

# Analysis of the Cost Efficiency of Public General Hospitals in Croatia

Romario Marijanović

University of Rijeka, Faculty of Economics and Business, Croatia

Institute of Public Finance, Croatia

romario.marijanovic@ijf.hr

<https://orcid.org/0009-0001-8622-5563>

Mihaela Bronić

Institute of Public Finance, Croatia

mihaela.bronic@ijf.hr

<https://orcid.org/0000-0002-0863-2040>

Simona Prijaković

Institute of Public Finance, Croatia

simona.priakovic@ijf.hr

<https://orcid.org/0000-0001-7835-582X>

Received: 10. 4. 2025

Revised: 2. 9. 2025

Accepted: 8. 9. 2025

Published: 11. 11. 2025

## ABSTRACT

**Purpose:** The Croatian population is rapidly ageing, and if current demographic trends continue, by 2050 one in three Croatians will be over the age of 65. This demographic shift implies that a smaller working-age population will need to support a growing number of elderly individuals, placing considerable strain on economic performance. Simultaneously, increasing demand for public health services has driven up public health-care expenditures, with general hospitals bearing the majority of accumulating unpaid obligations. In this context, assessing the cost efficiency of general hospitals becomes crucial in minimising resource wastage.

**Design/Methodology/Approach:** Cost efficiency is assessed by analysing how monetary inputs are converted into intermediate outputs. The cost efficiency of 19 Croatian general hospitals is analysed using the most common method—input-oriented Data Envelopment Analysis (DEA)—during the pre-pandemic years of 2015 and 2016, and the pandemic years of 2021 and 2022. One input is used (total expenditures and outlays of general hospitals, excluding investments in facilities) and three outputs (number of inpatient treatment days, beds/chairs occupancy rate in day hospitals, and number of outpatient services in polyclinic-consultative healthcare).

**Findings:** Cost efficiency scores range from 48% to 100%. On average, hospitals could have reduced expenditures by 7% in 2015, 14% in 2016 and 2021, and by 16% in 2022 while maintaining current output levels. During the COVID-19 pandemic, the overall cost efficiency of general hospitals declined. Pula-Pola and Varaždin consistently emerged as benchmark (most efficient) hospitals across all four years. In contrast, Vukovar underperformed, with cost efficiency scores below 70% throughout. For most hospitals, relative efficiency rankings remained stable over time—high performers before the pandemic continued to perform well afterward; low performers remained low. The data also indicate that larger hospitals, in terms of expenditures, generally demonstrate better cost efficiency.

**Academic contribution to the field:** This study contributes to the literature by measuring cost inefficiencies in general hospitals, which are often overlooked in international health economics research, particularly in Central and Eastern European countries. It identifies persistent benchmarks and inefficiencies, offering a data-driven foundation for policy reforms aimed at enhancing financial sustainability and operational efficiency in Croatia's healthcare system.

**Research limitations:** The model incorporates a limited set of variables due to data constraints. Including additional indicators, such as pharmaceutical expenditures or case-weighted inpatient discharges, could provide a more nuanced cost efficiency assessment. This limitation highlights the need for more comprehensive and standardised healthcare data collection in Croatia, especially from the Ministries of Health and Finance.

**Practical implications:** These findings may assist policymakers, as cost-efficient general hospitals are vital to economic and social prosperity. Benchmark general hospitals can serve as models, sharing best practices in cost management and resource use that could help improve cost efficiency across general hospitals. Less efficient general hospitals should be targeted for audits, managerial training, or support with budgeting and resource allocation. Furthermore, the study provides a foundation for enhancing national hospital performance monitoring systems and data reporting standards.

**Originality/Value:** This is the first study to calculate the cost efficiency of 19 Croatian general hospitals.

*Keywords:* cost efficiency, Croatia, Data Envelopment Analysis, health, public general hospitals

## **Analiza stroškovne učinkovitosti javnih splošnih bolnišnic na Hrvaškem**

### **POVZETEK**

**Namen:** Hrvaško prebivalstvo se hitro stara, in če se bodo sedanji demografski trendi nadaljevali, bo do leta 2050 vsak tretji Hrvat starejši od 65 let. Ta demografski premik pomeni, da bo moralo manjše delovno aktivno prebivalstvo podpirati čedalje več starejših, kar bo močno obremenilo gospodarsko uspešnost. Hkrati naraščajoče povpraševanje po javnih zdravstvenih storitvah povečuje javne izdatke za zdravstvo, pri čemer največji delež nakopičenih neporavnanih obveznosti nosijo splošne bolnišnice. V tem kontekstu postane ocenjevanje stroškovne učinkovitosti splošnih bolnišnic ključno za zmanjševanje razsipavanja virov.

**Zasnova/metodologija/pristop:** stroškovna učinkovitost je ocenjena z analizo, kako se denarni vložki pretvorijo v vmesne rezultate. Stroškovna učinkovitost 19 hrvaških splošnih bolnišnic je analizirana z najpogostejše uporabljeno metodo – vhodno usmerjeno analizo ovojnice podatkov (DEA) – v predpandemičnih letih 2015 in 2016 ter v pandemičnih letih 2021 in 2022. Uporabljen je en vhod (skupni izdatki in odhodki splošnih bolnišnic, brez naložb v objekte) in trije izhodi (število bolnišničnih oskrbnih dni, zasedenost postelj oziroma stolov v dnevni bolnišnicah ter število ambulantnih storitev v poliklinično-konzultativni dejavnosti).

**Ugotovitve:** ocene stroškovne učinkovitosti segajo od 48 % do 100 %. Povprečno bi bolnišnice lahko znižale izdatke za 7 % v letu 2015, za 14 % v letih 2016 in 2021 ter za 16 % v letu 2022, ne da bi zmanjšale obstoječe ravni izhodov. Med pandemijo covid-19 se je skupna stroškovna učinkovitost splošnih bolnišnic poslabšala. Bolnišnici Pula-Pola in Varaždin sta v vseh štirih letih dosledno izstopali kot referenčni (najučinkovitejši) enoti. Nasprotno pa je Vukovar dosegal slabše rezultate, s stroškovno učinkovitostjo pod 70 % v celotnem obdobju. Pri večini bolnišnic so relativne uvrstitve po učinkovitosti ostale stabilne skozi čas – visoko učinkovite pred pandemijo so ostale učinkovite tudi po njej; manj učinkovite so ostale nizko uvrščene. Podatki kažejo tudi, da večje bolnišnice, merjeno po izdatkih, praviloma dosegajo boljše stroškovno učinkovitost.

**Akademski prispevek k področju:** študija prispeva k literaturi z merjenjem stroškovnih neučinkovitosti v splošnih bolnišnicah, ki jih mednarodne raziskave zdravstvene ekonomike pogosto spregledajo, zlasti v državah Srednje in Vzhodne Evrope. Identificira vztrajne referenčne primere in neučinkovitosti ter ponuja podatkovno podlago za politične reforme, usmerjene v izboljšanje finančne vzdržnosti in operativne učinkovitosti hrvaškega zdravstvenega sistema.

**Omejitve raziskave:** model vključuje omejen nabor spremenljivk zaradi podatkovnih omejitev. Vključitev dodatnih kazalnikov, kot so izdatki za zdravila ali po primerih uteženi akutni bolnišnični odpusti, bi lahko omogočila bolj niansirano oceno stroškovne učinkovitosti. Ta omejitev poudarja potrebo po celovitejšem in standardiziranem zbiranju zdravstvenih podatkov na Hrvaškem, zlasti s strani ministrstev za zdravstvo in finance.

**Praktične implikacije:** ugotovitve lahko pomagajo oblikovalcem politik, saj so stroškovno učinkovite splošne bolnišnice ključne za gospodarsko in socialno blaginjo. Referenčne bolnišnice so lahko vzor, delijo dobre prakse upravljanja stroškov in uporabe virov ter s tem pomagajo izboljšati stroškovno učinkovitost v celotnem sklopu splošnih bolnišnic. Manj učinkovite bolnišnice naj bodo cilj revizij, managerskega usposabljanja ali podpore pri proračunskem načrtovanju in načrtovanju virov. Poleg tega je študija podlaga za izboljšanje nacionalnih sistemov spremljanja uspešnosti bolnišnic in standardov poročanja podatkov.

**Izvirnost/vrednost:** gre za prvo študijo, ki je izračunala stroškovno učinkovitost 19 hrvaških splošnih bolnišnic.

*Ključne besede:* stroškovna učinkovitost, Hrvaška, analiza ovojnice podatkov (DEA), zdravje, javne splošne bolnišnice

JEL: H75, I18

## 1 Introduction

The Croatian public health system is struggling with financial stability due to two main factors. On the one hand, there is a growing demand for medical services driven by an aging population and the increasing need for expensive treatments and medications. On the other hand, limited public resources are available to support the healthcare system. As a result, the health system consistently faces budget deficits. Hospitals (especially general hospitals) are major contributors to these deficits. For instance, in 2022, 19 general hospitals accounted for around 45% of the deficit (total revenues and receipts minus total expenditures and outlays) of all healthcare institutions (MoF, 2025). Further, it must be emphasised that in 2021, 2022, and 2023, all general hospitals faced cumulative deficits, incurred during these years and/or in the periods before 2021 (MoF, 2025). A fiscal sustainability study by Šimović et al. (2021) found that hospitals account for the majority of healthcare debt, with 73% of debt older than 60 days, further indicating deep-rooted financial instability.

In 2022, Croatia's public health expenditure was in line with the EU average, with the EU and Croatia spending 7.7% of their GDP on health (Eurostat, 2025a). The major difference is that, on average, the EU spends (3.2% of GDP) on hospital services and (2.3% of GDP) on outpatient services, while Croatia spends more on hospital services (4.3% of GDP) and less on outpatient services (1.2% of GDP).

In terms of health outcomes, Croatia lags behind most EU countries. In 2023, life expectancy at birth in Croatia was 78.6 years, below the EU average of 81.5 years (Eurostat, 2025b). Additionally, Croatia's infant mortality rate was 4.1 deaths per 1,000 live births in 2022, which is higher than the EU average of 3.3 (Eurostat, 2025c).

Improving health outcomes in Croatia while containing costs requires greater efficiency. That is why one of the main goals of the Croatian National Health Development Plan for 2021 to 2027 is to improve the financial sustainability of the healthcare system. It is stipulated that there is a need to analyse the revenue and expenditure side of healthcare thoroughly and to define specific short-term and long-term steps to bring health financing into balance. The existing system of financing is sustainable neither in the short nor in the long term (Ministry of Health, 2021). There is inevitably a need to find new financing sources and improve cost efficiency of healthcare system.

We analysed the cost efficiency of 19 general hospitals in Croatia using an input-oriented DEA model with variable returns to scale. General hospital Sisak was excluded from the analysis due to the unavailability data for 2021 and 2022 because of the consequences of the earthquake. Also, general hospitals Nova Gradiška and Pakrac were excluded from the analysis due to the unavailability of data for 2015 and 2016. In this way, we want to find out which general hospitals could spend less on expenditures and outlays, maintaining the existing level of output. We calculate the cost efficiency, that is, the efficiency of the transformation of monetary input (total expenditures and outlays of

hospitals without investments in building facilities in euro) into intermediate outputs (number of days in hospital treatment for hospital (inpatient) health-care, beds/chairs occupancy rate in the day hospital, and number of services in polyclinic-consultative (outpatient) healthcare). To increase the robustness of the analysis and allow for a better understanding of the impact of the pandemic, the analysis includes two years before the pandemic (2015 and 2016), as well as two years during the pandemic (2021 and 2022). Including pre-pandemic years allows for a comparison of the performance of hospitals under normal and emergency circumstances and a more precise identification of changes and challenges in resource management during the COVID-19 pandemic, when hospitals were operating under special restrictions and reorganisation.

The paper is organised as follows. After the introduction, the literature review first defines cost efficiency; and then identifies the results and gaps in existing research on the efficiency of healthcare expenditures in Croatia and abroad. The third section discusses the data and methodology. The fourth section presents the results while the fifth presents the discussion. The paper ends with conclusions and recommendations for future research.

## **2 Literature Review**

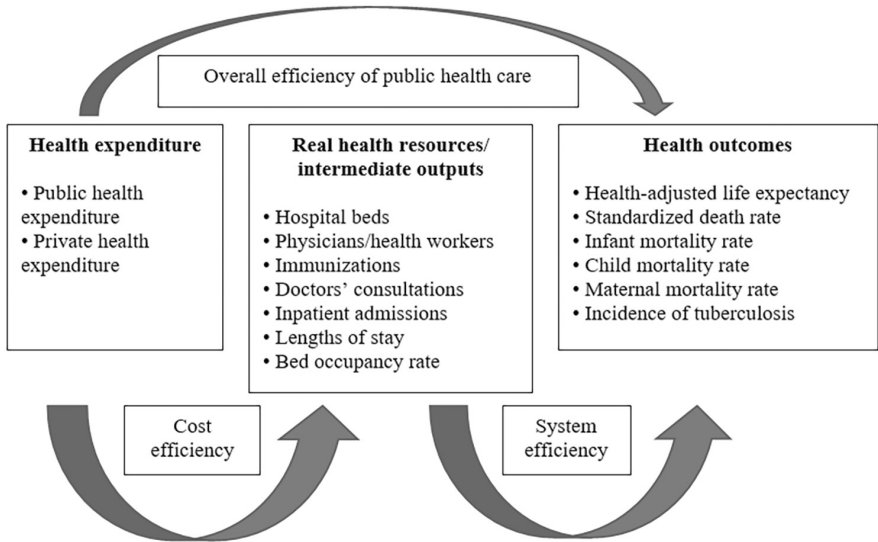
Public health efficiency is a key concept in evaluating health systems, focusing on how effectively governments utilise resources to achieve optimal health outcomes for their citizens. The goal is to ensure that resources are allocated rationally to achieve the best possible health outcomes within available financial constraints (Yi et al., 2020). Health outcomes reflect the core objectives that policymakers aim to achieve (in terms of mortality rates, standardised death rates from all causes per 1,000 people, life expectancy, etc.).

The overall efficiency of public healthcare expenditures measures the ratio of total health expenditures to the health outcomes achieved (Figure 1). Verhoeven et al. (2007) argue that overall efficiency can be divided into cost efficiency and system efficiency. Cost efficiency represents the efficiency of converting monetary inputs (total health expenditures) into intermediate outputs (e.g., the number of physicians, pharmacists, healthcare workers, hospital beds, and immunisation vaccines). System efficiency represents how well the intermediate outputs are used to achieve health outcomes (such as life expectancy).

Asbu et al. (2020), in their literature review on determinants of hospital efficiency, conclude that hospital efficiency is influenced by internal factors – elements that hospitals can directly manage and change – and external factors, which are outside a hospital's immediate control and require broader interventions at the health system or cross-sectoral level. Internal factors include size, specialisation, teaching status, case-mix index, bed occupancy rate, outpatient-to-inpatient ratio, etc. External factors include geographic location (related to demand for hospital services), competition, reimbursement system, provider incentives, etc. Linna et al. (2010) focused on how

well hospitals manage to achieve desired outcomes within a given budget, analysing hospital care in four Nordic countries on a sample of 184 hospitals. The study confirms that hospitals cannot directly influence the level of demand for health services, as they depend on patient referrals, and concludes that deviations in efficiency result from a combination of objective factors (e.g., patient structure) and subjective factors (e.g., management practices). The key takeaway from the literature review is that since hospital efficiency is affected by internal and external factors, there is no universal policy or magic formula that can broadly enhance performance across all hospitals (Asbu et al., 2020). However, we would also argue that the first step involves analysing the efficiency of hospitals to identify which ones are less efficient according to various criteria, followed by further analysis to pinpoint internal factors they could change – such as adjusting outpatient-to-inpatient ratios, staffing issues, or medication procurement practices – to improve the efficiency of less efficient hospitals. In that manner, Sheikhzadeh et al. (2012) studied the efficiency of hospitals in Iran, also using DEA, with a particular focus on input variables such as staffing and number of beds, and output variables such as patient discharges and outpatient visits. They concluded that there are significant inefficiencies in resource use and recommended targeted management interventions.

Figure 1. The efficiency relationship between health expenditure, resources/ outputs, and outcomes



Source: Adapted by authors from Verhoeven et al. (2007).

In this paper, we focus on the cost efficiency of 19 general hospitals, as defined by Verhoeven et al. (2007), which refers to the efficiency of converting monetary inputs into intermediate outputs. We decided not to investigate the overall efficiency of general hospitals since health outcomes data (e.g.,

life expectancy) are available only at the county level, where general hospitals operate. However, these health outcomes (e.g., life expectancy in one county) are influenced not only by the operations of general hospitals but also by other healthcare facilities in that county (such as healthcare centres, private and public hospitals, and health institutes) as well as behavioural and environmental factors beyond the control of the health system (such as diet, alcohol and tobacco consumption, the proportion of the population over 65 years of age).

We have focused exclusively on an analysis of general hospitals; Rabar (2010) focused on the efficiency of all hospitals in Croatia together, but the results of her research make it obvious that different types of hospitals should be divided into separate categories. She emphasised the importance of a categorical approach in calculating efficiency based on similarities between different types of hospitals. Accordingly, clinical, general and special hospitals should be analysed separately. Linna et al. (2010) also analysed the efficiency of hospitals in Finland using DEA, with a focus on cost effectiveness and resource allocation, highlighting the importance of distinguishing hospital types and the impact of patient structure on efficiency results.

Seven papers in Croatia analysed the efficiency of the whole healthcare system or the efficiency of hospitals using DEA methodology. However, cost efficiency, as defined by Verhoeven et al. (2007), was analysed only in two DEA studies regarding the efficiency of the whole Croatian health system (Buljan and Šimović, 2022; Jafarov and Gunnarsson, 2008). The other five studies that we found regarding the efficiency of hospitals in Croatia using DEA methodology did not analyse cost efficiency. In their analysis, they either did not use healthcare expenditures as inputs (Rabar, 2010, 2013; Blecich et al., 2024) or else did not use healthcare expenditures as the only inputs (Dukić Samaržija et al., 2018; Hodžić et al., 2019). Since we did not find any study on the cost efficiency of hospitals, this is the first time that the cost efficiency of 19 general hospitals is calculated in Croatia.

Jafarov and Gunnarsson (2008) evaluated the efficiency of social spending in Croatia and the EU-15, the EU-10, Cyprus, Malta, and OECD countries. They concluded that the inefficiency of the Croatian healthcare system primarily stems from high expenditures, as well as extended hospital stays, elevated drug costs, and minimal levels of private healthcare financing. Buljan and Šimović (2022) analyse the efficiency of the healthcare system in Croatia and compare it with other EU countries in the period 2013-2018. Croatia has the lowest overall efficiency in the EU, with a healthcare expenditure efficiency of only 57% in 2018. Although cost efficiency is high (100%), system efficiency is only 48%, which means that Croatia could achieve the same health outcomes with fewer resources.

Three studies on the efficiency of hospitals in Croatia highlight similar issues regarding resource allocation. Rabar (2010; 2013) and Blecich et al. (2024) find inefficiency due to the excess of beds and doctors in some hospitals. Hodžić et al. (2019) carried out research into the efficiency of healthcare ex-

penditures in Croatian counties for the period from 2010 to 2017, arguing that one of the main causes of inefficiency should be sought in better organisation of primary healthcare. Dukić Samaržija et al. (2018) analysed the efficiency of Croatian hospitals, focusing on 28 specific hospitals included in the DRG (Diagnostic-Related Groups) system for the classification of diabetes without comorbidities and complications. According to this study, the main source of inefficiency is the number of days spent in hospitals, which should be decreased. Another reason for inefficiency is also overspending on drugs and materials, which should also be reduced.

For measuring the efficiency of health services as an input variable, authors often use health expenditures, health expenditures per capita, or health expenditures as % GDP (Buljan and Šimović, 2022). There are several reasons in the literature why healthcare expenditures are used as an input variable. First, they represent costs that hospital management can control, which leads to more efficient financial management. The second reason is that expenditures are used to describe the economic burden. Expenditure analysis helps to assess government spending and shows where costs can be reduced, enabling higher efficiency (Jafarov and Gunnarsson, 2008; Slijepčević, 2019; Azreena et al., 2018; Yi et al., 2020; Wu, 2023; Hodžić et al., 2019).

Andrews and Emvalomatis (2024) note that measuring actual health outcomes is difficult due to limited data and high costs. As a result, researchers frequently rely on proxy indicators instead. Common outcome proxies include the number of inpatient episodes, outpatient visits, and the length of hospital stays. To better reflect both case complexity and severity in assessing healthcare output, studies commonly use inpatient days. This approach aims to capture the intensity of care and resource usage, with longer stays generally indicating more complex or severe cases. An excellent overview of variables and models used for efficiency measurement in healthcare can be found in Andrews and Emvalomatis (2024). They argue that there is a considerable variation in the use of inputs, outputs, and price variables in international studies, suggesting that the use of variables in healthcare productivity and efficiency literature rests on the balance between data availability and the research scope. In addition, Kruse et al. (2018) also conducted a systematic review of hospital efficiency studies at the EU level, identifying the wide range of used methodologies and variables, and highlighting the challenges of comparing efficiency across different healthcare systems. The output healthcare variables used in the previous cost efficiency DEA analysis of the Croatian healthcare system varied. Buljan and Šimović (2022) regarding the efficiency of the whole Croatian health system used the number of available hospital beds, the number of CT and MR scanners, and the number of doctors. Jafarov and Gunnarsson (2008) used the number of available hospital beds, the density of physicians, pharmacists, and healthcare workers, and the number of immunisation vaccines. As output, Dukić Samaržija et al. (2018) used the number of cases/discharges (a performance indicator that measures hospital activity relevant for DRG payments, given that it is an activity-based reimbursement system). Hodžić et al. (2019), used as outputs the number



of examinations, the number of patients per bed, and the vital index. Rabar (2010) used as outputs the number of hospital treatment cases and days of hospital treatment.

### **3 Data and Methodology**

According to the Law on Health Care (2024), Croatia's healthcare system is structured into four levels: primary, secondary, and tertiary care, as well as health institutes. Primary healthcare is primarily provided through healthcare centres, where patients receive basic check-ups, consultations, and treatment for minor health issues. Secondary healthcare is offered through general and specialised hospitals and specialist consultations. General hospitals provide a broad range of services, including surgery, internal medicine, paediatrics, gynaecology and obstetrics, while ensuring patient accommodation and nutrition. Specialised hospitals focus on specific diseases or age groups, offering specialist consultations and hospital treatment, and also providing patient accommodation and nutrition. Specialist-consulting services involve complex medical procedures and diagnostic services, which are performed in polyclinics, day hospitals, and healthcare centres (they do not include accommodation). Tertiary healthcare is delivered by clinics, clinical hospitals, and clinical hospital centres, which handle the most complex medical cases, offer a wide range of services, and often engage in higher education and scientific research. Health institutes include state health institutes (such as the Croatian Institute of Public Health and the Croatian Institute of Emergency Medicine), public health institutes of regional self-government units, and emergency medicine institutes of regional self-government units.

Until January 1, 2024, general hospitals were established by regional self-government units, such as the City of Zagreb or Split-Dalmatia County (with the exception of the general hospital in Vukovar, which was founded by the Republic of Croatia). However, starting January 1, 2024, the Republic of Croatia became the founder of all general hospitals, as outlined in the Law on Amendments to the Law on Health Care (2023).

Many authors use the deterministic non-parametric frontier method – Data Envelopment Analysis (DEA) to assess the cost efficiency of public hospitals (Andrews and Emvalomatis, 2024). By calculating the cost efficiency, it is possible to determine how well a hospital uses its resources to get the best possible health outputs/outcomes. Each hospital is a decision-making unit (DMU), i.e., the object under evaluation is a member of a group that produces comparable results using comparable inputs. DEA determines the efficiency limit of 1, limiting input from below and outputs from above.

Inefficient DMUs should aim for the efficiency limit, and every deviation from the frontier (efficiency score less than 1) is considered inefficient. DEA analysis, in addition to providing an evaluation of the efficiency of the observed units, also identifies examples of best practices that can serve as examples for improving inefficient units (Buljan and Šimović, 2022). Efficiency is meas-

ured by the ratio of output to input, where input represents the resources used in the production process, and output is the results that are achieved using these inputs. The advantages and, at the same time, the reasons for the popularity of the DEA method are that it enables the simultaneous analysis of a number of different inputs and outputs without prior assumptions about the functional form of their connection. Input and output data are used to form the efficiency frontier as a linear combination of the best units in the sample. The best units are those that achieve the highest output with a given input level or use the smallest combination of inputs to achieve a given output level. Then, efficiency indicators are calculated based on the distance of each individual unit from the efficiency frontier. Efficient units located at the efficiency frontier are assigned the highest indicator value of 1, while for other units located below the efficiency frontier, the indicator value is between 0 and 1. The efficiency indicator represents the room for efficiency improvement, i.e. the maximum value by which a unit could increase its outputs with given inputs or reduce its inputs with a constant output value. The efficiency indicators of the input-oriented DEA analysis show how much inputs could be reduced proportionally without compromising the achieved outputs.

The most commonly used models in the DEA analysis are (1) the Charnes, Cooper and Rhodes (1978) model, which assumes that the production function shows a constant return to scale (CCR model), and (2) the Banker, Charnes and Cooper (1984) model which assumes a variable return to scale (BCC model). For choosing the orientation of the model, one should take into account whether the unit has a greater influence on inputs or on outputs. Since healthcare decision makers have more control over inputs than outputs, we have chosen the input-oriented DEA model which is confirmed by international literature (Zubir et al., 2024). Variable return to scale assumes that a proportional increase in input results in a more or less proportional output increase. This BCC model has been chosen because the health sector operates in conditions of imperfect competition and has limited budgets and regulatory constraints (Buljan and Šimović, 2022).

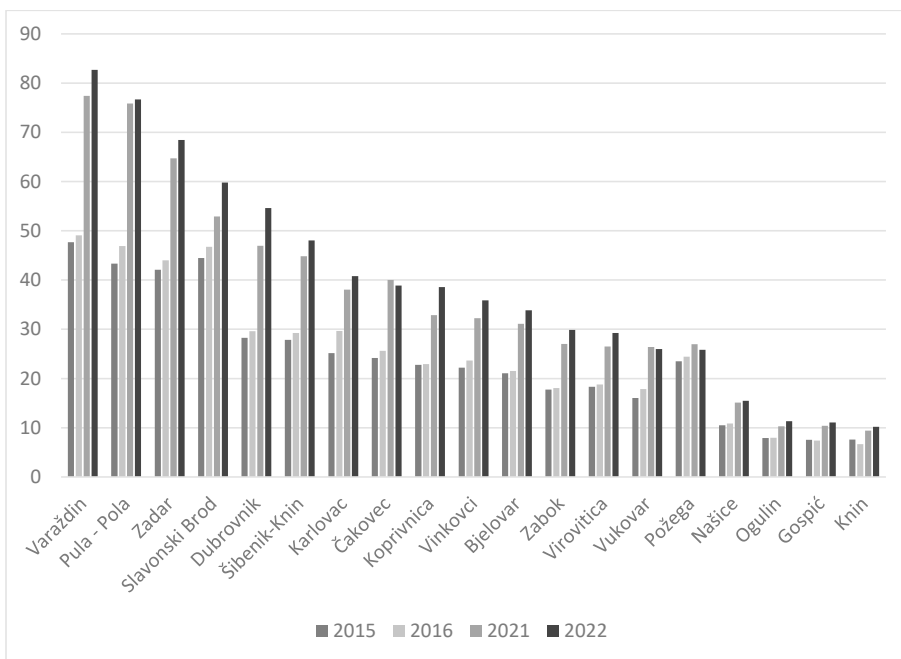
The formulation of the model is:

$$\begin{aligned} \max \theta &= \sum_{j=1}^m u_j y_{j0} + u_0 \\ \sum_{i=1}^s v_i x_{i0} &= 1 \\ \sum_{j=1}^m u_j y_{jk} - \sum_{i=1}^s v_i x_{ik} + u_0 &\leq 0 \\ v_i &\geq 0; u_j &\geq 0. \end{aligned}$$

The given model is used to obtain the value of efficiency  $\theta_j$ , the optimal input  $v_i$  and the optimal output  $u_j$ .

Most important in the DEA analysis is the selection of inputs and outputs, which significantly influence the results. Thus, it is recommended that only fundamental inputs and outputs be used (Blecich et al., 2024). To calculate the cost efficiency of hospitals in Croatia, as outputs, we gathered data for four years – 2015, 2016, 2021 and 2022 – for 19 hospitals from the State Audit Office reports. Specifically, we used data from the Reports on the Completed Audit for 2016 (which includes data for 2015 and 2016), and Reports on the Completed Audit for 2022 (which includes data for 2021 and 2022). As an input variable, we used data for the 2015, 2016, 2021 and 2022 from the Ministry of Finance on total expenditures and outlays without investments in building facilities, calculated in mil. euro (Graph 1). Since, for e.g., the hospital in Bjelovar in 2021 spent around 20 mil. euro for construction objects, we excluded expenditures for investments in building facilities for all analysed hospitals. A similar input variable is used in many other research projects (e.g., Buljan and Šimović, 2022; Hodžić et al., 2019).

**Graph 1. Total expenditures and outlays without investments in building facilities for 19 general hospitals, 2015, 2016, 2021, and 2022 (in mil. €)**



Source: Authors.

Each general hospital performs three types of activities: hospital healthcare (where patients are treated and stay in the hospital for longer periods), day hospital (where patients come to the hospital for a day) and polyclinic-consultative healthcare (where patients come to the hospital to do consultative and diagnostic examinations). As output variables, we decided to use: the number of days in hospital treatments for hospital healthcare (as in e.g., Rabar, 2010;

Dukić Samaržija et al., 2018; Blecich et al., 2024), the average beds/chairs occupancy rate in day hospital (similarly to e.g., Hodžić et al., 2019), and the number of polyclinic-consultative services provided (similarly to e.g., Dukić Samaržija et al., 2018; Hodžić et al., 2019; Rabar, 2010). For outputs, we used data from Financial Audit Reports from the State Audit Office for general hospitals for 2015, 2016, 2021 and 2022, because that was the only source where we could find output variables for all three types of hospital activities. For more information about the variables used, see Table 1.

We did not include the number of beds or doctors in hospitals as an output indicator because Rabar (2010; 2013) and Blecich et al. (2024) find inefficiency due to excess of beds and doctors in some Croatian hospitals. Also, Imani et al. (2022) concluded that hospitals with higher bed numbers have lower efficiency than other hospitals. In addition, we do not think that a hospital is efficient if it has more beds, but for efficiency, it is more important that the existing beds are used. Thus, we use as output indicator the average bed occupancy rate in a hospital (like Azreena et al., 2018; Nwagbara et al., 2016; Vrabková and Lee, 2023; Yi et al., 2020).

Table 1. Definition of variables for each general hospital

Variable	Definition and measurement		Source
Input			
Expenditures	$x_{ij}$	Total expenditures and outlays without investments in building facilities. Based on data from a hospital's financial reports (in million €).	MoF (2025)
Outputs			
Days	$y_{ij}$	The number of days of hospital treatment in hospital healthcare (in 000).	State Audit Office (2018; 2024)
Beds	$y_{2j}$	The beds/chairs occupancy rate in the day hospital (in %).	
Services	$y_{3j}$	The number of services in polyclinic-consultative healthcare (in 000).	

Source: Authors.

4 Results

The correlation matrix for all variables in all years 2015, 2016, 2021 and 2022 are presented in Table 2, and it can be concluded that there is no high correlation between variables. To reduce computations and increase efficiency discrimination among DMUs, according to Sean et al. (2005), if there is a correlation between two variables higher than 0.9, one of the variables can be excluded. We tested the variable number of doctors and it was highly correlated with expenditures, thus for this reason, it is also excluded from the

analysis, even though it has been used in many research projects (e.g., Buljan and Šimović, 2022; Hodžić et al., 2019; Rabar, 2010). All data used are presented in Table A1 in the Appendix.

Table 2. Correlation matrix

	Expenditures	Days	Beds	Services
Expenditures	1			
Days	0.63	1		
Beds	0.48	0.34	1	
Services	0.73	0.58	0.45	1

Source: Authors.

The descriptive statistics is in Table 3 for all four years and reveal significant differences in all values of the variables. Hospital Varaždin has the highest total expenditures and outlays (82.7 mil. euro) and the highest number of days in treatment (275.2 th.). In contrast, hospital Pula-Pola has the highest number of services provided (2,945.8 th.), while hospital Slavonski Brod has the highest beds/chairs occupancy rate for day hospitals (239%). Hospital Knin reports the lowest expenditures and outlays (6.7 mil. euro) and the lowest number of services provided (146.2 th.). Finally, hospital Gospić has the lowest number of days in treatment (16.1 th.), while hospital Vukovar has the lowest beds/chairs occupancy rate in a day hospital (16%).

Table 3. Descriptive statistics for the variables of each general hospital

Variables	Minimum	Median	Mean	Maximum	Standard deviation
<b>Input</b>					
Expenditures	6.7	27.0	31.1	82.7	18.3
<b>Outputs</b>					
Days	16.1	68.3	75.2	275.2	49.1
Beds	15.8	83.6	85.7	238.6	37.6
Services	146.2	1,047.0	1,153.8	2,945.8	620.2

Source: Authors.

Analysis of cost and super efficiency conducted using the input-oriented DEA method with a variable return to scale for the years 2015, 2016, 2021 and 2022, are presented in Tables 4 and 5. In our study, the efficiency frontier includes hospitals that can achieve the best possible health outcomes with the least amount of resources (total expenditures and outlays). After calculating cost efficiency, we also calculate super efficiency to rank all cost efficient

general hospitals (score of 1). General hospitals with super efficiency infinity are the benchmarks.

Cost efficiency was higher in the COVID-19 pre-pandemic period than in the pandemic period (Tables 4 and 5). Like other authors we observe during pandemic cost efficiency decreased (e.g., Hamdollahzadeh et al., 2024). This was probably because hospitals were operating under special restrictions and re-organisation which increased costs in general hospitals. However, the level of cost efficiency did not change significantly during the observed period for most of the general hospitals analysed. General hospitals that were most efficient before the pandemic (Pula-Pola and Varaždin) continued to be the most efficient during the pandemic. Similarly, those general hospitals that were least efficient before the pandemic (like Dubrovnik and Vukovar) also remained the least efficient afterward. Comparing our results with the study by Blatnik et al. (2017), which analysed the technical, cost, and allocative efficiency of 12 Slovenian general hospitals from 2005 to 2014 using the DEA method, we observe a similar pattern. That study also emphasised that efficiency did not change significantly over the years: hospitals that were inefficient initially remained so for the next nine years, while efficient hospitals maintained their status.

According to our findings, cost efficiency among Croatian general hospitals varies considerably, with only 7 or 8 out of 19 general hospitals achieving full efficiency (score of 1) each year, while the remaining general hospitals are inefficient. On average, the efficiency score is 0.93 (or 93%) in 2015, 0.86 (or 86%) in both 2016 and 2021, and 0.84 (or 84%) in 2022, indicating that on average general hospitals could maintain the same output level while reducing their input by 7%, 14% or 16%, respectively. The cost efficiency of general hospitals ranges from 48% to 100%.

Our findings (see Figure 2, and Tables 4 and 5) show that the following hospitals were cost-efficient (cost efficiency = 1) in all analysed years: Knin, Našice, Pula-Pola, and Varaždin. Požega and Zadar were cost-efficient in 2022. Gospić was cost-efficient in 2015, 2016, and 2021; Šibenik-Knin in 2015 and 2021; Ogulin in 2015; Virovitica in 2015 and 2016; Zabok in 2016, 2021, and 2022; and Slavonski Brod in 2021 and 2022.

**Table 4. Cost efficiency and super efficiency results and rankings for the 19 Croatian general hospitals, ranked by highest efficiency score in 2016**

General hospital	2015			2016		
	Cost efficiency	Super efficiency	Rank	Cost efficiency	Super efficiency	Rank
Pula - Pola	1	Benchmark	1.	1	Benchmark	1.
Varaždin	1	Benchmark	1.	1	Benchmark	1.
Knin	1	1.2821	3.	1	1.5080	2.
Gospić	1	2.1439	2.	1	1.2724	3.
Zabok	0.9778	0.9778	9.	1	1.1520	4.
Virovitica	1	1.1146	4.	1	1.0481	5.
Našice	1	1.1092	6.	1	1.0363	6.
Ogulin	1	1.1135	5.	0.9756	0.9756	7.
Čakovec	0.9738	0.9738	10.	0.9045	0.9045	8.
Šibenik-Knin	1	1.0073	7.	0.8927	0.8927	9.
Bjelovar	0.8056	0.8056	15.	0.8778	0.8778	10.
Slavonski Brod	0.9406	0.9406	12.	0.8442	0.8442	11.
Vinkovci	0.9449	0.9449	11.	0.8417	0.8417	12.
Požega	0.9097	0.9097	13.	0.7421	0.7421	13.
Koprivnica	0.7248	0.7248	17.	0.7393	0.7393	14.
Zadar	0.8829	0.8829	14.	0.6389	0.6389	15.
Dubrovnik	0.9821	0.9821	8.	0.6325	0.6325	16.
Vukovar	0.6725	0.6725	18.	0.6282	0.6282	17.
Karlovac	0.7919	0.7919	16.	0.6212	0.6212	18.
Average	0.9267	-	-	0.8599	-	-

Source: Authors.

**Table 5. Cost efficiency and super efficiency results and rankings for the 19 Croatian general hospitals, ranked by highest efficiency score in 2022**

General hospital	2021			2022		
	Cost efficiency	Super efficiency	Rank	Cost efficiency	Super efficiency	Rank
Pula - Pola	1	Benchmark	1.	1	Benchmark	1.
Slavonski Brod	1	Benchmark	1.	1	Benchmark	1.
Varaždin	1	Benchmark	1.	1	Benchmark	1.
Zabok	1	1.8504	3.	1	1.9552	2.
Knin	1	1.7257	4.	1	1.8250	3.
Našice	1	1.1507	5.	1	1.1619	4.
Požega	0.6249	0.6249	14.	1	1.1503	5.
Zadar	0.8476	0.8476	9.	1	1.0005	6.
Čakovec	0.9212	0.9212	7.	0.9607	0.9607	7.
Gospić	1	1.9437	2.	0.9193	0.9193	8.
Ogulin	0.9455	0.9455	6.	0.9001	0.9001	9.
Karlovac	0.8647	0.8647	8.	0.7972	0.7972	10.
Virovitica	0.7828	0.7828	12.	0.7412	0.7412	11.
Vinkovci	0.7897	0.7897	11.	0.7118	0.7118	12.
Koprivnica	0.8029	0.8029	10.	0.7096	0.7096	13.
Bjelovar	0.7553	0.7553	13.	0.6779	0.6779	14.
Šibenik-Knin	1	Benchmark	1.	0.5664	0.5664	15.
Vukovar	0.4958	0.4958	16.	0.5397	0.5397	16.
Dubrovnik	0.5836	0.5836	15.	0.4810	0.4810	17.
Average	0.8639	-	-	0.8424	-	-

Source: Authors.

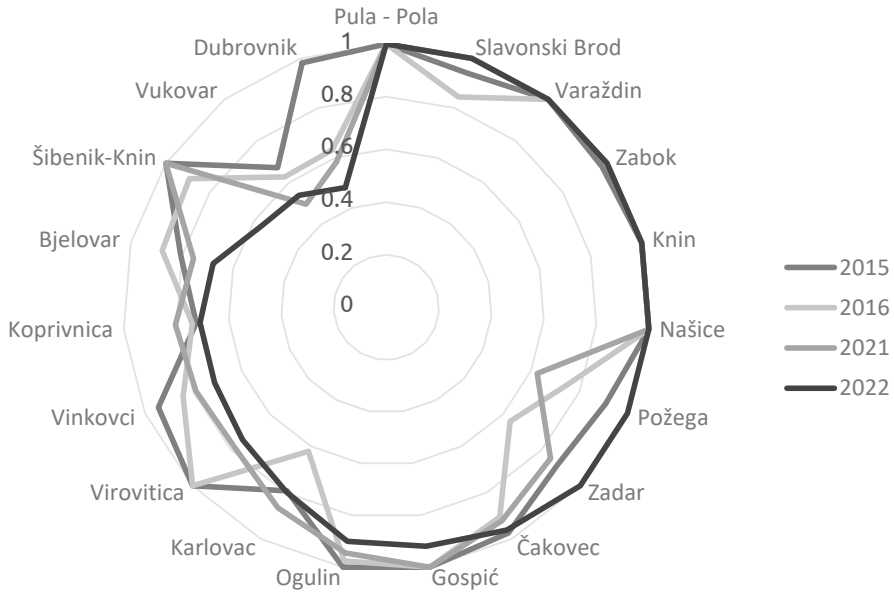
Notably, Gospić, Knin, Našice, and Ogulin consistently lie near the frontier's origin – indicating they operate with relatively low input and output levels (Table A1 in Appendix). Their proximity to the origin signals input minimisation, though it doesn't necessarily reflect optimal output quality or quantity. Rather, from an efficiency standpoint, these general hospitals are making effective use of limited resources.

In contrast, hospital Pula-Pola stands higher on the efficiency frontier, indicating that it is performing well relative to its peers – achieving relatively high outputs with its inputs. Similarly, hospital Varaždin is positioned very high and close to the efficiency frontier, indicating that it is also among the top performers in terms of converting inputs into outputs. However, it should be noted that this positioning reflects relative performance within the sample, not absolute optimisation. DEA evaluates a hospital's performance against other



hospitals rather than against a theoretical maximum (Jorge et al., 2006), i.e., efficiency is determined based on how well a hospital performs compared to its peers using the same set of resources.

**Figure 2. Cost efficiency for 19 general hospitals in 2015, 2016, 2021 and 2022, ranked by highest efficiency score in 2022**



Source: Authors.

Figure 2 also presents cost efficiency for 19 general hospitals. General hospitals mostly achieve the same (in)efficiency scores in all years, except for some. Hospitals Dubrovnik, Zadar, Karlovac, and Požega exhibit the most differences in inefficiency scores between the two years – 2015 and 2016. For example, the decrease in the efficiency of hospital Dubrovnik from 98% in 2015 to 63% in 2016 was due to an increase of 1.4 mil. euro of expenditures and outlays in 2016, and simultaneously a lower number of services and days in treatment while beds/chairs occupancy rate were higher. The decrease in the efficiency of hospital Zadar from 88% in 2015 to 64% in 2016 was due to an increase of 1.9 mil. euro of expenditures and outlays in 2016, and simultaneously a lower number of services and days in treatment, while beds/chairs occupancy rate were higher. Hospitals Šibenik-Knin, Požega, and Zadar exhibit the most differences in inefficiency scores between the two years – 2021 and 2022. For example, a decrease in cost efficiency of hospital Šibenik-Knin from 100% in 2021 to 57% 2022 occurred because expenditures and outlays increased by 3.2 mil. euro while days in treatment and the number of services declined (beds/chairs occupancy rate remained the same).

To rank all cost efficient general hospitals, we calculated super efficiency for observable years (Tables 4 and 5). General hospitals with super efficiency

score of infinity are unique in their characteristics, and there is no similar general hospital that could serve as a reference sample for them. Those hospitals are considered benchmark (best practice) general hospitals, and they all share rank 1. The benchmark hospitals operate at the frontier of efficiency, meaning they use the least amount of input to produce the most output. These benchmarks could serve as standards, showing how less efficient general hospitals can improve by mimicking their practices. Hospitals Pula-Pola and Varaždin were benchmark institutions in 2015 and 2016. In 2021 the benchmark institutions were Pula-Pola, Varaždin, Slavonski Brod, and Šibenik-Knin, while in 2022 only Pula-Pola, Varaždin, and Slavonski Brod were so rated. Hospital Pula-Pola had the highest number of services provided in 2015 and 2016, and Šibenik-Knin in 2021. Hospital Slavonski Brod had the highest beds/chairs occupancy rate in 2022, while hospital Varaždin recorded the highest expenditures and outlays in both 2021 and 2022, as well as the number of days in treatment throughout all observing years.

## 5 Discussion

This study adds to the literature by measuring cost inefficiencies in Croatian general hospitals. It identifies persistent benchmarks and inefficient general hospitals, offering a data-driven foundation for policy reforms aimed at enhancing financial sustainability in Croatia's healthcare system. It is important to notice that benchmark general hospitals (the most efficient ones) in each year are the largest general hospitals (in terms of expenditures) (except Slavonski Brod in 2015, Dubrovnik in 2021, and Zadar in 2021 and 2022) (Table A1 in Appendix). In addition, benchmark general hospitals on average in the analysed four years had much lower total due liabilities in total expenditures (12.4%) than low efficiency general hospitals (36.8%) (Table A1). This might be due to economies of scope and/or scale. Economies of scope refer to cost advantages gained by producing a variety of products using shared resources, while economies of scale refer to cost advantages gained by increasing production of a single product. Lindaas et al. (2025) show that general hospitals producing a diversified mix of services typically achieve greater cost efficiency through joint production of services (economies of scope). Furthermore, literature on hospital economies of scale confirms that larger hospitals – particularly those with 200-300 beds – often operate at an optimal scale, benefiting from cost efficiencies unavailable to smaller hospitals (Giancotti et al., 2017).

Interestingly on the other hand, some general hospitals reported the lowest expenditures (below 16 mil. euros), yet were still classified as efficient (cost efficiency = 1), but not as benchmark hospitals. Našice and Knin in all four years, Gospić in 2015, 2016 and 2021, and Ogulin in 2015. This may indicate effective resource management and operational efficiency in these facilities, despite limited financial resources. Smaller general hospitals could be more efficient due to simpler organisational structures and lower costs. Their limited scope of services enables more targeted resource allocation, resulting in reduced expenditures while still ensuring adequate service delivery.

However, smaller general hospitals often lack access to the latest technology, leading specialists, or the ability to perform complex interventions, so their efficiency should be assessed in relation to the scope and complexity of the services they provide. In Slovenia, DEA results showed that medium and relatively small general hospitals, such as Brežice and Trbovlje, consistently scored at or near full technical and cost efficiency, in contrast to large university hospitals which underperformed (Blatnik et al., 2017). In Slovakia, a regional DEA window analysis also suggested that regions with fewer beds and less advanced technological infrastructure often achieved higher health-care technical efficiency scores, implying that smaller-scale operations with simpler input structures can sometimes outperform more complex systems (Vaňková and Vrabková, 2022; Stefko et al., 2018).

The least efficient general hospital in all years of our analysis was Vukovar (cost efficiency score below 70%). Similarly, Dubrovnik had a cost efficiency score below 70% in all years except in 2015. According to Pecoraro et al. (2021), such differences can be a consequence of poor management, such as planning and local organisation of health. Thus, these two general hospitals should be prioritised as the best candidates for further cost efficiency analysis.

Looking at the broader picture, one of the most striking observations from this cost efficiency analysis is the recurrent deficit faced by all general hospitals in Croatia. This raises important questions about their financial sustainability. Similar problems exist in other Central and Eastern European (CEE) countries like Poland where in 2018 a majority of county hospitals (55.3%) reported a gross financial loss, and nearly half (48.5%) faced overdue liabilities (Dubas-Jakóbczyk et al., 2020).

How is it possible that almost all Croatian general hospitals continue to operate in deficit year after year; i.e. why general hospitals cannot cover their expenditures with their revenues and why do they create overdue liabilities? How to reduce deficits without compromising the achieved outputs? It is already mentioned that hospital efficiency is affected by internal and external factors and that there is no universal policy or magic formula that can broadly enhance performance across all hospitals (Asbu et al., 2020). However, the first step involves analysing the efficiency of hospitals to identify which ones are less efficient according to various criteria, followed by further analysis to pinpoint internal factors they could change – such as adjusting outpatient-to-inpatient ratios, staffing issues, or medication procurement practices – to improve the efficiency of less efficient hospitals.

Literature review points out that Croatian general hospitals face deficits because of problems relating to their revenues and expenditures. On the revenue side, the DRGs, which determine the pricing for services provided by general hospitals, appear to be set too low (Horvat, 2024). If the current DRG prices do not adequately cover the costs of services, they need to be reevaluated and increased. Insufficient reimbursement for the services rendered by general hospitals contributes to their financial struggles and inefficiencies. This is an external factor that influences hospital efficiency, which lies outside

a general hospital's immediate control and requires broader interventions at the health system or cross-sectoral level (responsibility of the Ministry of Health and Government). Research by Kalanj et al. (2021) confirmed that the introduction of DRG-based hospital financing in Croatia during 2009-2018 did not significantly improve hospital cost efficiency. Despite reductions in the average length of stay, number of beds, and hospitalisations, the average cost per DRG-weighted case increased by 17%. Research shows that many other CEE countries face significant financial challenges due to the debts accumulated by public hospitals, and one of the key contributing factors is the inadequate pricing of public hospital services, which is often set below the actual cost of providing care (Jovanović, 2020; Dubas-Jakóbczyk and Kozieł, 2020).

On the expenditure side, as already mentioned, less efficient general hospitals (such as Dubrovnik and Vukovar) should be prioritised for further analysis to identify specific causes of inefficiency. Some of these causes of inefficiency are elements that general hospitals can manage and change directly. For example, as the major share of general hospital expenditures and outlays is directed towards employee costs and materials, further research should be conducted to explore the impact of these expenditures and outlays on general hospital cost efficiency. In both 2021 and 2022, 19 general hospitals in Croatia allocated an average of around 60% of their total expenditures and outlays to employee costs and 20% to materials costs (e.g., medicines, food for patients, medical consumables) (MoF, 2025). For example, in 2021 and 2022 the general hospital in Dubrovnik spent more on material costs than the average for all general hospitals, and the general hospital Vukovar spent more on employee costs than the average for all general hospitals. Understanding the specific allocation of these costs can guide targeted interventions to reduce inefficiencies in the most impactful areas. Also, there may be an excess of doctors in certain hospitals, which contributes to higher personnel costs without necessarily improving service delivery, as argued by Rabar (2010; 2013) and Blečić et al. (2024). Additionally, some Croatian doctors may be splitting their working time between public and private healthcare sectors, reducing their effective working hours in public general hospitals. If this is the case, the system may need to consider policies similar to those in Slovenia, where doctors are prohibited from working in private hospitals while employed in the public sector. Alternatively, a system could be implemented to ensure that doctors are only compensated for the hours they spend working in public hospitals, thus preventing the misuse of public funds. The high expenditure on materials raises questions about potential inefficiencies in medication use. The same is argued by Jafarov and Gunnarsson (2008) and Đukić Samaržija et al. (2018). Are (expensive) medications being used unnecessarily? Bubaš (2022) analysed the Croatian hospital system from 2015 to 2022 and, on the example of clinical hospital centres, showed that almost all outstanding liabilities were attributed to material expenses, specifically, unpaid medicines and medical supplies. The State Audit Office (2024) argues that numerous general hospitals have problems with transparent tracking of medication consumption and public procurement practices. Inefficiencies in these areas could be a major contributor to the financial deficits experienced by general hospitals.

Similarly, Dubas-Jakóbczyk et al. (2020), argue that in Poland, the financial instability and indebtedness of public hospitals result from a complex interplay of external and internal factors. At the external level, contributing issues include insufficient funding mechanisms, inadequate tariff structures, weak governance of the hospital sector, oversized and inefficient infrastructure, centrally regulated salary increases for medical staff, and a lack of comprehensive health needs assessments. At the internal level, factors such as poor financial and managerial practices – particularly in cost containment, weak oversight by hospital owners, and aging infrastructure requiring capital investment – further exacerbate financial difficulties. The same authors point to significant variation in financial performance across hospitals, with both highly indebted and financially stable institutions coexisting, underscoring the importance of these individual, hospital-specific factors. A recent scoping review of hospital financial performance in Europe, Dubas-Jakóbczyk et al. (2025), also found that public hospitals in many CEE countries (including Croatia) consistently run deficits and accumulate debts, particularly for pharmaceutical and medical products and personnel costs. These deficits are often attributed to weak management accountability and lack of staff cost control. Taken together, these findings show that public hospitals across the region – not only in Croatia – frequently operate under chronic financial strain, accumulating arrears despite ongoing reform efforts.

Our study complements existing research from CEE, where public hospital inefficiencies, debts and overdue liabilities are a widespread concern, especially due to misalignment between service costs and reimbursement, and poor cost control in areas such as pharmaceuticals and staffing (e.g., Dubas-Jakóbczyk et al., 2025). However, unlike most previous studies, our analysis offers a detailed hospital-level comparison based on cost efficiency scores. This allows us to propose concrete, evidence-based strategies for cost optimisation and better alignment between resources and services for each general hospital. In doing so, our research contributes a novel, data-driven approach to understanding and improving hospital cost efficiency in Croatia and potentially in similar CEE health systems.

## **6 Conclusion**

This study addresses a critical challenge facing Croatia's healthcare system, mounting financial obligations in general hospitals. The central question was whether cost efficiency of general hospitals – measured through input-oriented DEA – can reveal opportunities for reducing expenditures without compromising healthcare outputs.

This is the first time that the cost efficiency of 19 Croatian general hospitals has been calculated. Using the input-oriented BCC DEA model, we evaluated 19 general hospitals across two pre-pandemic years (2015-2016) and two pandemic years (2021-2022). Cost efficiency scores ranged from 48% to 100%. On average, the efficiency score is 0.93 (or 93%) in 2015, 0.86 (or 86%) in both 2016 and 2021, and 0.84 (or 84%) in 2022, indicating that on average general

hospitals could maintain the same output level while reducing their input by 7%, 14% or 16%, respectively. Though overall efficiency declined during COVID-19 – likely due to operational disruptions – individual hospital performance remained largely consistent. Pula-Pola and Varaždin emerged as persistent benchmarks, while Vukovar consistently scored below 70%. Moreover, larger hospitals – measured by total expenditures – consistently demonstrate higher cost efficiency when compared to their peers. Also, in the analysed four years benchmark general hospitals (with higher cost efficiency) on average had much lower total due liabilities in total expenditures (12.4%) than low efficiency general hospitals (36.8%).

Our study demonstrates that cost-efficiency assessment can pinpoint both high-performers and underperformers, offering a roadmap for targeted managerial and policy reforms. While no universal efficiency solution exists, because general hospital efficiency is influenced by internal and external factors, Croatia's general hospitals can benefit from data-driven identification of inefficient hospitals and strategic efforts to emulate top performers. By adopting practices from benchmark general hospitals, less efficient general hospitals could achieve substantial cost savings without reducing service levels. This aligns with national and international findings that emphasise the need for continuous performance monitoring and the dissemination of best practices for resource use and general hospital management.

Our research underscores the existence of cost inefficiencies within Croatia's general hospitals and highlights the potential for substantial cost savings. If a hospital has low cost efficiency, it may indicate operational issues. Thus, further analysis, especially in less efficient hospitals, can guide decisions like reallocating staff or reducing bed numbers. In the future, it would be very interesting to further analyse the least cost effective general hospital (Vukovar) and explore the impact of employees and materials costs on general hospital cost efficiency. It would also be interesting to find out why the largest general hospitals are usually the most cost efficient ones (benchmarks).

Our findings have direct implications for public administration and hospital governance. Based on the results, decision-makers in the health sector, such as the Ministry of Health, hospital founders, and financing bodies, could introduce regular performance monitoring, adjust hospital payment models (e.g., DRG pricing), analyse and improve staffing efficiency, and strengthen cost control in key spending categories like pharmaceuticals and materials. Additionally, more systematic use of financial and audit reports could support evidence-based management decisions. Recent research highlights that politicians and public managers in Croatia, including those in healthcare, often consult public sector financial reports; however, these are still underutilised as primary tools for decision-making (Barbieri et al., 2025). Greater reliance on such reports could support more effective management and cost efficiency in public hospitals. By applying these measures, public administration can support the long-term financial sustainability and operational efficiency of Croatian general hospitals.

The major limitation of this paper's analysis is that we used the inputs and outputs that were accessible to us, but other inputs and outputs might better reflect the efficiency of public general hospitals (e.g., pharmaceutical costs – how much medication has been spent in each general hospital or case-weighted inpatient discharges). Thus, this is only the first step in the cost efficiency analysis of Croatia's general hospitals. Unfortunately, from the currently available data, it was not possible to find out the structure of general hospitals' materials costs (how much was separately spent on medicines, food for patients, and medical consumables). Thus, there is a need for the Ministries of Health and Finance to produce more detailed data regarding the functioning of public general hospitals. Improving the availability and granularity of hospital-level data – especially on pharmaceutical and material costs – would not only enhance national performance monitoring, but also facilitate international benchmarking and research collaboration. This would enable comparative studies using harmonised indicators and DEA methodologies that could situate the Croatian general hospital's performance within an international framework.

---

*Funded by the European Union–NextGenerationEU. Views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.*

***The use of AI (Artificial Intelligence) model:*** *The authors acknowledge the use of OpenAI. (2025). ChatGPT-4 free version <https://chatgpt.com> to enhance the translation, readability, and overall language quality of the paper.*

## References

- Andrews, A. and Emvalomatis, G. (2024). Efficiency Measurement in Healthcare: The Foundations, Variables, and Models – A Narrative Literature Review. *Economics*, 18(1), pp. 1–24. <https://doi.org/10.1515/econ-2022-0062>
- Asbu, E. Z, Masri, M. D. and Naboulsi, M. A. (2020). Determinants of hospital efficiency: A literature review. *International Journal of Healthcare*, 6(2), pp. 44–53. <https://doi.org/10.5430/ijh.v6n2p44>
- Azreena, E., Muhamad, H. J. and Rosliza, A. M. (2018). A Systematic Review of Hospital Inputs and Outputs in Measuring Technical Efficiency Using Data Envelopment Analysis. *International Journal of Public Health and Clinical Sciences*, 5(1), pp. 17–35. At <<https://publichealthmy.org/ejournal/ojs2/index.php/ijphcs/article/download/563/431>>, accessed 1 February 2025.
- 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), pp. 1078–1092. <https://doi.org/10.1287/mnsc.30.9.1078>
- Barbieri, I., Kostić, M. D. and Botica Redmayne, N. (2025). The Use of Different Public-Sector Financial Reports: A Comparative Analysis of Information-User Groups. *Central European Public Administration Review*, 23(1), pp. 181–201. <https://doi.org/10.17573/cepar.2025.1.07>
- Blatnik, P., Bojnec, Š. and Tušak, M. (2017). Measuring efficiency of secondary healthcare providers in Slovenia. *Open Medicine*, 12(1), pp. 214–225. <https://doi.org/10.1515/med-2017-0031>
- Blecich, A. A., Dukić Samaržija, N. and Samadžija, L. (2024). Investigating the efficiency of Croatian hospitals at county level: data envelopment approach. *Proceedings of 19th international symposium Unlocking the hidden potentials of organisation through merging of humans and digitals, Zlatibor*.
- Bubaš, Z. (2022). The Croatian Hospital System: Insight into a Case of Financial Unsustainability. *Interdisciplinary Description of Complex Systems*, 20(5), pp. 606–620. <https://doi.org/10.7906/indexs.20.5.7>
- Buljan, A. and Šimović, H. (2022). Efficiency of the Croatian Healthcare System – a Comparison With Eu Countries. *Revija Za Socijalnu Politiku*, 29(3), pp. 321–355. <https://doi.org/10.3935/rsp.v29i3.1933>
- Charnes, A., Cooper, W. W. and Rhodes, E. J. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6), pp. 429–444. [https://doi.org/10.1016/0377-2217\(78\)90138-8](https://doi.org/10.1016/0377-2217(78)90138-8)
- Dubas-Jakóbczyk, K., Kocot, E. and Kozieł, A. (2020). Financial Performance of Public Hospitals: A Cross-Sectional Study among Polish Providers. *International Journal of Environmental Research and Public Health*, 17(7), 2188, pp. 1–14. <https://doi.org/10.3390/ijerph17072188>
- Dubas-Jakóbczyk, K. and Kozieł, A. (2020). Towards Financial Sustainability of the Hospital Sector in Poland-A Post Hoc Evaluation of Policy Approaches. *Sustainability*, 12(12), 4801, pp. 1–19. <https://doi.org/10.3390/su12124801>
- Dubas-Jakóbczyk, K. et al. (2025). Financial performance of hospitals in Europe – a scoping review. *BMC Health Services Research*, 25(933), pp. 1–15. <https://doi.org/10.1186/s12913-025-13080-2>
- Dukić Samaržija, N., Blecich, A. A. and Najdek, T. (2018). Investigation of the reimbursement scheme in Croatian public hospitals: a data envelopment analysis approach. *Proceedings of the 28th International Scientific Conference on Economic and Social Development*, pp. 358–366. <https://doi.org/10.4324/9780203004937>



- Eurostat (2025a). Government expenditures on health. At <[https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Government\\_expenditure\\_on\\_health](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Government_expenditure_on_health)>, accessed 20 February 2025.
- Eurostat (2025b): Life expectancy by age and sex. At <[https://ec.europa.eu/eurostat/databrowser/view/demo\\_mlexpec/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/demo_mlexpec/default/table?lang=en)>, accessed 20 February 2025.
- Eurostat (2025c): Infant mortality rates. At <[https://ec.europa.eu/eurostat/databrowser/view/demo\\_minfind/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/demo_minfind/default/table?lang=en)>, accessed 20 February 2025.
- Giancotti, M., Guglielmo, A. and Mauro, M. (2017). Efficiency and optimal size of hospitals: Results of a systematic search. *PLoS ONE*, 12(3), 1–40. <https://doi.org/10.1371/journal.pone.0174533>
- Hamdollahzadeh, A., Nabilou, B. and Yusefzadeh, H. (2024). Efficiency of hospitals in COVID-19 era: a case study of an affected country. *Cost Effectiveness and Resource Allocation*, 22(50), pp. 1–7. <https://doi.org/10.1186/s12962-024-00549-w>
- Hodžić, S., Vuković, D. and Muharemović, A. (2019). The Efficiency of Healthcare System Expenditures: Evidence From Croatia. *Ekonomski Vjesnik*, 32(2), pp. 361–371.
- Horvat, J. (2024). Analiza efikasnosti financijskog poslovanja bolničkih zdravstvenih ustanova u Republici Hrvatskoj (Završni specijalistički). Rijeka: Sveučilište u Rijeci, Ekonomski fakultet. At <<https://repository.efri.uniri.hr/islandora/object/efri:5339>>, accessed 10 February 2025.
- Imani, A. et al. (2022). Key Indicators Affecting Hospital Efficiency: A Systematic Review. *Frontiers in Public Health*, 10(March), pp. 1–5. <https://doi.org/10.3389/fpubh.2022.830102>
- Jafarov, E. and Gunnarsson, V. (2008). Efficiency of Government Social Spending in Croatia. *Financial Theory and Practice*, 32(3), pp. 289–320.
- Jorge, S. M. et al. (2006): Portuguese local government relative efficiency: a dea approach. 8th CIGAR Workshop on Performance Measurement and Output Based Budgeting in the Public Sector.
- Jovanović, T. (2020). Challenges of the Slovenian Healthcare System Exposed in Hospitals' Recovery Plans. *Studies in Health Technology and Informatics*, 26(272), pp. 354–357. <https://doi.org/10.3233/SHTI200568>
- Kalanj, K. et al. (2021). The effects of diagnosis-related groups payment on efficiency of the hospital health care in Croatia. *Croatian Medical Journal*, 6 (6), pp. 561–568. <https://doi.org/10.3325/cmj.2021.62.561>
- Kruse, F. M. et al. (2018). Do private hospitals outperform public hospitals regarding efficiency, accessibility, and quality of care in the European Union? A literature review. *International Journal of Health Planning Management*, 33(2), April, pp. 434–453. <https://doi.org/10.1002/hpm.2502>
- Law on Amendments to the Law on Health Care (2023). Zakon o izmjenama i dopunama zakona o zdravstvenoj zaštiti, Official Gazette NN 33/23. At <[https://narodne-novine.nn.hr/clanci/sluzbeni/full/2023\\_03\\_33\\_582.html](https://narodne-novine.nn.hr/clanci/sluzbeni/full/2023_03_33_582.html)>, accessed 28 February 2025.
- Law on Health Care (2024). Zakon o zdravstvenoj zaštiti, Official Gazette NN 100/18, 125/19, 147/20, 119/22, 156/22, 33/23, 36/24. At <<https://www.zakon.hr/z/190/Zakon-o-zdravstvenoj-za%C5%A1titi>>, accessed 1 February 2025.

- Lindaas, N. A et al. (2025). Economies of scope in the Norwegian public hospital sector. *The European Journal of Health Economics*, 26, pp. 325–335. <https://doi.org/10.1007/s10198-024-01704-z>
- Linna, M. et al. (2010). Measuring cost efficiency in the Nordic Hospitals-a cross-sectional comparison of public hospitals in 2002. *Health Care Management Science*, 13, pp. 346–357. <https://doi.org/10.1007/s10729-010-9134-7>
- Ministry of Finance – MoF (2025). Registar proračunskih i izvanproračunskih korisnika – RKPRFI portal (PR-RAS from 2015-2023). At <<https://rkpfi.drzavna-riznica.hr/PORTAL/Rkp>>, accessed 1 June 2025.
- Ministry of Health (2021). Nacionalni plan razvoja zdravstva za razdoblje od 2021. do 2027. godine. At <<https://zdravlje.gov.hr/UserDocsImages/2022%20Objave/Nacionalni%20plan%20razvoja%20zdravstva%202021.-2027..pdf>>, accessed 10 March 2025.
- Nwagbara, V. C., Rasiah, R. and Aslam, M. (2016). An approach toward public hospital performance assessment. *Medicine (United States)*, 95(5), pp. 1–6. <https://doi.org/10.1097/MD.0000000000004688>
- Pecoraro, F., Luzi, D. and Clemente, F. (2021). The efficiency in the ordinary hospital bed management: A comparative analysis in four European countries before the COVID-19 outbreak. *PLoS ONE*, 16(3), pp. 1–18. <https://doi.org/10.1371/journal.pone.0248867>
- Rabar, D. (2010). Ocjenjivanje efikasnosti poslovanja hrvatskih bolnica metodom analize omeđivanja podataka. *Ekonomski Pregled*, 61 (9-10), pp. 511–533.
- Rabar, D. (2013). Assessment of Regional Efficiency in Croatia Using Data Envelopment Analysis. *Croatian Operational Research Review*, 4(1), pp. 76–88.
- Sean, F. R., Memariani, A. and Lotfi, F. H. (2005). The effect of correlation coefficient among multiple input vectors on the efficiency mean in data envelopment analysis. *Applied Mathematics and Computation*, 162(2), pp. 503–521. <https://doi.org/10.1016/j.amc.2003.12.117>
- Sheikhzadeh, Y. et al. (2012). Public and Private Hospital Services Reform Using Data Envelopment Analysis to Measure Technical, Scale, Allocative, and Cost Efficiencies. *Health Promotion Perspectives*, 2(1), pp. 28–41. <https://doi.org/10.5681/hpp.2012.004>
- Slijepčević, S. (2019). Measuring Efficiency at the Regional Level: A Data Envelopment Analysis Approach. *Lex localis - Journal of Local Self-Government*, 17(3), pp. 679–696. [https://doi.org/10.4335/17.3.679-696\(2019\)](https://doi.org/10.4335/17.3.679-696(2019))
- State Audit Office (2018). Izvješće o obavljenoj financijskoj reviziji općih bolnica za 2016.godinu. At <<https://www.revizija.hr/izvjesca/10?godinalD=92&tema=852>>, accessed 5 June 2025.
- State Audit Office (2024). Izvješće o obavljenoj financijskoj reviziji općih bolnica za 2022. godinu. At <<https://www.revizija.hr/izvjesca/10>>, accessed 13 January 2025.
- Stefko, R., Gavurova, B. and Kocisova, K. (2018). Healthcare efficiency assessment using DEA analysis in the Slovak Republic. *Health Economics Review*, 8(6), pp. 1–12. <https://doi.org/10.1186/s13561-018-0191-9>
- Šimović, H., Mihelja Žaja, M. and Primorac, M. (2021). Fiscal (un)sustainability of the Croatian healthcare system: additional impact of the COVID-19 crisis. *Public Sector Economics*, 45(4), pp. 495–515. <https://doi.org/10.3326/ps.e.45.4.5>

- Vaňková, I. and Vrabková, I. (2022). Productivity analysis of regional-level hospital care in the Czech republic and Slovak Republic. *BMC Health Services Research*, 22(180), pp. 1–14. <https://doi.org/10.1186/s12913-022-07471-y>
- Verhoeven, M., Gunnarsson, V. and Lugaresi, S. (2007). The Health Sector in the Slovak Republic: Efficiency and Reform. *IMF Working Papers*, 07(226), pp. 1–25. <https://doi.org/10.5089/9781451867909.001>
- Vrabková, I. and Lee, S. (2023). Approximating the influence of external factors on the technical efficiency score of hospital care: evidence from the federal states of Germany. *Health Economics Review*, 13(1), pp. 1–14. <https://doi.org/10.1186/s13561-022-00414-7>
- Wu, J. S. (2023). Applying frontier approach to measure the financial efficiency of hospitals. *Digital Health*, 12(9), pp. 1–13. <https://doi.org/10.1177/20552076231162987>
- Yi, M., Peng, J., Zhang, L. and Zhang, Y. (2020). Is the allocation of medical and health resources effective? Characteristic facts from regional heterogeneity in China. *International Journal for Equity in Health*, 19(1), pp. 1–21. <https://doi.org/10.1186/s12939-020-01201-8>
- Zubir, M. Z. et al. (2024). Approach in inputs and outputs selection of Data Envelopment Analysis (DEA) efficiency measurement in hospitals: A systematic review. *PLoS ONE*, 19(8), pp. 1–29. <https://doi.org/10.1371/journal.pone.0293694>

## Appendix

Table A1. Data on used variables on 19 general hospitals in Croatia during years 2015, 2016, 2021 and 2022

General hospital	Year	Expenditures (in mil. €)	Due liabilities in total expenditures (in %)	Days (in 000)	Beds (in %)	Services (in 000)	Cost efficiency
<i>Benchmark – best practice</i>							
Varaždin	2016	49.1	20.7	275	105	1.382	1
Varaždin	2021	77.4	17.8	174	97	1.524	1
Varaždin	2022	82.7	17.7	184	129	1.737	1
Pula - Pola	2016	46.9	16.2	118	180	2.946	1
Varaždin	2015	47.7	15.2	273	126	1.692	1
Pula - Pola	2015	43.3	13.4	128	112	2.812	1
Pula - Pola	2021	75.9	10.2	74	130	2.149	1
Šibenik-Knin	2021	44.8	9.4	61	100	2.162	1
Pula - Pola	2022	76.7	5.7	92	121	2.283	1
Slavonski Brod	2021	52.9	5.4	92	168	1.160	1
Slavonski Brod	2022	59.8	5.1	92	239	1.313	1
<i>Efficient</i>							
Gospić	2015	7.5	15.9	20	91	311	1
Zabok	2022	29.9	9.4	64	148	1.702	1
Gospić	2021	10.4	9.7	19	120	327	1
Zabok	2021	27.0	11.0	62	144	1.513	1
Knin	2022	10.2	61.7	35	100	304	1
Knin	2021	9.4	61.1	34	82	237	1
Knin	2016	6.7	23.2	38	36	146	1
Knin	2015	7.6	18.2	36	55	309	1
Gospić	2016	7.4	17.6	20	67	416	1
Našice	2022	15.5	2.3	26	57	859	1
Zabok	2016	18.1	8.7	70	91	1.397	1
Našice	2021	15.1	5.7	27	59	825	1
Požega	2022	25.8	3.4	46	153	866	1
Virovitica	2015	18.3	15.6	62	100	1.028	1
Ogulin	2015	7.9	19.9	26	25	478	1
Našice	2015	10.5	14.9	36	47	698	1
Virovitica	2016	18.8	20.9	61	85	1.484	1
Našice	2016	10.9	19.5	34	45	777	1
Šibenik-Knin	2015	27.8	8.3	78	100	1.755	1
Zadar	2022	68.5	4.4	100	75	2.095	1

Analysis of the Cost Efficiency of Public General Hospitals in Croatia

General hospital	Year	Expenditures (in mil. €)	Due liabilities in total expenditures (in %)	Days (in 000)	Beds (in %)	Services (in 000)	Cost efficiency
<i>Near-efficient</i>							
Dubrovnik	2015	28.3	35.0	85	40	1.802	0.9821
Zabok	2015	17.7	7.9	63	74	1.013	0.9778
Ogulin	2016	8.0	15.4	26	63	274	0.9756
Čakovec	2015	24.2	7.9	95	100	1.210	0.9738
Čakovec	2022	38.9	6.0	88	100	1.099	0.9607
<i>Emerging</i>							
Ogulin	2021	10.3	3.0	18	38	274	0.9455
Vinkovci	2015	22.2	30.7	92	88	1.031	0.9449
Slavonski Brod	2015	44.5	15.2	158	100	2.359	0.9406
Čakovec	2021	40.0	6.7	89	100	851	0.9212
Gospić	2022	11.1	9.0	16	80	306	0.9193
Požega	2015	23.5	10.2	92	97	1.024	0.9097
Čakovec	2016	25.6	13.8	92	100	1.035	0.9045
Ogulin	2022	11.3	3.5	17	44	295	0.9001
Šibenik-Knin	2016	29.3	7.4	71	100	1.866	0.8927
Zadar	2015	42.1	11.1	122	61	2.292	0.8829
Bjelovar	2016	21.5	17.1	92	51	921	0.8778
Karlovac	2021	38.0	8.6	78	71	1.203	0.8647
Zadar	2021	64.7	9.5	105	71	1.814	0.8476
Slavonski Brod	2016	46.8	15.4	158	100	1.976	0.8442
Vinkovci	2016	23.7	37.6	87	88	1.170	0.8417
Bjelovar	2015	21.1	12.8	73	69	885	0.8056
Koprivnica	2021	32.9	9.0	68	50	693	0.8029
<i>Low efficiency</i>							
Karlovac	2022	40.8	7.0	75	79	1.298	0.7972
Karlovac	2015	25.2	1.1	90	59	1.018	0.7919
Vinkovci	2021	32.2	79.2	63	101	1.059	0.7897
Virovitica	2021	26.5	11.3	52	95	1.063	0.7828
Bjelovar	2021	31.1	39.2	59	71	1.014	0.7553
Požega	2016	24.4	23.2	80	82	928	0.7421
Virovitica	2022	29.3	8.1	53	100	1.063	0.7412
Koprivnica	2016	22.9	24.5	89	61	618	0.7393
Koprivnica	2015	22.8	19.9	87	45	654	0.7248
Vinkovci	2022	35.9	84.7	61	124	1.092	0.7118
Koprivnica	2022	38.6	5.6	69	56	811	0.7096
Bjelovar	2022	33.8	44.1	53	87	1.227	0.6779
Vukovar	2015	16.1	34.4	36	16	718	0.6725

General hospital	Year	Expenditures (in mil. €)	Due liabilities in total expenditures (in %)	Days (in 000)	Beds (in %)	Services (in 000)	Cost efficiency
Zadar	2016	44.0	17.2	120	71	1.578	0.6389
Dubrovnik	2016	29.6	45.3	83	52	1.154	0.6325
Vukovar	2016	17.9	34.9	34	27	809	0.6282
Požega	2021	27.0	5.9	44	100	796	0.6249
Karlovac	2016	29.7	0.2	86	75	1.009	0.6212
Dubrovnik	2021	46.9	84.9	64	77	1.438	0.5836
Šibenik-Knin	2022	48.1	9.9	57	100	1.547	0.5664
Vukovar	2022	26.0	20.5	34	46	656	0.5397
Vukovar	2021	26.4	164.2	23	37	616	0.4958
Dubrovnik	2022	54.6	80.2	59	80	1.438	0.4810

Source: Authors.