovakia. In the broader context, it may appear that the problem of insufficient capacity will ease in the future. Data from the Statistical Office of the Slovak Republic (ŠÚ SR, 2026) show that, between 2021 and 2024, the number of live births in Slovakia declined year on year by 2,300 to 4,000 children. This trend, however, cannot be interpreted mechanically. The decline in fertility is more pronounced particularly in economically more developed regions, while in regions with marginalised communities a higher number of pre-school children may still be expected. The shrinking size of population cohorts therefore need not in itself lead automatically to the resolution of the capacity deficit in problem areas. Moreover, solving the lack of capacity is not straightforward even where the construction of new classes or new kindergartens is financially covered from external sources. Practical implementation often encounters limited interest, low administrative preparedness, or weaker implementation capacities of local self-governments. Even in cases where a municipality makes efforts to expand capacity, compliance with the so-called ‘3D principle’ – desegregation, destigmatisation and de-ghettoisation<sup>4</sup> – may prove problematic (Office of the Government Plenipotentiary of the Slovak Republic for Roma Communities, 2024). Precisely in socially vulnerable territories, the expansion of the kindergarten network therefore represents not only a technical or investment problem, but also a sensitive issue of social integration and the quality of public policy.

Finally, differences between economically stronger and lagging regions suggest that the adaptive mechanisms of households and local governments are

spatially highly uneven (Sládeková Madajová et al., 2025). In more developed regions, parents are generally able to respond more flexibly to a lack of capacity in the municipality of residence, whether by using a broader spectrum of facilities, greater mobility, or better transport accessibility. In lagging regions, however, one cannot expect the situation to be resolved spontaneously or merely through the mobilisation of endogenous resources. It is precisely there that the consequences of capacity deficits, social vulnerability and poor transport accessibility accumulate most strongly, and these territories therefore require more targeted and sensitive public interventions (Švecová et al., 2025).

## 7 CONCLUSION

The comparison of normative and functional pre-primary catchment areas in the Banská Bystrica Region reveals a substantial discrepancy between administratively defined attendance arrangements and the empirically observed spatial organization of pre-primary education. Whereas the normative model is based primarily on proximity and available capacity, the identified functional regions indicate that enrolment patterns are also shaped by transport accessibility, settlement structure, broader socio-spatial relations and parental mobility practices. The results point to a fundamental tension between these two principles. The normative approach, despite its formal emphasis on proximity, fails to ensure effective allocation of available capacities and leaves a considerable number of children without placement, thereby revealing its limited empirical applicability. At the same time, the functional approach provides a more realistic representation of attendance patterns and enables a more efficient use of existing capacities, but it simultaneously reflects and reproduces existing socio-spatial inequalities in access to pre-primary education. In this sense, what appears functionally efficient is not necessarily spatially just.

These findings suggest that a purely normative approach is of limited value for the planning of an equitable and efficient kindergarten network. At the same time, an approach based on functional regions should not be understood as a substitute for the formal delimitation of pre-primary catchment areas; rather, it should be regarded as a supporting and complementary analytical tool. A combination of both approaches therefore appears to be the most promising strategy, as it allows for the incorporation of naturally emerging attendance patterns while enabling targeted policy interventions aimed at mitigating extreme forms of spatial inequality in access.

The results also point to the persistent problem of an uneven spatial distribution of kindergarten capacities, which is likely to become even more pronounced with the extension of compulsory pre-primary education to younger age cohorts, namely four- and three-year-old children from 2027 and 2028 onwards. In this context, the key policy challenge lies not only in increasing overall capacity, but also in addressing its marked territorial imbalance, particularly in socially vulnerable and structurally disadvantaged regions.

Beyond the specific case of the Banská Bystrica Region, the study demonstrates the potential of functional regionalisation methods for analysing service catchment areas characterised by low-volume daily flows. The proposed modification of the CURDS-based procedure may therefore be applicable not only to pre-primary education, but also to other public services whose utilisation depends on everyday mobility patterns and local accessibility conditions.

## Footnotes

<sup>1</sup> The 20 km threshold was also adopted to ensure consistency with the normative model, in which this distance represents a theoretical upper limit of accessibility rather than a realistic commuting distance for pre-primary education.

<sup>2</sup> Road distance was used as a standardized measure of spatial accessibility because it provides a stable basis for comparing accessibility across municipalities and reflects the fact that kindergarten attendance is typically linked to parental travel patterns rather than to children's independent use of public transport.

<sup>3</sup> The threshold of 44 places was used as a necessary operational modelling assumption to ensure a realistic representation of capacity constraints, rather than as a statutory limit. It approximately corresponds to the capacity of two standard kindergarten classes, assuming a usual hygienic capacity of 22 places per class. This threshold was also introduced to identify municipalities with a substantial number of unplaced children who, even under different model parameter settings, could not realistically be accommodated within the existing kindergarten capacity.

<sup>4</sup> The principles of desegregation, destigmatization, and de-ghettoization constitute a tool through which the Office of the Plenipotentiary of the Government of the Slovak Republic for Roma Communities, as the guarantor of state policy for coordinating the implementation of inclusion of marginalized Roma communities, ensures that the activities implemented under the Slovakia Programme 2021–2027 are aligned with national and European legislation in the field of non-discrimination and equal treatment on the grounds of ethnic or national origin.

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