# Chapter 11
# Possibilities of Using Data Envelope Analysis for Quality Management of Public Services at the Local Level

**Marek Jetmar, Jan Kubat, Vit Fabera ⓘ, and Michal Jerabek ⓘ**

## 11.1 Introduction

The nature of public administration reflects the institutional aspects and principles of governing individual countries [1]. Public administration implements (fulfills) decisions of elected bodies, i.e., deals with the governance of public issues, ensures compliance of practice with law. On the European continent, its activities are carried out only on the basis and within the limits of the law, i.e., its competences are strictly defined by the law. However, its constitution and organization are also subject to law. Public administration addresses the needs of society and operates on the basis of organizational structures, processes, roles, relationships, policies, and programs. It creates sustainable economic prosperity, ensures social cohesion and human well-being [2].

Public administration has very often been seen as a service to the population, a service to the public, which is reflected in the ways in which it operates [3]. Its quality affects not only social confidence in the public sector but also in the whole political system. It therefore also affects the willingness of citizens to respect the guidelines and abide by the regulation enforced by authorities, i.e., to comply voluntarily with decisions of public authorities. The quality of the institutions and the effectiveness of the services they offer play an essential role in identifying the common good, strengthening reciprocity and belonging, enabling long-term prosperity.

M. Jetmar · J. Kubat
AMBIS, Prague, Czech Republic
e-mail: marek.jetmar@ambis.cz; jan.kubat@wo.cz

V. Fabera · M. Jerabek (✉)
Czech Technical University in Prague, Prague, Czech Republic
e-mail: fabera@fd.cvut.cz; jerabem1@fd.cvut.cz

From the economic point of view, public administration represents a managerial structure ensuring mainly the supply of public goods. From our point of view, the allocation function of the public sector and its ability to efficiently provide public goods and public services are particularly important.

## 11.2   Material and Methods

### 11.2.1   Distribution of Public Services at Local Level, Czech Context

After the territorial reform of public administration in the Czech Republic at the beginning of the millennium, the attention of the Ministry of the Interior focused on supporting processes aimed at modernizing public administration. It is about increasing the efficiency of public expenditure at all levels of public administration, effectiveness, strengthening the transparency of decision-making, and accountability to citizens. Particularly in recent years, the focus has been on implementing system approaches to quality management. Strategic Framework for the Development of Public Administration, Conceptual Document of the Ministry of the Interior for 2014–2020, adopted by Government Resolution No. 680/2014 on the Strategic Framework for the Development of Public Administration of the Czech Republic and updated by Government Resolution No. 1088/2016 for the period 2014–2020 [4] and the Implementation Plans including annexes, the Czech Republic, through specific objective 3.2, advocates the application of sustainable system approaches to quality management. Attention is focused not only on the institutions of state administration but also on the activities of territorial self-governing units. Services provided by the territorial public administration do not fulfill only the obligatory defined characteristics. Local and regional self-government tries to reflect within its delegated and independent competence also the requirements of stakeholders, which typically include clients of the offices, local citizens, and entrepreneurs and many others [4].

Territorial self-governing units carry out a number of development activities, including the provision of local public goods, which lead to increased satisfaction of the clients of the authorities as well as to the improvement of the quality of life for citizens in their territory. Each unit has its own procedures through which its management manages the organization—planning, organizing, communicating, or controlling the activities carried out. To ensure efficient and effective management of the organization, it is advisable to link the individual activities into a functional management system. The high number of self-governing units at local and regional level makes it possible to compare or develop tools to visualize the comparison.

The issue of efficiency of public services at local level in the Czech Republic is a subject of both professional and political interest. This is due, among other things, to the high degree of atomization of local government, which is represented

by 6258 independent municipalities, and the impossibility of their aggregation through administrative mergers or municipalization. This is a consequence of a high degree of autonomy, which is unusual even in the context of the European Union. Municipalities are free to exercise their autonomous powers; they are governed only by laws. The possibility of intervention by the state or state administration is limited to the supervision of legality. Municipalities defend their position very strongly and are highly sensitive to any indications of restrictions or interventions by the state.

All Czech municipalities are obliged to provide basic administrative services to a minimum extent and with regard to their population size and budget also local public services. Public libraries and elementary schools represent traditional public service provided by communities and towns. Their above-average number, compared to other countries, correlates with the high number of municipalities.

According to Ref. [5], public libraries can be defined as organizations that are established, supported, and subsidized by the society, either via local, regional, or national governments that ensure the access to knowledge, information, artworks, and lifelong education via various sources and services. The main services fulfill the mission of public libraries as defined by a specific Library Act [13]; an important feature and a necessary condition of public libraries is their unlimited social–economic accessibility.

The education system provides above all education that we classify as essential human needs. It provides a wide range of knowledge, ideas, attitudes, values, and abilities for life. Education is according to paragraph 2 of the School Act [14] referred to as public service. From an economic point of view, these are net public goods, the purpose of which is to extend positive externalities. It is an important part of the public sector; schools and school facilities are nonprofit organizations of the public sector, typically primary schools [3].

In the Czech Republic, however, a consistent policy for the development of public services is not formulated by the public administration. Unlike in other countries (e.g., Germany, Austria), the availability of public services is not standardized at the territorial level. Facilities are dealt with on an ad hoc basis with a view to ensuring accessibility in the area. The competition between settlements is a significant factor.

The high number of observations makes it possible to investigate efficiency by various statistical methods. The possibility of using the DEA method for the purposes of managing the efficiency of public services is discussed by researchers.

## 11.2.2 Theoretical Background

DEA is a benchmarking tool in operations research and has a wide range of applications including but not limited to banking, business, agriculture, transportation but also in the field of public services such as health care [6], education [7], public libraries [8], or research [9].

The Data Envelopment Analysis or DEA is a nonparametric method for estimating the production boundary presented in Ref. [10]. DEA measures the technical

efficiency of a decision-making unit (DMU) relative to other units. Technical efficiency is therefore relative and depends on the set of all units. Units that lie at the production line are marked as effective, while units that lie below the production line are marked as ineffective. Inefficient units are also assigned an efficiency score between 0 and 1, which indicates how far the unit is from the production boundary. Units with an efficiency rate of 1 are effective and units with an efficiency rate of less than 1 are ineffective. The method was originally applied in the business sector, but later it has been also applied in evaluating the effectiveness of public services or public administration services.

One particular issue many studies face is a heterogeneous operating environment. For DEA to make sense, however, the operating environment should be homogeneous.

## 11.3   Methodology

In the original DEA model of Ref. [10], all effective units are equal. There are many extension models of the so-called superefficiency in the literature that evaluate and compare the effective units among themselves.

We use the following assumptions when using this method. The output should be homogeneous as the quality of services is standardized by legislation. However, service providers vary widely in terms of population size, number of consumers, amount of resources available, i.e., income of municipal budgets, etc. The consequence is that the smallest municipalities do not provide services to their citizens and use the capacities of larger municipalities. We also consider the impact of the municipality's position on development centers, or their position within the functional agglomeration, on the efficiency of the services provided. Therefore, in the first step, we examine the efficiency of the whole set of municipalities providing the services. Above all, we are interested in efficiency in smaller, more homogeneous groups reflecting the size of the municipality/town and its position in the settlement structure.

The separation approach splits the heterogeneous data sample into several homogeneous subsamples according to one or more environmental variables and performs DEA separately for each subsample. The advantage of this approach is its simplicity and straightforward interpretability. However, it significantly reduces the sample size making it unusable in many studies. The all-in-one model directly includes environmental variables in DEA as inputs or outputs. The two-stage model adjusts the efficiency scores based on the dependence between preliminary efficiency scores and environmental variables using regression analysis.

From the range of DEA models, we selected DEA model with Chebyshev distance (not Euclidean, like classical DEA models) with variable returns to scale (VRS), input oriented, and with superefficiency proposed by Ref. [8]. We choose it because of its robustness and because it is a DEA model with superefficiency so it is possible to compare also efficient units.

All the efficiency results later in the article are calculated by this DEA model in its linear approximation form. Anyway, according to Ref. [8], the inefficient unit order by efficiency scores of DEA model from [8] is the same as in CCR model [10] with VRS.

### 11.3.1   Variable Selection

When evaluating the efficiency of public libraries, we utilize ten variables in total. All variables except the town distance are strongly positively correlated, while the town distance is moderately negatively correlated with the others. For the efficiency analysis, we consider the following $r = 3$ input variables:

- Total expenditures: The total expenditures in CZK by the municipality on library activities (class 3314 in the sectoral classification of budget structure) in 2016 and 2017. We aggregate the expenditures in 2 years to capture long-term investments and smooth out annual budget changes. The data source is the information portal MONITOR of the Ministry of Finance of the Czech Republic.
- Employees: The number of full-time equivalents of library employees in 2017. Note that 64.07% of libraries have no own employees as very small libraries are run either by employees of the municipal office or volunteers. The data source is NIPOS.
- Collection: The total number of book units owned by the library in 2016. This variable represents the capital of the library. We use the value from the previous year as we consider the increase in the book collection in the current year to be an output variable reflecting the performance of the library management. The data source is the National Information and Consulting Centre for Culture (NIPOS).

    We consider the following four output variables:

- Registrations: The total number of users registered in the library in 2017. This variable captures the size of the reader base. The data source is NIPOS.
- Circulation: The total number of book loans in 2017. This variable captures the main activity of libraries—book lending. The data source is NIPOS.
- Events attendance: The total number of visitors of events organized by the library in 2017. This variable captures the cultural role of libraries. Many libraries do not organize any events while others offer regular cultural program. The data source is NIPOS.
- Collection additions: The positive part of difference between the book collection in 2017 and 2016. This variable captures the increase of the capital of libraries. The book collection of 50.56% libraries remains the same as in 2016 or in some cases even decreases. The data source is NIPOS.

    In case of elementary schools, we considered seven output variables and just one input variable for DEA and two segmentation variables. We were very limited by the data availability and quality.

As DEA input variables we chose, due to availability and quality of data, only:

- Current expenditures on primary schools, $E(T)$.

The school year starts on September 1st and finishes on June 30th in the Czech Republic, but the expenditures are for the period 1.1–31.12. So for the analyses, we transformed the expenditures as

$$E(T) = \frac{1}{3}\text{CE}(T) + \frac{2}{3}\text{CE}(T+1) \qquad (11.1)$$

where $E(T)$ is the current expenditures on primary schools for the school year $T$ and $\text{CE}(T)$ is the current expenditures on primary schools for the calendar year $T$.

There were also separate categories for current expenditures on the first- and second-grade primary schools, but most of the municipalities do not fill them in although they had both grades, they just filled in the total for primary schools. So we rather do not use the split. Please note that salaries of teachers are paid from the central budget and not from municipality budgets.

As DEA output variables we considered:

- Primary schools count in a municipality, $S(T)$
- Total number of pupils in primary schools in a municipality, $P(T)$
- Total number of classes in primary schools in a municipality, $C(T)$
- Total number of pupils in the first-grade primary schools in a municipality, $P1(T)$
- Total number of pupils in the second-grade primary schools in a municipality, $P2(T)$
- Total number of the first-grade classes in primary schools in a municipality, $C1(T)$
- Total number of the second-grade classes in primary schools in a municipality, $C2(T)$

Where the first-grade means first five classes (i.e., pupils from 6 to 10 years old as on September 1st, when the school year starts) and the second-grade comprises four classes (pupils aged 11–14). The output variables relate to school years.

As segmentation variables we chose

- Number of inhabitants in a municipality as of January 1st, 2018, $I(T)$. The data source is the Czech Statistical Office (CSO).
- Time to drive by car to the closest municipality with extended competence or regional development centers, centers of regional agglomerations, or metropolitan areas. The data source is the web mapping service Mapy.cz.

Public services are provided by a very heterogeneous spectrum of municipalities, represented by small villages with several dozens of citizens up to big cities. In order to make comparisons in as homogeneous groups as possible, categories of municipalities were proposed that reflect the size of the domestic population and the position of municipalities in the settlement structure. Regarding the hierarchy of settlements, it is based on the Government-approved Strategy of Regional

**Table 11.1** Mean efficiency scores within each expert category of local public libraries in 2017

| Expert category | Population (*I*) | Distance (*D*) | Units | Mean efficiency (in segments) | Mean efficiency (whole sample) |
|---|---|---|---|---|---|
| E01 | 0–199 | ≤15 | 101 | 0.789 | 0.138 |
| E02 | 0–199 | >15 | 545 | 0.292 | 0.117 |
| E03 | 200–499 | ≤15 | 354 | 0.492 | 0.114 |
| E04 | 200–499 | >15 | 1113 | 0.212 | 0.115 |
| E05 | 500–999 | ≤15 | 343 | 0.412 | 0.151 |
| E06 | 500–999 | >15 | 872 | 0.376 | 0.149 |
| E07 | 1000–1999 | ≤15 | 228 | 0.683 | 0.213 |
| E08 | 1000–1999 | >15 | 484 | 0.583 | 0.208 |
| E09 (non ORP) | 2000+ | ≤15 | 359 | 0.655 | 0.437 |
| E10 (non ORP) | 2000+ | >15 | 123 | 0.837 | 0.394 |
| ORP towns | | | 138 | 0.926 | 0.801 |
| All | | | 4660 | 0.434 | 0.192 |

Development of the Czech Republic for 2021–2027 (Government Resolution No. 775/2019), which as higher ranking settlements distinguishes regional centers and core agglomerations (essentially regional cities), metropolitan areas (the largest cities of the Czech Republic). Most of them have the role of a municipality with extended competence (a third type municipality, ORP). Thus, the size of the population representing potential local demand and the proximity of the municipality to the municipality with extended competence (third type) or the position of the municipality within the agglomeration, metropolitan area is monitored. The distance of the municipality to these higher centers is monitored by means of time availability when using a passenger car.

On the basis of the above-mentioned data, an analysis of the effectiveness of municipalities in individual expert categories was performed. Due to the small number of observations in the cities with the largest population, these expert groups were aggregated. Prague and Brno were completely excluded as unique cases that are not comparable (Table 11.1).

The efficiency of libraries regardless of categorization by municipalities reaches an average of 0.192. Subsequently, the mean efficiency values for the given expert category were calculated. In the case of the smallest municipalities, the values range from 0.2 to 0.5, which represents a significant inefficiency. The category E01 is an outlier that showed average efficiency within a category nearly 0.8. It happened due to fact that 25% of units were efficient within the category. This high share of efficient units was usually caused by zero expenditures or employees and this happened more often than in other categories. It can be argued that the operation of most municipal libraries is ineffective with respect to the input and output data analyzed. As the size of the settlement increases, efficiency increases on average. The most effective are library services in towns and cities.

**Table 11.2** Average DEA elementary schools efficiency calculated on whole sample in distinction by expert-based categories and with different DEA output variables (in columns) in 2018

| Segment definition | | | Efficiency calculated in segments | | |
|---|---|---|---|---|---|
| $I(T)$ | $D(T)$ | $N$ | $P(T), C(T)$ | $P(T), C(T), S(T)$ | $P1(T), C1(T), P2(T), C2(T)$ |
| 0–500 | ≤15 | 124 | 0.080 | 0.080 | 0.120 |
| 0–500 | >15 | 145 | 0.072 | 0.093 | 0.083 |
| 500–999 | ≤15 | 548 | 0.224 | 0.231 | 0.241 |
| 500–999 | >15 | 346 | 0.207 | 0.217 | 0.240 |
| 1000–1999 | ≤15 | 458 | 0.240 | 0.258 | 0.287 |
| 1000–1999 | >15 | 243 | 0.338 | 0.366 | 0.443 |
| 2000–4999 | ≤15 | 257 | 0.539 | 0.569 | 0.587 |
| 2000–4999 | >15 | 166 | 0.667 | 0.692 | 0.704 |
| 5000–9999 | #NA | 142 | 0.709 | 0.746 | 0.741 |
| 10,000–19,999 | #NA | 69 | 0.869 | 0.914 | 0.924 |
| 20,000–49,999 | #NA | 44 | 0.829 | 0.880 | 0.865 |
| 50,000+ | #NA | 18 | 0.996 | 1.012 | 1.006 |
| Total | | 2560 | 0.340 | 0.359 | 0.380 |

The influence of the agglomeration, or the position of the municipality in the hinterland of a larger city, is noticeable only from municipalities with more than 500 inhabitants. Easily accessible regional center, metropolises, where the population of the village spend at least a few hours during the day—employment, use of higher public services, reduces the efficiency of the operation of local libraries (Table 11.2).

From the table, we can see that segments with more inhabitants had higher efficiency in general. Only municipalities with inhabitants from 500 to 999 had the lowest efficiency, both with the driving distance below and above 15 min to the closest bigger town.

The results of the DEA analysis can be viewed in the web-based application in the web browser—http://ambis.fd.cvut.cz. The architecture of the application is typical for such applications: three layer one: the database layer is composed by the Oracle DB server, application layer uses PL-SQL, R-language and PHP, final dynamic web pages are created dynamically by PHP on the presentation layer; AJAX is used on the client side. The architecture of the application and the relational model of the database were presented in Refs. [11, 12] in more details.

The configuration on the server and the installed software is concluded in Table 11.3.

The database contains information about 6251 towns/villages in the Czech Republic (the state from 2017). The total count of towns/villages is currently 6258, i.e., we have included 99.88% of them. Financial and statistical data containing budget, number of populations related to each town/village are filed in the range 2014–2018. The disk capacity is utilized at 33%.

After logging to application, splash screen with menu is displayed. The user can display list of town/villages, their statistical data, result of computing, and the comparison. AJAX script "buffers" always part of data. The time from selection

**Table 11.3**  Hardware and software solution for WebDEAr application

| *Hardware* | |
| --- | --- |
| Processor | 4 × Intel(R) Xeon(R) CPU E5-2630L v2 @ 2.40 GHz |
| Memory | 8 GB |
| Disk | 161 + 97 GB |
| *Software* | |
| OS | Oracle Linux 64-bit, kernel 4.14.35 |
| DBMS | Oracle DB server ver. 18 |
| Oracle Instant Client | Oracle Instant Client 19.3 |
| R-library | R 3.3.0 |
| WebServer | HTTPD 2.6.4 |
| PHP | PHP 7.3 |
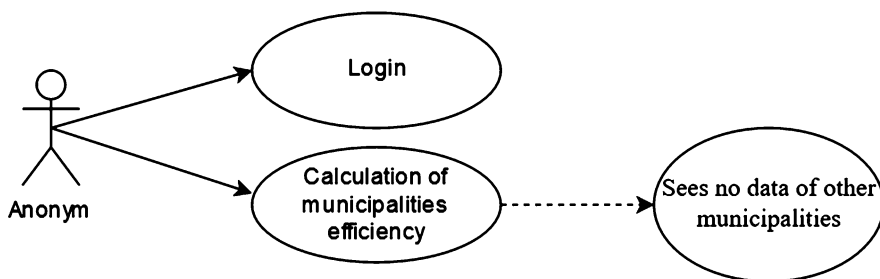


**Fig. 11.1**  Used by an anonymous user

from menu to display is up to 5 s. The measurement was performed on the local network in one building (two segments) using Google Chrome Browser. When it was accessed using 4G mobile network; the time from selection from menu to display is up to 10 s.

The application can be used by three types of users:

(a) An anonymous user, without the need to register or provide any personal information (use cases see Fig. 11.1)
(b) A registered user with the role of analyst (use cases see Fig. 11.2)
(c) A registered user with the role of administrator (use cases see Fig. 11.3)

An anonymous user can either log in or select the option to use the functionality of calculating the efficiency comparison with other municipalities. For municipalities with which they compare the fictitious municipality with the selected parameters, the user sees only the calculated number, which is used for comparison, not the values of the parameters that were used for the calculation.

A registered user with the role of analyst can see the list of municipalities that contains basic information about each of them. This user can see all information about previous calculations and the value of all parameters used to calculate the municipalities' efficiency.
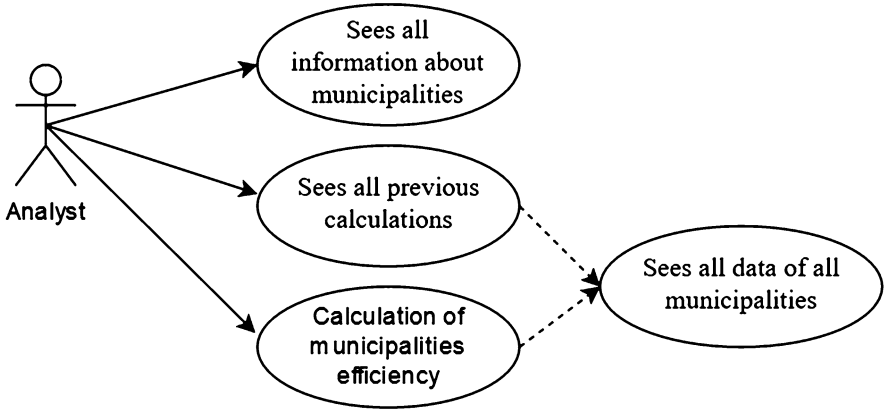
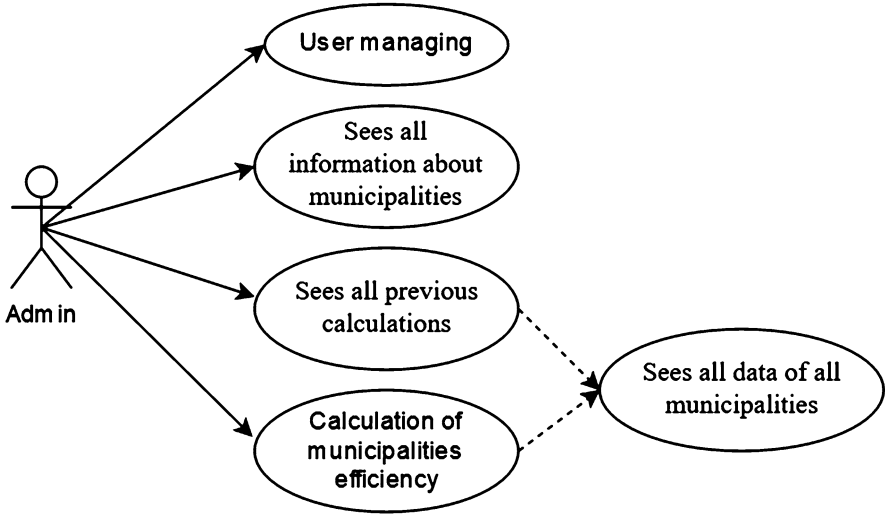**Fig. 11.2** Used by an analyst user



**Fig. 11.3** Used by an admin user

A registered user with the role of administrator has the same rights as the user with the role of analyst. His higher rights allow him to edit users, registration, change, and delete data.

## 11.4   Conclusion

Public services are provided by a very heterogeneous spectrum of municipalities, represented by small villages with several dozens of citizens up to big cities. In order to make comparisons in as homogeneous groups as possible, categories of municipalities were proposed that reflect the size of the domestic population and the position of municipalities in the settlement structure.

The efficiency of libraries regardless of categorization by municipalities reaches an average of 0.4458. In the case of the smallest municipalities, the mean efficiency values range from 0.3 to 0.8, which represents a significant inefficiency. It can be argued that the operation of most municipal libraries is ineffective with respect to the input and output data analyzed. As the size of the settlement increases, efficiency increases on average. The most effective are library services in towns and cities.

The segments with more inhabitants had higher efficiency of elementary schools in general. Only municipalities with inhabitants from 500 to 999 had the lowest efficiency, both with the driving distance below and above 15 min to the closest bigger town.

The findings are important for the discussion on how to set the availability of public services. At present, efficiency does not play a key role in capacity building. The establishment of a municipal library actually depends solely on an independent decision of the municipal council. The funding is conditioned by the willingness to cover the deficit of its operation with regard to the overall size of the municipal budget.

The operating costs of municipal libraries are covered often at the expense of other agendas performed by municipalities (e.g., in the form of sharing staff capacity). This means that some of the costs are not reflected in the financial statements associated with the library service, or are not even monetized. This means that the efficiency of small municipal libraries may in fact be even lower on average.

When it comes to the provision of school education, citizens of a community usually consider this role as a basic function of the municipality. It follows that even small communities, if they already have a school established (either in its entirety or only the first grade), strive to maintain them even at the cost of massive subsidies from their own budget. It is often the case that various exceptions apply, such as small classes, or teaching 2 years in just 1 year in order to maintain schooling. In the case of some rapidly developing municipalities close to large centers (affected by the process of suburbanization), the lagging of capacities behind the current need is observed. Therefore, the capacity of the core city is often used. If the municipality is in debt due to the construction boom, this behavior may be classified as a form of parasitism. The system of shared taxes does take into account the fact that the municipality operates a school when redistributing tax income among municipalities. However, this bonus covers only a fraction of the cost of running a school and is not an incentive to set up new or expand the capacity of existing schools. Some municipalities continue to enforce compensation payments for pupils commuting from other municipalities although this is not entirely in line with the law.

Through the administrative activities of municipalities of the third type (ORP—Municipalities with extended competence), school districts are created, which define the commute area of individual schools. The aspect is the size of capacities and transport accessibility. However, the efficiency of schools does not play a crucial role in this decision-making.

The Ministry of the Interior, as the guarantor of the project, has initiated the introduction of various tools for monitoring and evaluating the efficiency of public administration activities. The created application represents a progressive tool for the application of digital technologies in public administration, it enables further evolution of this tool with regard to data availability.

Representatives of municipalities, as well as civil servants of the Ministry of the Interior, will obtain a tool enabling them not only to compare the efficiency of individual municipalities, but thanks to the extensive database and a map display also a tool for modeling of catchment circuits and service efficiency.

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