Assessing the pure technical efficiency of public primary schools in the City of Zagreb

Branko Stanić[1] **Simona Prijaković**[1,*], and **Mihaela Bronić**[1]

[1] *Institute of Public Finance, Smičiklasova 21, 10000 Zagreb, Croatia*
E-mail: ⟨branko.stanic, simona.prijakovic, mihaela.bronic@ijf.hr⟩

Abstract. This paper is the first to assess the pure technical efficiency (PTE) of 111 public primary schools in the City of Zagreb during the 2022/2023 school year, using an input-oriented Data Envelopment Analysis (DEA) – BCC model. PTE was measured using two input variables (expenditures and number of teachers) and three output variables (average grades, number of pupils who passed the class, and secondary school enrolment points). The analysis revealed substantial variation in efficiency scores, with 20% of schools identified as fully efficient. The average efficiency score was 0.90, suggesting that, on average, schools could reduce inputs by 10% while maintaining current output levels. A follow-up super-efficiency DEA model was applied to rank efficient schools and identify best-practice examples that could serve as models for others. Based on super-efficiency scores, schools were grouped into five performance categories – best practice, efficient, near-efficient, emerging, and low efficiency. Additional findings suggest that larger schools tend to be more efficient and that benchmarking within peer-size groups can help uncover high-performing schools that might otherwise remain under the radar. The results underscore the importance of context-sensitive efficiency evaluation in education and highlight the need for improved data on school characteristics to support more comprehensive, actionable assessments.

Keywords: City of Zagreb, Data Envelopment Analysis, public primary schools, pure technical efficiency, super-efficiency

Received: September 9, 2024; accepted: April 11, 2025; available online: June 3, 2025

DOI: 10.17535/crorr.2026.0001

Original scientific paper.

1. Introduction

The growing number of studies on the efficiency of public services can be seen as a consequence of the increasing demand for more and better public services worldwide. The most visible to and important for each citizen, it is the efficiency of public services at the local level of government that has been the most researched (e.g., [30], [31], [35]).

According to the theory of fiscal federalism, lower levels of government are more capable of delivering public services to citizens because they have a greater understanding of the needs of their inhabitants [42]. Similarly, Seabright [38] stresses that the local authorities' physical closeness to the end users fosters local authority accountability and improves public service delivery because of better electoral controls. On the other hand, service delivery at the local government level may impair efficiency if, for instance, there is limited managerial capacity, the service relies on economies of scale, or if influential interest groups exert undue control over local decision-making [26].

*Corresponding author.

The efficiency of local public services refers to the extent to which local governments deliver services to citizens, minimising use of resources while meeting public needs. The resources necessary for the provision of public services are input variables (inputs). The services provided are treated as output variables (outputs). Therefore, an input-output analysis can be used to assess the efficiency of local governments – that is, their ability to deliver a greater quantity and quality of public services using limited resources [26]. Results from various countries consistently highlight significant disparities in efficiency scores among local governments, indicating the existence of substantial room for improvement in the delivery of public services (e.g., [6], [33]).

The efficiency of public primary schools in the City of Zagreb has not been previously assessed. Given the vital role primary education plays in shaping the future of pupils, families, and society at large – and considering the limited resources within city budgets – it is essential to identify which schools are able to optimize resource use while maintaining strong educational outcomes. This study employs the deterministic nonparametric frontier method – DEA – to evaluate the efficiency of 111 primary schools in the City of Zagreb during the 2022/2023 school year. We identified 20% of schools as fully efficient, with an average efficiency score of 0.90 across the sample. The super-efficiency DEA analysis allowed for the ranking of efficient schools and the identification of five best-practice schools. Additional findings suggest that larger schools generally demonstrate higher efficiency, and that benchmarking within peer-size groups can reveal high-performing schools that might otherwise go unnoticed. This analysis serves as an initial step toward identifying which primary schools in the City of Zagreb could improve their efficiency in terms of the criteria used in the study. National and local governments, as well as researchers, should give particular attention to schools with low efficiency levels and undertake further analysis to uncover opportunities for improvement.

The structure of the paper is as follows: Section 2 reviews the literature on efficiency measurement, with a focus on public services, education, and relevant findings from the Croatian context. Section 3 describes methodology, context, and the data used in the analysis. Section 4 presents the results and discussion, while Section 5 offers a conclusion.

2. Literature review

Defining efficiency in public services is inherently complex. Farrell [18] distinguishes between two key components: technical efficiency, referring to the ability to maximise output from a given set of inputs, and allocative efficiency, which concerns using inputs in optimal proportions to minimise cost. Expanding on this, Andrews and Entwistle [3], propose a broader framework, including distributive efficiency – the equitable allocation of services among different social groups – and dynamic efficiency, which considers the balance between current and future public spending. While these definitions vary, technical efficiency remains the most widely applied in empirical research, particularly due to its compatibility with quantifiable input-output relationships. As noted by Narbón-Perpiñá and De Witte [30, 31], technical efficiency (the ability to maximise output from a given set of inputs) captures the cost-effectiveness and quality of services delivered and is the definition adopted in this study. Efficiency assessments typically rely on either parametric or non-parametric methods. Among parametric models, stochastic frontier analysis (SFA) allows for random error in efficiency estimation and has been used in studies such as Grosskopf et al. [22] and Conroy and Arguea [11]. Non-parametric methods, particularly DEA, have become increasingly prevalent due to their flexibility and ability to handle multiple inputs and outputs without imposing a functional form [9]. Another non-parametric approach, Convex Nonparametric Least Squares (CNLS), has also been applied in efficiency analysis. Some scholars have combined both approaches for greater robustness (e.g., [13]), while De Witte and López-Torres [14] provide an extensive review of these methodologies in the education sector. DEA is also used for ranking by Dobos [16] in various areas. For example, Sinha et al. [40] used CNLS to evaluate the efficiency of Indian general insurance companies, demonstrating the method's potential for application in different sectors, Kumari et al. [24] applied DEA to the stock market. Models of DEA continues to evaluate, e.g. inverse DEA [21]. The modelling of educational efficiency often distinguishes between input-oriented and output-oriented perspectives. While input-oriented models emphasise minimising resources to achieve a given level of output, output-oriented models seek to maximise outcomes with the available inputs.

In the education sector, schools are commonly treated as decision-making units (DMUs) that convert resources into educational outcomes. Measuring their efficiency poses challenges, particularly in defining appropriate output indicators. Primary education aims not only at academic achievement but also at fostering behavioural, emotional, and social development. As a result, outputs may include test scores, graduation or promotion rates, pupil satisfaction, or engagement in extracurricular activities ([37], [19]). Input variables typically include school expenditures, number of teachers, teacher qualifications, class size, and infrastructure ([15], [20]). Due to data limitations, many studies use proxies and tailor their variables to the context and availability of information.

In decentralised systems, several studies have assessed educational efficiency using local governments as DMUs. Inputs commonly include public expenditures on education, while outputs reflect the scale of service provision – most often the number of enrolled pupils, interpreted as a proxy for demand [35]. Other studies adopt alternative proxies for education services provided, such as the number of schools (e.g., [34]) or the number of classes per school [32]. Sampaio de Sousa and Stošić [36] propose more nuanced output indicators, including enrollment and attendance rates, grade progression, and age-appropriate placement, aiming to reflect both the quantitative and qualitative dimensions of service delivery.

Although DEA has not yet been applied to assess primary education efficiency in Croatia, several studies have explored the factors influencing educational success at the primary school level. Babarović et al. [4] emphasise that pupils' cognitive abilities are the most significant predictors of academic outcomes, followed by family background characteristics such as parental education and household income. A nationwide study by Burušić et al. [8], involving 842 primary schools, quantified these influences: pupil-related factors explained between 5.3% and 15.9% of the variance in achievement across subjects; teacher-related variables (e.g., gender, qualifications, continuity) added 0.2% to 1.1%, while school-level characteristics (e.g., size, governance, support staff, principal's tenure) accounted for an additional 0.2% to 0.8%. These findings highlight the importance of multi-layered contextual factors in modelling school performance.

The literature review reveals three compelling reasons to examine primary education in Croatia. First, existing research has highlighted persistent inefficiencies in Croatia's public education spending compared to other EU member states (e.g., [41]). Second, existing research on the efficiency of public primary education in Croatia remains limited. Third, to date, no study has applied DEA or a similar method to evaluate the efficiency of primary education in the Croatian context. To address this research gap, we focus on all primary schools established by the City of Zagreb – the country's capital and largest city – as a starting point for such analysis.

3. Methodology, context, and data

3.1. Methodology

We use DEA to assess the PTE of primary schools. Analysing PTE allows us to assess how efficiently a school utilises its available resources to achieve optimal educational outcomes. Each school is treated as a DMU, meaning it is evaluated as part of a group that uses similar inputs to produce comparable outputs. DEA establishes an empirical efficiency frontier, where a score of

1 indicates full efficiency. This frontier is defined by minimizing inputs and maximizing outputs. The efficiency frontier serves as an attainable benchmark that inefficient DMUs should aim to reach. Any deviation from this frontier, as determined by the deterministic DEA method, is considered inefficiency and may reflect the influence of random external factors, such as institutional and socioeconomic conditions or measurement errors [10].

The most commonly used basic DEA models are: (1) the Charnes, Cooper and Rhodes [9] model, which assumes that the production function shows a constant return to scale (CCR model), and (2) the Banker, Charnes and Cooper [5] model which assumes a variable return to scale (BCC model). The choice of model depends on the content of the analysis and whether a short- or a long-term analysis is concerned. The CCR model primarily focuses on measuring scale efficiency, aiming to evaluate whether a school's size – defined by factors such as resources and infrastructure – is optimised to achieve the best possible educational outcomes. The BCC model measures PTE, i.e., how efficiently a unit utilises its available resources (inputs) to produce outputs, focusing solely on its management and operational practices, without accounting for the scale of operations (i.e., whether the unit is operating at an optimal size). BCC assumes variable returns where a proportional increase in input results in more or less than a proportional increase in output.

Following Cooper et al. [12], if a set of n DMUs is considered ($DMU_j, j = 1, \ldots, n$), each of them produces s outputs using m inputs. Let the $x_j = \{x_{ij}, i = 1, \ldots, m\}$ represent the input vector and $y_j = \{y_{rj}, r = 1, \ldots, s\}$ the output vector of DMU_j. The data set is determined by input matrix $X = (x_{ij}, i = 1, \ldots, m, j = 1, \ldots, n)$ and output matrix $Y = (y_{rj}, r = 1, \ldots, s, j = 1, \ldots, n)$. The fundamental aim of the DEA model is the evaluation of DMU efficiency. The vectors $X\lambda$ and $Y\lambda$, $\lambda = (\lambda_1, \ldots, \lambda_n), \lambda > 0$ represents the proportions contributed by efficient DMUs to the DMU projections onto the efficient frontier, and e is the unit vector.

In our paper, we employ the BCC input-oriented model. Seeking the efficiency score of the DMU could be formulated as a standard linear programming model. The BCC input-oriented model for evaluation of the DMU_0 that will be applied in our paper can be formulated as follows:

$$\max_{\theta\lambda} \theta_0$$

subject to (1)

$$\begin{aligned} -y_0 + Y\lambda &\geq 0, \\ \theta x_0 - X\lambda &\geq 0, \\ e^T\lambda &= 1, \\ \lambda &\geq 0, \end{aligned}$$

where x_0 and y_0 are vectors of inputs and outputs of the unit under evaluation, θ_0 is the BCC efficiency score of the DMU_0, and e^T is the unit row vector. The goal is to achieve assigned weights that maximise the ratio for the particular DMU being analysed. Due to the setting of real constraints, the optimal value is 1. An input-oriented DEA model aims to assess how much input quantities can be proportionally reduced while maintaining the same output level. If a unit is inefficient, it suggests there is potential to improve operations, such as through better resource management, to achieve the same output with fewer inputs. This approach is particularly relevant for public institutions facing pressures to reduce costs while maintaining a certain level of services [6], which is why we have opted for the input-oriented approach. This study adopts a variable returns to scale model, based on the assumption that schools may be suboptimal in producing public services due to constraints, such as budget limitations [35].

3.2. Context and data

Primary education in Croatia, typically lasting eight years, is both compulsory and provided free of charge. Its objectives and responsibilities are defined by curricula set out by the Ministry of Science, Education, and Youth (MSEY). Although primary schools can be established by national, regional, and local authorities, as well as other legal entities and individuals, our analysis specifically focuses on public schools established by the City of Zagreb. This choice was driven by their considerable number, consistency in organisational structure and funding, and the greater accessibility of relevant data. Additionally, focusing on this homogeneous group enhances the comparability of results and ensures greater policy relevance at the city level. We exclude specialised public primary schools for pupils with disabilities (e.g., Center for Autism, Goljak Education Center, Suvag Polyclinic, and Nad Lipom Primary School) due to significant differences in their curricula, resources, and educational objectives, making comparisons with regular schools unsuitable.

Public primary schools in Croatia are funded by the central government, counties, and cities. However, the majority of the funding comes from the central government, primarily through MSEY. This funding covers teachers' salaries and professional development, education for children with developmental difficulties, gifted pupils, and ethnic minorities, as well as initiatives related to digitalization and library resources (Eurydice Network [17]). Counties and cities, as the governing authorities of public primary schools, are responsible for financing the so-called decentralised functions. These include material costs, maintenance and investment in infrastructure, equipment and teaching aids, pupil transportation, capital construction in line with standards set by the central government, co-financing of extended and full-day programs, and the provision of school meals (Eurydice Network [17]). Each year, the central government sets a minimum financial standard for these decentralised functions. Funding is primarily secured through an increased share of personal income tax allocated to counties and cities, supplemented by equalisation grants in cases where these local governments cannot meet the standard solely through tax revenue. Counties and cities may also provide additional funding from their own budgets; for instance, the City of Zagreb has for many years provided free textbooks to all primary school pupils.

Our research analyses 111 primary schools in the City of Zagreb in the 2022/2023 school year. This year was selected as it is the most recent period for which comprehensive data are available. Drawing on available data and existing literature, we selected two input variables at the school level (see Table 1): total annual expenditures, representing overall resource input (similar to [35]), and the number of teachers employed at each school, representing human resource input (as in [36]). We considered three output variables at the primary school level: average pupil grades, the number of pupils successfully passing the class, and the average points pupils achieve when enrolling in secondary schools. These outputs capture distinct dimensions of school performance. Specifically, average grades reflect the quality of teaching and learning, passing rates indicate operational efficiency in delivering the curriculum, and secondary school enrolment points show how effectively schools prepare pupils for subsequent educational stages – a critical outcome of primary education. Previous studies have employed similar output variables: average pupil grades (e.g., [7]), the number of pupils passing classes (e.g., [36], [7]), and secondary school enrolment points (e.g., [1], at the national level). We expect that primary schools with higher average pupil grades, higher pass rates, and higher average secondary school enrolment scores achieve superior educational outcomes, both in terms of quality and quantity.

Variable		Definition and measurement	Source
Inputs			
Expenditures	x_{1j}	Total expenditures are based on data from school financial reports.	MF [27]
Teachers	x_{2j}	The number of teachers as of November 1, 2022.**	MSEY [28]
Outputs			
Average grades	y_{1j}	The average pupil grades at the end of the school year.	MSEY[29]
Pupils passed	y_{2j}	The total number of pupils who pass the class, i.e., the number of pupils who receive a passing grade.	MSEY[29]
Enrolment points	y_{3j}	The average number of points achieved by pupils who complete eight years of primary school for enrolment into secondary school, based on their performance in the summer and fall terms.***	MSEY[29]

Table 1: *Definitions of variables used for public primary schools**

* All primary schools may have branch schools, which are included in our analysis.

** Since data on the number of teachers can vary significantly from day to day due to frequent replacements and other factors, using figures for the entire school year would result in unrealistically high numbers. Therefore, the situation as of November 1, 2022, was used to obtain a more accurate and realistic number of teachers for the 2022/2023 school year.

*** The number of points that Croatian primary school pupils achieve when enroling in secondary school is mostly based on their final school achievement from 5th to 8th grade and the school achievement in a specific set of subjects from 7th and 8th grades (e.g., Croatian, Mathematics). Pupils can also earn points based on criteria established through knowledge competitions and school sports club competitions. Finally, an additional few points can be awarded according to special criteria, including pupils with health problems, those living in difficult economic, social, and educational conditions, Roma pupils, and pupils whose parents are civil servants working on behalf of the Republic of Croatia abroad.

Note: The variable expenditures refers to the average values for 2022 and 2023; while the variables teachers, average grades, pupils passed, and enrolment points correspond to the 2022/2023 school year. Data on both output and input variables are available upon request.

Source: Authors.

4. Results and discussion

The descriptive statistics in Table 2 for the 2022/2023 school year reveal significant differences in the values of the variables, particularly in expenditures, number of teachers, and number of pupils passed. Matija Gubec Primary School has the highest total expenditures (3,133,744 EUR), while Tituš Brezovački Primary School has the highest number of teachers (89). In contrast, Savski Gaj Primary School has the highest number of pupils passed (1,139). Stjepan Benceković–Horvati Primary School reports the lowest expenditures (541,028 EUR), the lowest number of teachers (20), and the lowest number of pupils who pass the class (126). Dr. Vinko Žganec Primary School has the lowest average grade for all pupils at the end of the school year (4.09), while Matija Gubec Primary School has the highest (4.89). Finally, the highest average number of points achieved by 8th-grade pupils for enrolment into secondary school is found at August Harambašić Primary School (84.45), while the lowest is at Žitnjak Primary School (50.67).

Variable	Min	Mean	Median	Max	Standard deviation
Inputs					
Expenditures	541,028	1,791,060	1,788,155	3,133,744	46,897.27
Teachers	20	54	54.30	89	1.43
Outputs					
Average grades	4.09	4.68	4.65	4.89	0.01
Pupils passed	126	542	557.5	1,139	20
Enrolment points	50.67	71.40	70.09	84.45	0.79

Table 2: *Descriptive statistics for public primary schools*
Source: Authors.

Our analysis employs model (1), which measures PTE – that is, how efficiently a school utilises its resources (inputs) to generate outputs – focusing exclusively on internal management and operational practices. Moreover, several authors point out that this approach is the most commonly used and considered reliable for minimizing the risk of model misspecification [39]. The results of the efficiency analysis are presented in Table 3. The initial DEA model (1) identified an efficiency frontier comprising 20% of the schools in the sample, each achieving a full efficiency score of 1. The average PTE scores across the entire sample, as measured by the initial DEA model (1), was 0.90. This indicates that, on average, schools could reduce input usage by approximately 10% while maintaining the same output level. Building on the initial DEA model, we conducted a supplementary super-efficiency analysis to make further distinctions among the high-performing schools. Super-efficiency scores were calculated by removing the evaluated DMU (achieving a full efficiency in model (1)) from the reference set, allowing efficiency values to exceed 1 and enabling full ranking of efficient units [2]. This additional analysis enabled a more precise ranking of the efficient schools and facilitated the identification of benchmark units, thus providing valuable insights into best practices within the system of primary schools in the City of Zagreb.

Based on the distribution of super-efficiency scores and the identification of leading units, schools were grouped into five performance categories to allow a more refined interpretation of efficiency levels. The categories are defined as follows:

1. *Best practice*: A selected group of highly efficient schools identified through super-efficiency analysis as benchmarks. These schools not only score above 1 but also serve as reference points for others due to their superior performance.
2. *Efficient*: Schools with a super-efficiency score greater than or equal to 1 but not included in the best practice group. These schools operate efficiently but are not among the top-performing benchmarks.
3. *Near-efficient*: Schools with scores between 0.95 and 1 (excluding 1), indicating performance close to the efficiency frontier with little room for improvement.
4. *Emerging*: Schools with scores between 0.80 and 0.95 (excluding 0.95), showing moderate deviation from the efficiency frontier and higher potential for improvement.
5. *Low efficiency*: Schools with scores below 0.80, reflecting the considerable room for performance improvement.

This classification provides a clearer view of relative efficiency levels and supports the identification of top-performing schools as well as those with development management needs (Table 3). While the DEA identifies schools that are relatively efficient within the sample, it is important to note that this does not necessarily mean a school is fully optimised in an absolute sense. DEA evaluates each school's performance in relation to others in the same dataset, rather than against a theoretical maximum [23]. In other words, efficiency scores reflect how well a school performs compared to its peers using the same set of resources, rather than whether it operates at a universally optimal level.

Primary school	PTE	Super-efficiency	Rank	Category
August Harambašić	1	Benchmark	1	Best practice
Bartol Kašić	1	Benchmark	2	Best practice
Savski Gaj	1	Benchmark	3	Best practice
Tituš Brezovački	1	Benchmark	4	Best practice
Matija Gubec	1	Benchmark	5	Best practice
Stjepan Benceković-Horvati	1	1.5295	6	Efficient
Središće	1	1.5147	7	Efficient
Remete	1	1.3981	8	Efficient
Trnjanska	1	1.2743	9	Efficient
Ivan Cankar	1	1.2167	10	Efficient
Jabukovac	1	1.1633	11	Efficient
Alojzije Stepinec	1	1.0960	12	Efficient
Ksaver Šandor Gjalski	1	1.0799	13	Efficient
Pavlek Miškina	1	1.0655	14	Efficient
Ivan Filipović	1	1.0515	15	Efficient
Granešina	1	1.0507	16	Efficient
Marin Držić	1	1.0472	17	Efficient
Josip Juraj Strossmayer	1	1.0445	18	Efficient
Dragutin Tadijanović	1	1.0281	19	Efficient
Gračani	1	1.0252	20	Efficient
Antun Gustav Matoš	1	1.0046	21	Efficient
August Šenoe	1	1.0027	22	Efficient
Vjenceslav Novak	0.9979	0.9979	23	Near-efficient
Izidor Kršnjavi	0.9979	0.9979	24	Near-efficient
Većeslav Holjevac	0.9911	0.9911	25	Near-efficient
Grof Janko Drašković	0.9898	0.9898	26	Near-efficient
Antun Branko Šimić	0.9864	0.9864	27	Near-efficient
Dragutin Domjanić	0.9781	0.9781	28	Near-efficient
Brestje-Sesvete	0.9718	0.9718	29	Near-efficient
Čučerje	0.9684	0.9684	30	Near-efficient
Josip Račić	0.9661	0.9661	31	Near-efficient
Horvati	0.9630	0.9630	32	Near-efficient
Brezovica	0.9627	0.9627	33	Near-efficient
Cvjetno Naselje	0.9619	0.9619	34	Near-efficient
Dragutin Kušlan	0.9614	0.9614	35	Near-efficient
Bukovac	0.9585	0.9585	36	Near-efficient
Dr. Ante Starčević	0.9535	0.9535	37	Near-efficient
Šestine	0.9524	0.9524	38	Near-efficient
Retkovec	0.9514	0.9514	39	Near-efficient
Medvedgrad	0.9511	0.9511	40	Near-efficient
Vladimir Nazor	0.9490	0.9490	41	Emerging
Jure Kaštelan	0.9484	0.9484	42	Emerging
Braće Radić	0.9471	0.9471	43	Emerging
Pantovčak	0.9466	0.9466	44	Emerging
Lučko	0.9449	0.9449	45	Emerging
Luka-Sesvete	0.9420	0.9420	46	Emerging
Ljubljanica	0.9403	0.9403	47	Emerging

Primary school	**PTE**	**Super-efficiency**	**Rank**	**Category**
Rapska	0.9395	0.9395	48	Emerging
Ivanja Reka	0.9376	0.9376	49	Emerging
Ivan Mažuranić	0.9358	0.9358	50	Emerging
Stenjevec	0.9319	0.9319	51	Emerging
Ante Kovačić	0.9294	0.9294	52	Emerging
Vukomerec	0.9290	0.9290	53	Emerging
Sesvete	0.9271	0.9271	54	Emerging
Malešnica	0.9260	0.9260	55	Emerging
Borovje	0.9257	0.9257	56	Emerging
Žuti Brijeg	0.9241	0.9241	57	Emerging
Julije Klović	0.9233	0.9233	58	Emerging
Tin Ujević	0.9228	0.9228	59	Emerging
Sveta Klara	0.9219	0.9219	60	Emerging
Odra	0.9079	0.9079	61	Emerging
Vrbani	0.9073	0.9073	62	Emerging
Oton Iveković	0.9066	0.9066	63	Emerging
Silvije Strahimir Kranjčević	0.9064	0.9064	64	Emerging
Voltino	0.8968	0.8968	65	Emerging
Markuševec	0.8963	0.8963	66	Emerging
Sesvetska Sela	0.8960	0.8960	67	Emerging
Kralj Tomislav	0.8945	0.8945	68	Emerging
Matko Laginja	0.8941	0.8941	69	Emerging
Otok	0.8869	0.8869	70	Emerging
Špansko Oranice	0.8792	0.8792	71	Emerging
Kustošija	0.8789	0.8789	72	Emerging
Jelkovec-Sesvete	0.8784	0.8784	73	Emerging
Marija Jurić Zagorka	0.8767	0.8767	74	Emerging
Iver-Sesvetski Kraljevec	0.8752	0.8752	75	Emerging
Ivan Granđa-Solblinec	0.8696	0.8696	76	Emerging
Sesvetski Kraljevec	0.8614	0.8614	77	Emerging
Rudeš	0.8586	0.8586	78	Emerging
Mato Lovrak	0.8583	0.8583	79	Emerging
Ban Josip Jelačić	0.8572	0.8572	80	Emerging
Fran Galović	0.8563	0.8563	81	Emerging
Dobriša Cesarić	0.8541	0.8541	82	Emerging
Trnsko	0.8534	0.8534	83	Emerging
Mladost	0.8519	0.8519	84	Emerging
Lovro Pl. Matačić	0.8491	0.8491	85	Emerging
Zapruđe	0.8461	0.8461	86	Emerging
I. primary school Dugave	0.8393	0.8393	87	Emerging
August Cesarec	0.8377	0.8377	88	Emerging
Sesvetska Sopnica	0.8347	0.8347	89	Emerging
Nikola Tesla	0.8333	0.8333	90	Emerging
Gornje Vrapče	0.8319	0.8319	91	Emerging
Hrvatski Leskovac	0.8314	0.8314	92	Emerging
Dr. Vinko Žganec	0.8305	0.8305	93	Emerging
Ivan Meštrović	0.8282	0.8282	94	Emerging

Primary school	PTE	Super-efficiency	Rank	Category
Gustav Krklec	0.8145	0.8145	95	Emerging
Ivan Gundulić	0.8054	0.8054	96	Emerging
Petar Preradović	0.8025	0.8025	97	Emerging
Kajzerica	0.8014	0.8014	98	Emerging
Miroslav Krleža	0.8010	0.8010	99	Emerging
Davorin Trstenjak	0.7978	0.7978	100	Low efficiency
Žitnjak	0.7938	0.7938	101	Low efficiency
Dr. Ivan Merz	0.7719	0.7719	102	Low efficiency
Ivan Goran Kovačić	0.7645	0.7645	103	Low efficiency
Petar Zrinski	0.7572	0.7572	104	Low efficiency
Prečko	0.7517	0.7517	105	Low efficiency
Antun Mihanović	0.7466	0.7466	106	Low efficiency
Fran Krsto Frankopan	0.7443	0.7443	107	Low efficiency
Ivo Andrić	0.7306	0.7306	108	Low efficiency
Vugrovec-Kašina	0.7170	0.7170	109	Low efficiency
Jordanovac	0.6798	0.6798	110	Low efficiency
Grigor Vitez	0.5305	0.5305	111	Low efficiency

Table 3: *DEA PTE and super-efficiency results with ranking and category assignment for 111 primary schools in the City of Zagreb*
Source: Authors.

Best practice units – also referred to as benchmark units – are those that not only achieve full efficiency but also serve as reference points in the construction of the efficiency frontier ([12]). These schools are used as comparators for less efficient schools and play a key role in defining what is considered optimal input-output performance. In the super-efficiency model, best practice schools are identified by their ability to maintain or exceed an efficiency score of 1 even when they are excluded from the reference set. This indicates that they outperform other schools without relying on themselves as benchmarks [25]. In our super-efficiency DEA analysis, the schools identified as benchmarks are August Harambašić, Bartol Kašić, Savski Gaj, Tituš Brezovački, and Matija Gubec. These schools not only demonstrate optimal performance relative to their peers but also serve as exemplary models within the system. They represent a tangible standard of excellence in both resource utilisation and educational outcomes and can play a key role by sharing efficient practices with other schools.

Since Burušić et al. [8] identified primary school size as a significant predictor of pupils' academic success in Croatia; we also sought to examine whether schools with more pupils tend to achieve higher efficiency scores. Interestingly, in the initial model (1), the average number of pupils in efficient schools (score = 1) is almost identical to that of inefficient ones (565 vs. 557), suggesting that there is no clear relationship between school size and efficiency at this level. However, a much larger difference emerges when examining the best practice schools identified through the super-efficiency analysis. These schools have an average of 808 pupils, compared to 547 in the remaining schools. This contrast suggests that while size alone may not determine whether a school is efficient per se, it may influence the likelihood of becoming a top-performing benchmark. In addition, among the best practice schools, two – Savski Gaj and Tituš Brezovački – have the highest number of pupils in the entire sample, while four of the five exceed the median pupil count (all except August Harambašić).

To explore whether school size influences efficiency outcomes and to minimise potential bias in the efficiency assessment, an additional analysis was conducted. Schools were divided into two groups based on the median number of pupils: lower-capacity schools (below the median) and higher-capacity schools (above the median). For each group, average efficiency scores were calculated using the initial DEA model (1), without applying the super-efficiency extension (see Table 4). This approach ensured that all schools, including those on the efficiency frontier (score = 1), remained within the reference set, thereby preserving the comparability and integrity of the sample. Full results and rankings from this analysis are available upon request from the corresponding author.

School group	**Average efficiency (full sample)**	**Average efficiency (within their group)**
higher-capacity (above median)	0.92	0.94
lower-capacity (below median)	0.88	0.92

Table 4: *Average efficiency scores by school capacity group, model (1)*
Source: Authors.

Table 4 highlights a clear distinction in average efficiency scores between the two groups. In the full sample, the group of higher-capacity schools achieved a higher average efficiency score (0.92) than that of lower-capacity schools (0.88). This difference persisted even when efficiency was calculated within each group separately, with higher-capacity schools again outperforming lower-capacity ones (0.94 vs. 0.92). These findings suggest a moderate scale effect, where larger schools tend to operate more efficiently on average. While the gap is not large, its consistency across both the full sample and group-specific analyses indicates that school size may confer certain advantages in terms of input utilisation and output performance. Our findings align with those of Babarović et al. [4], who, in a study of 842 primary schools in Croatia, found that pupils in smaller schools tend to exhibit lower average academic performance. They attributed this outcome to the specific operational characteristics of smaller schools, while also noting that it may reflect structural features of Croatia's primary education system. This reinforces our earlier observation that best practice schools tend to have higher pupil numbers and underscores the importance of considering school size in both policy recommendations and the interpretation of DEA-based efficiency results.

Moreover, after dividing the sample into two groups based on the median number of pupils, four of the original five best practice schools retained their benchmark status within the higher-capacity group (Savski Gaj, Tituš Brezovački, Bartol Kašić, and Matija Gubec), while the one school below the median (August Harambašić) remained a benchmark within the lower-capacity group. In addition, five new benchmark schools emerged within the lower-capacity group – Jabukovac, Kustošija, Ivan Cankar, Izidor Kršnjavi, and Jordanovac – which had not been recognised as such in the full-sample analysis. These findings suggest that conducting efficiency analysis within more homogeneous groups allows for the identification of additional efficient units that may otherwise be underestimated when compared to significantly larger peers. In other words, smaller schools sometimes appear less efficient when compared with larger peers, although within their own peer group, they may demonstrate high performance.

5. Conclusion

This paper assessed the PTE of 111 public primary schools in the City of Zagreb in the 2022/2023 school year, using an input-oriented DEA – BCC model. The analysis aimed to evaluate how efficiently schools utilise available resources – measured by expenditures and the number of teachers – to generate key educational outcomes, including pupil achievement (average grades), academic progression (number of pupils passed), and preparedness for secondary education (secondary school enrolment points). The initial DEA model (1) identified 20% of schools as fully efficient, indicating a considerable share of schools already operating at the efficiency frontier. However, the average efficiency score of 0.90 in the full sample suggests that most schools could achieve the same level of output with approximately 10% fewer inputs. To further differentiate among efficient units, a super-efficiency DEA analysis was applied, which enabled the ranking of efficient schools and the identification of five best practice public primary schools that serve as benchmarks: August Harambašić, Bartol Kašić, Savski Gaj, Tituš Brezovački, and Matija Gubec. In addition to individual efficiency scores, schools were grouped into five performance categories – best practice, efficient, near-efficient, emerging, and low efficiency – based on the results of the super-efficiency analysis. This classification provided a more nuanced understanding of performance levels across schools and allowed for the identification of both high-performing units and those with greater potential for improvement.

The results also point to a possible impact of size on efficiency outcomes. While the initial DEA model showed almost no difference in average pupil numbers between efficient and inefficient schools, in super-efficiency analysis, best practice schools had a considerably higher average number of pupils, suggesting that school size may be associated with top-level efficiency. Additional analysis by capacity groups confirmed this finding: higher-capacity primary schools (those with pupil numbers above the median) achieved slightly higher average efficiency scores (0.92 vs. 0.88) in the full sample, a trend that remained consistent even within group-specific evaluations.

Furthermore, when schools were analysed within more homogeneous, size-based groups, additional efficient schools – including some smaller ones – emerged as benchmarks. This suggests that smaller schools may appear less efficient when directly compared to much larger peers, despite performing strongly within their own context. These findings underscore the importance of adjusting efficiency analyses to take account of structural characteristics, such as school size, highlighting the need for fairer and more context-sensitive evaluation approaches in public education.

Policymakers should be aware/take into consideration that school size alone does not determine efficiency, and smaller schools may operate efficiently given their specific constraints and environments. In light of these results, uniform efficiency improvement strategies may not be appropriate. Instead, differentiated policy measures are recommended, tailored to the specific conditions and capacities of schools of different sizes. In general, the results of this paper can support evidence-based decision-making in education planning. By identifying schools with high efficiency and those with management improvement potential, local and national authorities can allocate resources more effectively, promote knowledge sharing between schools, and enhance the overall quality and efficiency of public education.

A key limitation of the analysis lies in the availability and comprehensiveness of the input and output data. Expanding the set of performance indicators – especially qualitative or curriculum-related dimensions – and applying mixed methods, such as stakeholder surveys or case studies, would enrich future analyses. Therefore, the MSEY should consider producing and publishing additional data that could serve as valuable inputs and outputs for assessing the efficiency of public primary education. Furthermore, data on the characteristics of best practice schools and other contextual factors influencing performance would support a more in-depth interpretation of efficiency results. Relevant variables could include tracking average grades in the first year of secondary school, as a more direct and meaningful measure of long-term educational outcomes, pupil participation and success in academic competitions, the number and composition of school staff (e.g., teachers, teaching assistants, cleaners, cooks, janitors), teacher qualifications beyond the basic requirements, principal tenure, and the extent of extracurricular or curriculum-enriching activities. Additionally, information on schools' cultural and public engagement could offer further insights into their broader contributions to pupils' educational experiences. To complement quantitative data, surveys or interviews with school staff and community members could provide valuable perspectives on how efficiency in primary education is defined and perceived. For example, Burušić et al. [8] used survey data to investigate the determinants of school efficiency at the primary level. Regular implementation of such surveys would support the development of high-quality datasets for future research. Finally, to strengthen empirical findings, conducting case studies on selected schools could help uncover the underlying reasons for differences in efficiency scores, offering a more nuanced understanding of the factors driving variation in school performance.

Future research could go beyond the assessment of PTE by examining the scale efficiency of public primary schools, which considers whether schools operate at an optimal size to maximise educational outcomes while minimising resource use. Moreover, incorporating complementary methodologies such as SFA could provide deeper insights – not only identifying efficient schools but also exploring how different inputs and external contextual factors influence efficiency outcomes. Adopting this broader analytical approach would support a more comprehensive understanding of the drivers of school performance and help pinpoint areas with the greatest potential for improvement.

Funding: Funded by the European Union – NextGenerationEU. The views and opinions expressed are solely those of the authors and do not necessarily reflect the official views of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

References

[1] Afonso, A., Romero, A. and Monsalve, E. (2013). Public Sector Efficiency: Evidence for Latin America. Working Papers Department of Economics 2013/20, ISEG - Lisbon School of Economics and Management, Department of Economics, Universidade de Lisboa. Handle: RePEc:ise:isegwp:wp202013

[2] Andersen, P. and Petersen, N. C. (1993). A Procedure for Ranking Efficient Units in Data Envelopment Analysis. Management Science, 39(10), 1261–1264. doi: 10.1287/mnsc.39.10.1261

[3] Andrews, R. and Entwistle, T. (2013). Four Faces of Public Service Efficiency. Public Management Review, 15(2), 246-264. doi: 10.1080/14719037.2012.725760

[4] Babarović, T., Burušić, J. and Šakić, M. (2010). Psihosocijalne i obrazovne odrednice školskog uspjeha učenika osnovnih škola: dosezi dosadašnjih istraživanja. Suvremena psihologija, 13(2), 235–255. url: https://hrcak.srce.hr/83098

[5] Banker, R. D., Charnes, A. and Cooper, W. W. (1984). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. Management Science, 30(9), 1078–1092. doi: 10.1287/mnsc.30.9.1078

[6] Basílio, M., Pires, C., Borralho, C. and dos Reis, J. P. (2020). Local government efficiency: is there anything new after Troika's intervention in Portugal? Eurasian Economic Review, 10(2), 309–332. doi: 10.1007/s40822-019-00126-0

[7] Boareto, M. C., Fernandes, S. C., dos Reis, E. F., de Amorim, D. A. and Rosalem, V. (2019). Measurement of efficiency in the education on Goiás municipalities: An analysis from ideb and expenditure in basic education. Enciclopédia Biosfera, Centro Científico Conhecer - Goiânia, 16(29).

[8] Burušić, J., Babarović, T. and Šakić, M. (2009). Odrednice uspiješnosti osnovnih škola u Republici Hrvatskoj: rezutati empirijske provjere. Društvena Istraživanja, 18(4–5), 605–624. url: https://hrcak.srce.hr/42589

[9] Charnes, A., Cooper, W. W. amd Rhodes, E. J. (1978). Measuring the efficiency of decision making units. European Journal of Operational Research, 2(6), 429–444. doi: 10.1016/0377-2217(78)90138-8

[10] Cifuentes-Faura, J., Benito, B., Guillamón, M. D. and Faura-Martínez, Ú. (2023). Relationship between Transparency and Efficiency in Municipal Governments: Several Nonparametric Approaches. Public Performance and Management Review, 46(1), 193–224. doi: 10.1080/15309576.2022.2123007

[11] Conroy, S. J. and Arguea, N. M. (2008). An estimation of technical efficiency for Florida public elementary schools. Economics of Education Review, 27(6), 655–663. doi: 10.1016/j.econedurev.2007.08.002

[12] Cooper, W. W., Seiford, L. M. and Tone, K. (2007). Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software. New York, NY: Springer. doi: 10.1007/978-0-387-45283-8

[13] De Witte, K., Thanassoulis, E., Simpson, G., Battisti, G. and Charlesworth-May, A. (2010). Assessing pupil and school performance by non-parametric and parametric techniques. Journal of the Operational Research Society, 61(8), 1224–1237. doi: 10.1057/jors.2009.50

[14] De Witte, K. and López-Torres, L. (2017). Efficiency in education: A review of literature and a way forward. Journal of the Operational Research Society, 68(4), 339–363. doi: 10.1057/jors.2015.92

[15] Di Giacomo, G. and Pennisi, A. (2015). Assessing Primary and Lower Secondary School Efficiency Within Northern, Central and Southern Italy. Italian Economic Journal, 1(2), 287–311. doi: 10.1007/s40797-014-0002-3

[16] Dobos, I. (2023). Tiered Data Envelopment as a method for clustering suppliers. Croatian Operational Research Review, 14(2), 99-110. doi: 10.17535/crorr.2023.0009

[17] Eurydice Network (2024). Early childhood and school education funding. url: https://eurydice.eacea.ec.europa.eu/national-education-systems/croatia/early-childhood-and-school-education-funding [Accessed 12/05/2024]

[18] Farrell, M. J. (1957). The Measurement of Productive Efficiency. Journal of the Royal Statistical Society, 120, 253–290. doi: 10.2307/2343100

[19] Fatimah, S. and Mahmudah, U. (2017). Two-stage data envelopment analysis (DEA) for measuring the efficiency of elementary schools in Indonesia. International Journal of Environmental and Science Education, 12(8), 1971-1987.

[20] García-Díaz, R., del Castillo, E. and Cabral, R. (2020). Efficiency in Mexican elementary schools: a regional comparative. Investigación Económica, 79(313). doi: 10.22201/fe.01851667p.2020.313.75131

[21] Gholami Golsefid, F., Noveiri, M. J. S. and Kordrostami, S. (2025). Inverse cost and revenue efficiency in network processes with uncontrollable inputs. Croatian Operational Research Review, 16(2), 1-15. doi: 10.17535/crorr.2025.0015

[22] Grosskopf, S., Hayes, K. J., Taylor, L. L. and Weber, W. L. (2001). On the determinants of school district efficiency: Competition and monitoring. Journal of Urban Economics, 49(3), 453–478. doi: 10.1006/juec.2000.2201

[23] Jorge, S. M., Camões, P. J., da Costa Carvalho, J. B. and Fernandes, M. J. (2006). Portuguese local government relative efficiency: A DEA approach. 8th CIGAR Workshop on Performance Measurement and Output Based Budgeting in the Public Sector. Hamburg, Germany

[24] Kumari, R., Gupta, A. and Aggarwal, A. (2024). Stock assessment using cumulative prospect theory in DEA cross-efficiency model: A case study of the Indian stock market. Croatian Operational Research Review, 15(1), 1-11. doi: 10.17535/crorr.2024.0001

[25] Liang, L., Cook, W. D. and Zhu, J. (2008). DEA Models for Two-Stage Processes: Game Approach and Efficiency Decomposition. Naval Research Logistics, 55(7), 643–653. doi: 10.1002/nav.20308

[26] López, N. R., Milán García, J., Uribe Toril, J. and de Pablo-Valenciano, J. (2020). Evolution and latest trends of local government efficiency: Worldwide research (1928–2019). Journal of Cleaner Production, 261, 1-15. doi: 10.1016/j.jclepro.2020.121276

[27] Ministry of Finance – MF (2024). Financial reports of local government units. Expenditures – functional classification for 2019–2022 consolidated, obtained from MF on request.

[28] Ministry of Science, Education, and Youth – MSEY (2024). Number of teachers as of November 1, 2022, obtained on request.

[29] Ministry of Science, Education and Youth – MSEY (2023). Školski e-Rudnik (Vol. 1). Overall success in all primary school grades across cities at the end of the school year 2022/2023. Školski e-Rudnik (Vol. 2). Total number of schools (home and district schools), total number of pupils, total number of classes, average number of pupils per class at the beginning of the school year 2022/2023. url: https://mzom.gov.hr/ser-skolski-e-rudnik-3419/3419 [Accessed 15/6/2024]

[30] Narbón-Perpiñá, I. and De Witte, K. (2018a). Local governments' efficiency: a systematic literature review—part I. International Transactions in Operational Research, 25(2), 431–468. doi: 10.1111/itor.12364

[31] Narbón-Perpiñá, I. and De Witte, K. (2018b). Local governments' efficiency: a systematic literature review—part II. International Transactions in Operational Research, 25(4), 1107–1136. doi:

10.1111/itor.12389

[32] Plaček, M., Křápek, M., Čadil, J. and Hamerníková, B. (2020). The Influence of Excellence on Municipal Performance: Quasi-Experimental Evidence From the Czech Republic. Sage Open, 10(4), 1–16. doi: 10.1177/2158244020978232

[33] Rabar, D. (2013). Evaluation of Croatia's regional hospital efficiency: An application of data envelopment analysis. Interdisciplinary Management Research, 9, 649-659.

[34] Radulović, B. and Dragutinović, S. (2015). Efficiency of local self-governments in Serbia: An SFA approach. Industrija, 43(3), 123–142. doi: 10.5937/industrija43-8846

[35] Rahayu, W. S. and Khoirunurrofik, K. (2022). The Effect of Accountability on the Efficiency of Local Government Expenditures. Jurnal Tata Kelola Dan Akuntabilitas Keuangan Negara, March, 177–198. doi: 10.28986/jtaken.v8i2.647

[36] Sampaio de Sousa, M. D. C. and Stošić, B. D. (2005). Technical efficiency of the Brazilian municipalities: Correcting nonparametric frontier measurements for outliers. Journal of Productivity Analysis, 24(2), 157–181. doi: 10.1007/s11123-005-4702-4

[37] Scippacercola, S. and D'Ambra, L. (2014). Estimating the Relative Efficiency of Secondary Schools by Stochastic Frontier Analysis. Procedia Economics and Finance, 17(14), 79–88. doi: 10.1016/s2212-5671(14)00881-8

[38] Seabright, P. (1996). Accountability and Decentralization in Government: An Incomplete Contracts Model. European Economic Review, 40(1), 61–89. doi: 10.1016/0014-2921(95)00055-0

[39] Simar, L., and Wilson, P. W. (2002). Non-parametric tests of returns to scale. European Journal of Operational Research, 139(1), 115-132. doi: 10.1016/S0377-2217(01)00167-9

[40] Sinha, R. P., Cvetkovska, V. and Peovski, F. (2022). Efficiency of Indian General Insurance Companies: A Convex Nonparametric Least Squares Approach. Croatian Operational Research Review, 13(2), 187–201. doi: 10.17535/crorr.2022.0014

[41] Šonje, A., Deskar-Škrbić, M. and Šonje, V. (2018). Efficiency of Public Expenditure on Education: Comparing Croatia With Other Nms. INTED2018 Proceedings, 1(85152), 2317–2326. doi: 10.21125/inted.2018.0439

[42] Tiebout, C. M. (1956). A Pure Theory of Local Expenditures. Journal of Political Economy, 64(5), 416–424. url: https://www.jstor.org/stable/1826343