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Hospital Management of the Eastern Mexico Regional Administrative Operating Body in the Sars-Cov-2 Pandemic: Technical Efficiency

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ABSTRACT

Introduction: *In the face of the new health emergency due to SARS-COV-2, the Mexican Social Security Institute (IMSS) Spanish acronym, implements the Institutional Strategic Plan for Contingency Care due to COVID-19, which defines the modes of action in preparation and response in the presence and sustained SARS-COV-2 disease transmission cases Data envelopment analysis makes it possible to estimate the technical efficiency of service production systems.*

Objective: *to estimate the technical efficiency of the hospital units of the Eastern Mexico State Regional Decentralized Administrative Operation Body of the IMSS (Spanish acronym) in the response to the SARS-COV-2 health contingency from March 2020 to March 2021.*

Methods: *The COOPER Methodological Ordering was applied to define the input-oriented BCC model and estimate the hospitals' technical efficiency in the treatment response of COVID-19 during 1st and 2nd periods of highest incidence.*

Inputs: *Hospitalized and Covid-19 beds. Outputs: improvement/death ratio.*

Results: *in the study period, 30,656 were hospitalized and 1,324 Covid-19 beds were managed in 10 hospitals. Improvement 15,067; death 15,589 (improvement/death ratio: 0.97). Average technical efficiency: 82%.*

Conclusions: *8 of 10 hospitals in technical efficiency. Data envelopment analysis enables health managers to estimate the production capacity of health services and decision-making in the event of a public health emergency.*

Keywords
COVID-19. Efficiency, Organization and Administration of Hospitals, Pandemic.

Introduction
On January 30, 2020, the *World Health Organization* (WHO) declared the epidemic of coronavirus disease (COVID-19) as a public health emergency of international importance [1]. Faced with this new coronavirus, WHO asked the world for measures to ensure a quick development of vaccines, diagnostics, antiviral drugs, and other treatments in addition to being prepared to adopt containment measures, such as active surveillance, early detection, isolation and case management, contact tracing and prevention of the spread of the SARS-COV-2 virus. In Mexico, on March 30th, 2020, the Ministry of Health declared the epidemic of the disease generated by the SARS-COV-2 virus as a health emergency due to force majeure and recognized it as a serious disease requiring priority attention in the country [2].

As a result, the Mexican Social Security Institute (IMSS, Spanish acronym) implements in March 2020 the Institutional Strategic Plan for contingency care by COVID-19. In five sections, the plan articulates the procedures to obtain and mobilize additional human and material resources; the rational, ethical and transparent use of resources; continuous analysis of the evolution of the epidemiological situation; responsiveness; and, indicators to control the resources involved in dealing with this epidemic. Assigns each Decentralized Administrative Operation Body in the Federal Entities in Mexico, to estimate medical care, considering an attack rate of 0.5%, the population assigned to a Family Physician, the number of consultations, the number of admissions to hospitalization , the number of admissions to the intensive care unit, the number of patients with ventilation, the number of outpatients, the patient days in hospitalization and patient days with ventilators in the intensive care unit [3].

During the period from March 2020 to February 2021, ten hospital medical units and a temporary care center for convalescent patients circumscribed to the Decentralized Administrative Operation Body of the State of Mexico East, offered treatment responses to COVID-19 patients. According to the records of the institutional computer system (SINOLAVE Online Notification System for Epidemiological Surveillance), a total of 30,575 COVID-19 patients were treated who required hospitalization, whose volume of care is equivalent to 245,090 patient-days, which corresponds to an expense greater than USD $106,560,230 estimated for the bed-day cost of USD $435 in accordance with the Agreement regarding the Approval of the Unit Costs by Level of Medical Care updated to the year 2021 [4]. A maximum conversion of beds was achieved for the care of COVID patients of 1,324 registered beds in the ten Hospital Medical Units. During the referred period, 4,427 patients were intubated, reaching a total of 35,326 ventilator-days, 97 average patients intubated per day (maximum 198) and an average of 14.4 ventilator-days per intubated patient. There were 14,648 deaths, an average of 39 deaths per day (maximum 110). This information turns out to be relevant for hospital management due to its usefulness for the designing policies, which contribute to improve health services, as well as the performance of medical care units. Usually, the performance of health service units is evaluated through several indicators that are projected according to the perspective with which it is approached. Safety, efficacy and patient-centered responsiveness are the central dimensions in the evaluation of hospital performance [5].

From the Economics and Mathematics perspective, it is possible to achieve a concept of efficiency and productivity that enables alternative measures for their evaluation based on products or services of production units [6]. From this perspective, the analysis of efficiency depends mainly on the optimal use of the health services production each unit makes of its resources and their cost to obtain the best profit, given the available resources. In other words, efficiency is a measure of productivity in terms of what is produced and the cost of producing it. On health's field, efficiency evaluation is implemented in the health system, in health problems or diseases and in medical units [7]. In the evaluation of efficiency in health organizations, non-border and border methods are available, in the latter there are parametric and non-parametric techniques within which the data envelopment analysis is appreciated [8].

Data envelopment analysis (DEA) is one of the main techniques used in the public and private sectors to estimate the group's performance of homogeneous productive units with multiple resources and multiple products. It produces an empirical efficient frontier, given by the data supplied to the selected model. It makes it possible to obtain a single index of efficiency per evaluated unit and generates a reference set made up of efficient units, with which benchmarking is carried out, obtaining objectives to be achieved in order to improve efficiency (projection over the efficient frontier). In addition, it allows managing multiple inputs or inputs (resources) and multiple outputs or outputs (products), which is why it is applicable to production processes that are difficult to measure in monetary values [9,10].

The interest shown in the world for estimate the efficiency in response to the coronavirus pandemic (COVID-19) has resulted in various investigations that analyze the efficiency of health systems or hospitals through data envelopment analysis (Table 1). [11-29], who mostly applied the model proposed by Banker, Charnes and Cooper called BCC with returns of variable scales [30]. Due to the magnitude of the care in the treatment of the COVID-19 patient that this East Mexico State Regional Decentralized Administrative Operation Body has managed from March 2020 to date, our objective was to estimate the levels of technical efficiency of the hospitals that provided COVID-19 patient response using data envelopment analysis from March 2020 to March 2021.

Methods
The *COOPER Methodological Ordering* [31] was used as a reference framework, since it allowed to define and specify the enveloping data model, facilitating data processing and interpreting the results with methodological rigor. The data was obtained from

Table 1: Studies related to the efficiency of health-hospital systems in response to the Covid-19 pandemic through data envelopment analysis.

Autorship	Filiation	DEA Model	Efficiency	
Abdullah D	Indonesia	CCR	Healthcare system	(11)
Adabavazeh N	Iran	BCC	Hospitable	(12)
Bayram G	Turkey	CCR	Healthcare system	(13)
Breitenbach MC	South Africa	BCC	Healthcare system	(14)
Breitenbach MC	South Africa	BCC	Healthcare system	(15)
Caunic RL	Romania	BCC	Hospitable	(16)
Debela BK	Ethiopía	BCC	Healthcare system	(17)
Doğan Mİ	Turkey	SDEA	Healthcare system	(18)
Ferraz D	Brazil	BCC	Healthcare system	(19)
Hamzah NM	Malaysia	NDEA	Healthcare system	(20)
Ibrahim MD	United Arab Emirates	CCR - BCC	Healthcare system	(21)
Mariano EB	Brazil	NDEA	Healthcare system	(22)
Mohanta KK	India	CCR - BCC	Healthcare system	(23)
Mourad N	United Arab Emirates	CCR - BCC	Healthcare system	(24)
Nepomuceno TC	Brazil	CNM	Hospitable	(25)
Ordu M	Turkey	SDEA	Healthcare system	(26)
Shirouyehzad H	Iran	BCC	Healthcare system	(27)
Su ECY	Taiwan	CCR	Healthcare system	(28)
Xu Y	China	BCC	Healthcare system	(29)
CCR: Charnes, Cooper and Rhodes		NCM: Needs Complexity Model		
BCC: Banker, Charnes and Cooper		SDEA: Super-efficiency Data Analysis		
NDEA: Network Data Envelopment Analysis				

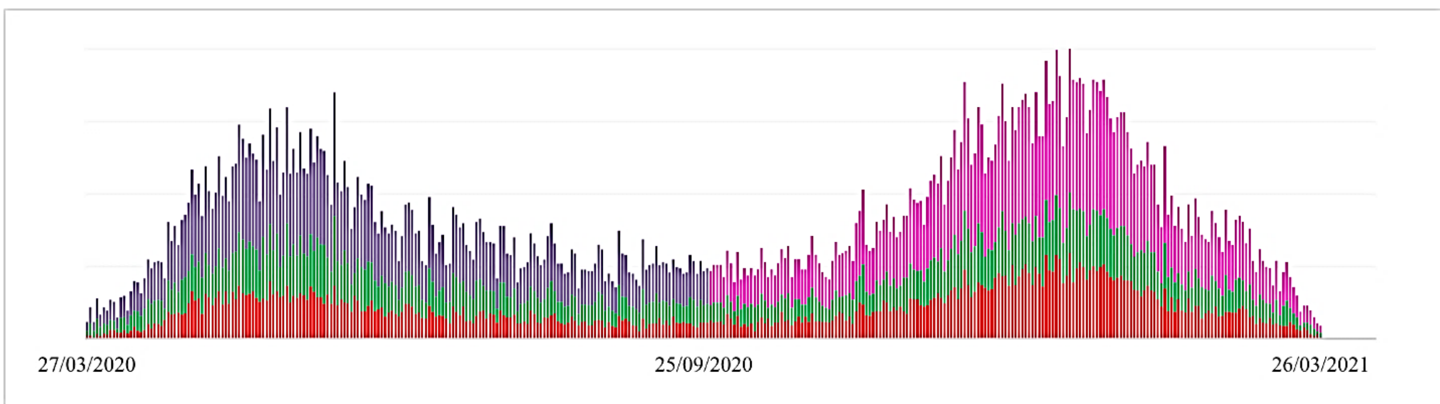

Figure 1: Daily trends in the number of hospitalized COVID-19 cases, with improvement, and deaths in ten hospitals managed by the East Mexico Regional Decentralized Administrative Operation Body Of the hospitalized patients, 40% women and 60% men; age: 56 ± 17 years, more than 54% above this mean. The case fatality rate was higher in men (32%) than in women (19%).

Hospitalized first period of highest incidence; Hospitalized second period of higher incidence; Improvement; Death.

the executive document *Productivity Covid-19*. Organ of Regional Decentralized Administrative Operation State of Mexico East, report that the Headquarters of Medical Benefits Services presented to the Head of the OOADREMO. Data validation was performed by two members of the research team, comparing them with the SINOLAVE institutional computer system. This validation confirmed the quality of the data and allowed the collection of a data-set? with no missing values.

The data envelopment analysis model for this study was the input-oriented Banker, Charnes and Cooper (BCC) model, which aims to reduce input quantities as much as possible while maintaining at least current output levels. To estimate the number of inputs - outputs and achieve stability in the DEA, the following equation proposed by Cooper was used [32].

$$n \geq \max \{m \times s, 3 (m + s)\} \quad \ldots\ldots (1)$$

Where n = number of DMUs, m = number of inputs and s number of outputs.

In this study, the DMUs correspond to the total of ten hospitals attached to the OOADREMO (seven).

Zone General Hospitals and three Regional General Hospitals). For the identification and choice of inputs and outputs, those referred to in the scientific background were considered. According to equation 1 and considering 10 DMUs, 2 inputs and 1 output result.

Inputs

1. Hospitalized patients. People treated and registered by hospital services in response to COVID-19 treatment during the period from March 2020 to March 2021.
2. Beds assigned for COVID-19: Beds destined to attend the hospitalization or hospitalization of the patient while he remains and is attended in response to the treatment of COVID-19 during the period from March 2020 to March 2021.

Outputs

1. Recovered/deceased ratio. Ratio between the desirable output (number of people recovered) and undesirable output (number of people deceased) calculated according to the proposal of Su [33].

The data envelopment analysis was performed in the Frontier Analyst 4.3.0 program. Once the inputs and outputs of the DMUs were described, the technical efficiency of the DMUs was contrasted in the first and second periods of highest incidence of SARS-COV-2 cases, for them a Student's t-test was applied at the confidence level of the 95% and 5% margin of error. All statistical analysis was performed in the IBM SPSS Statistics 20 program. The protocol for this research was approved and registered under number R-2021-1406-033 by the Local Health Research Committee 1406 of the IMSS.

Results

In twelve months of the epidemic, the Eastern Mexico Regional Decentralized Administrative Operation Body treated 164,556 subjects with COVID-19 infection, of which 30,656 required hospitalization during the period from March 27, 2020 to March 26, 2021. During this time, two points of greatest incidence were observed, the first from March 27 to September 25, 2020, and the second from September 26, 2020 to March 27, 2021 (Figure 1).

Technical efficiency

Table 2 describes the values of the variables selected to estimate the technical efficiency of the hospitals.

The results of the evaluation of the normality of the technical efficiency observed in the first and second periods of higher incidence, as well as for the global period using the Kolmogorov-Smirnov test, showed a parametric distribution of these (p: 0.694; 0.481 and 0.819 respectively), so to compare the mean technical efficiency and determine possible significant differences in the first and second periods of highest incidence, a subsequent statistical

Table 2: Input and output variables used in the data envelopment analysis to estimate the technical efficiency of hospitals managed by the East Mexico Regional Decentralized Administrative Operation Body.

Hospital	Hospitalized patients (input 1)	BedsCOVID-19 (input 2)	Improvement	Death	Ratio Improvement / Death (output 1)
A	3291	76	2187	1104	1.98
B	2417	140	1383	1034	1.34
C	1936	95	752	1184	0.64
D	2145	103	964	1181	0.82
E	2446	138	1149	1297	0.89
F	2728	144	1243	1485	0.84
G	2857	126	1140	1717	0.66
H	3950	122	2021	1929	1.05
I	3838	151	1860	1978	0.94
J	5048	229	2368	2680	0.88
Global	30656	1324	15067	15589	0.97

Table 3: Technical efficiency in the first and second periods with the highest incidence of COVID-19 cases (March 2020 to March 2021).

Hospital	Technical efficiency (%)			Efficiency level*
	First period of highest incidence	Second period of highest incidence	Full period	
A	100	100	100	High
B	100	100	100	High
C	100	100	100	High
D	96	99	97	High
E	89	89	86	High
F	82	98	74	Medium
G	92	68	76	Medium
H	65	71	69	Medium
I	60	59	60	Low
J	41	40	43	Low
Half	81	83	82	

*Efficiency level = Range / 3 levels: 43 to 62 low; 63 to 82 medium; 83 to 100 High analysis of the same order was established, using the Student's t-test for independent samples. assuming a two-tailed hypothesis and a significance level of 5%. It was observed that in both periods the technical efficiency is similar with no significant difference (p = 0.9916).

The results show 8 efficient units (from high to medium) and 2 inefficient, with the average technical efficiency being 82%, which represents an 18% inefficiency for the group of hospitals analyzed during the study period (Table 3).

Reference Hospitals

A relevant aspect in the application of the DEA model is the identification of hospitals that are referential for those inefficient with a similar combination of inputs, in such a way that the latter have at least one efficient unit with which they can carry out a benchmarking process that it will provide useful information to the medical manager to identify and emulate the best practices in order to achieve the estimated efficiency objectives for the production of services. The efficient hospitals were classified applying a benchmarking approach based on the frequency of appearance in the reference sets. Of the reference sets for each of the inefficient DMUs, the values for the intensity vector (λ) and the ranking of the efficient units, hospital C presented a frequency of 8 in the reference sets, so it was located by the DEA model at the top of the classification for constituting, in combination with other efficient DMUs, the best practices in dealing with the COVID-19 pandemic from March 2020 to 2021.

The following hospitals were hospital A with 6 references and hospital B with 5. The benchmark for hospital J corresponds to hospitals C, A and B, which have a value for the intensity vector of 76, 12 and 12, respectively, that is, the reference set built for the inefficient DMU that includes the best practices in dealing with the COVID-19 pandemic contributes to the objective values of the inefficient DMU in the following proportion: 76% corresponds to DMU C, 12% to DMU A and 12% to DMU B. Therefore, hospital C represents the most appropriate unit for the medical management of hospital J to identify the reasons for its non-optimal performance, in terms of the use of resources. and determine the best practices that allow it to increase efficiency in the care process in the COVID-19 pandemic.

Clearances and Potential Improvements

Slack analysis makes it possible to identify the amount by which an input is overused in relation to its use by efficient hospitals. In this sense, the effect of making a change in the combination of

Table 4: Observed and target values in hospitalized patients and COVID-19 beds in the response to the health contingency by SARS-COV-2 from March 2020 to March 2021

Hospital	Observed values			Target values		
	Inputs		Outputs	Inputs		Outputs
	Hospitalized patients	Beds COVID-19	Ratio Improvement / Death	Hospitalized patients	Beds COVID-19	Ratio Improvement / Death
C	1936	95	0.63	1936	95	0.63
A	3291	76	1.98	3291	76	1.98
B	2417	140	1.33	2417	140	1.33
D	2145	103	0.81	2086	100	0.81
E	2446	138	0.88	2108	111	0.88
G	2728	144	0.83	2073	108	0.83
F	2857	126	0.66	2101	93	0.79
H	3950	122	1.04	2720	84	1.41
I	3838	151	0.94	2289	90	0.98
J	5048	229	0.88	2161	98	0.88

Table 5: Input and output variables used in the data envelopment analysis to estimate technical efficiency with a new organization of hospitals managed by the East Mexico Regional Decentralized Administrative Operation Body

Hospital	Hospitalized patients (input 1)	Beds COVID-19 (input 2)	Ratio Improvement / Death (output 1)	Technical efficiency %
A	3291	76	1.98	100
B	2417	140	1.33	99
C	1936	95	1.00	100
D	2086	100	0.81	94
E	2108	111	0.88	91
F	2101	93	1.00	99
G	2073	108	0.83	93
H	2720	84	1.41	99
I	3100	80	0.98	94
J	3100	80	0.88	94
K	2860	75	1.10	100
L	2864	75	1.10	100

inputs that is currently used is evaluated with the aim of achieving efficient service production, focusing on the amount in which an input is used in excess and the effect of the improvement. on the level of efficiency. It should be remembered that the data envelopment analysis model applied for this study is of variable scales with minimization of inputs to produce the same output (radial movement); however, the results obtained indicated that to achieve efficiency an increase in output should be made. The observed and objective values for the evaluated hospitals are shown in Table 4, which correspond to the projection on the efficient frontier. The hospitals that did not reach 100% efficiency (D, E, G, F, H, I, J) hospitalized an average of 3,287 people and installed 145 COVID-19 beds for an Improvement/Death ratio: 0.84. The average goal of hospitalized patients was projected at 2,220 and 98 COVID-19 beds with an Improvement / Death ratio: 0.94.

Table 5 shows how Hospital J, in order to become efficient, should reduce COVID-19 hospitalizations and beds by 57%. In contrast, hospital H, in addition to reducing COVID-19 hospitalizations and beds by 31%, should increase the improvement/death ratio by 36%. In general terms, the results projected by the data envelopment analysis model indicated that the levels for hospitalization and COVID-19 beds should be reduced by an average of 28% and 29%, respectively, and increase the improvement/death ratio by an average of 20% (Table 6).

Technical Efficiency with a New Organization

Taking into account the target values detailed in Table 4, it is possible to test their technical efficiency with a new hospital organization. It was decided to reconsider the input and output values only of the two hospitals with low efficiency, this is how with the observed and objective values of these two hospitals and they were assigned to two hospitals called K and L, the technical efficiency with this new organization is shown in table 5.

Discussion

Data envelopment analysis is a deterministic non-parametric technique that uses mathematical programming to estimate the technical efficiency of a set of production systems for goods or services that are homogeneous with each other, in the sense that from the same inputs they produce the same type of results. Therefore, it is useful for the health manager since it allows estimating the operation of the different production units, its complexity is given by the great diversity of activities, services and products generated by hospital care practice. In the studies related to the efficiency of health-hospital systems in response to the Covid-19 pandemic through data envelopment analysis, they were carried out with a reduced and diverse set of input / output considered for this purpose, a fact that is reflected in the complexity for define the enveloping data model to use studies. This research, therefore, is not exempt from such limitations.

According to various scientific backgrounds, less than 50% consider unwanted outputs such as death. An undesirable output cannot be directly included in a standard data envelopment analysis because it would go against the basic precepts of the technique, which presupposes that outputs must be increased to improve efficiency. Among the different methodological options that can be used to address this problem, we use the method proposed by You [33], which consists of treating the unwanted output in the form of a desirable/undesirable ratio. This provides strong discrimination power by distinguishing the impact of unwanted output on DMU performance (higher improvement and death ratio decreases).

As for the BCC model, more than 50% of the antecedents have used it. In this study, the input-oriented BCC model was chosen since the maximum proportional reduction is sought in the vector of hospitalized patients and COVID-19 beds in the analyzed hospital, with the possibility of managing (modeling) said inputs, keeping the ratio constant. Improvement/death. Of the hospitals that are managed by the East Mexico Regional Decentralized Administrative Operation Body, 80% have medium to high efficiency and those that did not result must reduce the number of hospitalized patients and the use of COVID-19 beds to be on the efficient frontier. However, the improvement/death ratio must be optimized, so it is recommended to unroll a line of research expressly.

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