Composite Index of Health Indicators and Typology of the Mexican States Using and Extending the Performance Interval Approach

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Abstract

This study employs a performance-interval approach to assess health performance across Mexico's 32 states, addressing limitations of traditional single-value indices. Using OECD-selected indicators covering resources, health status, and risks, the methodology calculates a midpoint (MP) for average performance and an amplitude (A) for the balance of internal indicators. Extending this approach, the research develops a typology classifying states based on MP and A values to guide policy. Results reveal significant regional inequalities and institutional fragmentation; for instance, Mexico City exhibits high resource density yet high mortality rates due to its fragmented institutions. The analysis identifies four state groups, ranging from robust systems to those facing severe risks and uncertainty. By capturing internal disparities often obscured by single-value indices, the extended approach incorporates health system fragmentation into a composite index and a typology, as identified analytically in the current literature. The findings suggest that effective policy requires addressing resource scarcity and institutional coordination to reduce health disparities and improve outcomes across regions.

Keywords

Composite index; Performance interval; Health indicators; Health fragmentation; Mexico.

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INTRODUCTION

Health is a key aspect of human development and a universal right, reflecting a population's social, economic, and territorial conditions. In recent decades, population health has become strategically important in development agendas at both the international and national levels. In Mexico, access to quality

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services, along with the availability of human resources and infrastructure, is essential for understanding the health situation across the country's states (OECD, 2023). However, these conditions are not evenly distributed geographically (Bhattacharya, Hyde, Tu, 2014): health indicators in Mexico show significant inequalities between states, driven by structural factors, unequal resources, and varying risk dynamics across territories (Gómez-Dantés et al., 2024).

The availability of various tools and methods for measuring health enables comparisons and a better understanding of regional health system performance. The OECD health analytical framework categorizes indicators into health status, risk factors, and healthcare resources. This classification into meaningful groups provides a comprehensive, comparable, and policy-relevant basis for assessing health system performance and population health in OECD countries and their subregions (Joumard, André, Nico, 2008; OECD, 2023; Tolonen et al., 2021). The collected data enable consistent benchmarking across countries through uniform definitions and methods, enhancing comparability and facilitating tracking over time (Özen and Özen, 2024). The indicators cover multiple dimensions, including life expectancy, avoidable mortality, smoking, obesity, and health infrastructure, offering a holistic view of health system performance (OECD, 2023). This analytical foundation supports actionable, policy-relevant evaluations tailored to various health system needs while maintaining standardization (OECD, 2023). It encourages effective communication among policymakers by establishing a common language and promoting knowledge sharing across sectors (Özen and Özen, 2024). The indicators align with health determinants and cross-sectoral policies, fostering coherence in public health efforts (Tolonen et al., 2021). Well-organized methodological data ensures reliability and support analysis at both local and national levels (Özen and Özen, 2024; Braithwaite et al., 2017). Their adoption by many countries promotes collaboration and sets standards for health system evaluation (Özen and Özen, 2024). In summary, the OECD analytical framework effectively balances comprehensiveness, data quality, and global relevance in assessing state-level health performance (OECD, 2023; Tolonen et al., 2021).

Despite progress in recent decades, Mexico still faces growing fragmentation within its regional health system. Inequities in service access, medical infrastructure, health outcomes, and exposure to socio-environmental risks create a complex, uneven, and multifaceted landscape (Gómez-Dantés et al., 2023; Meneses-Navarro et al., 2022). This work provides a multidimensional analysis of health across Mexico's 32 states. Composite indicators of state-level health performance offer a concise summary that helps identify issues and guide public policy. Traditional assessments that rely solely on single averages or indicators often obscure differences between states, making it harder to develop effective policies and prioritize resources. The lack of tools that combine resources, status, and risk with variability criteria limits the effectiveness of public health strategies. The methodological approach shows that the performance interval index (Mazziotta and Pareto, 2020) is a practical option for capturing variability within each state's health system.

The research presents an analytical and methodological approach to developing a composite indicator of state-level health performance in Mexico. The study examines key concepts, the rationale for the issue, and its social importance. It also establishes a systematic, methodological process and a logical framework for combining indicators into an interval index with three levels of compensation: full compensation, partial compensation, and full non-compensation. The aim is to enrich academic literature and inform public policies to reduce health disparities and improve social well-being.

Accurate measurement of state-level health performance is essential for developing effective and equitable public policies. Mexico's health issues, including chronic diseases and resource disparities, require innovative methodological approaches to capture their complexity. The performance interval-based method for composite indices not only identifies states with low and high performance but also pinpoints those with wide or narrow internal variations in their indicators (Mazziotta and Pareto, 2020; Drago and Gatto, 2023). This information is essential for designing strategies tailored to specific regions.

Furthermore, this approach enables the comparison and visualization of regional patterns that are often overlooked by traditional techniques, thereby supporting the creation of regionally focused and fair public policies (Drago, 2021).

Objectives. To analyze the performance and hierarchy of a composite health index for Mexico's states and to recommend a policy framework. Achieving this involves five specific tasks:

1. Use the OECD conceptual framework of resources, status, and risk to select key health indicators that answer the question: What are representative indicators of the health system, as defined in the database?
2. Develop a composite health index for Mexican states using an adapted version of the performance interval method by Mazziotta and Pareto (2020), referred to as the original version in this study. This task aims to determine: What is the performance and ranking of each state based on its interval midpoint (MP), and how balanced the indicators are in each case based on the interval amplitude (A)?
3. Identify the key indicators in the MP and the geometric mean and verify the relationship between these two partially compensatory indices. This activity addresses the question: How can we confirm that MP is a partially compensatory index, and which indicators are most important?
4. Propose a regional classification of state-level health performance based on the MP and A of the states, using an arithmetic interval (interval average). The key question is: How can the MP and A be combined to create a typology that informs the design of policy frameworks?
5. Recommend tailored courses of action based on the previous performance typology. The relevant question is: Which tasks and actions are appropriate given the performance typology?

The main purpose of these general and specific objectives is to guide the narrative in this document rather than address each question individually in the case study.

1 CONCEPTUAL APPROACHES

1.1 Dimensions and indicators of health

The concept of health is multidimensional, encompassing structural, individual, and territorial factors and determinants. According to the WHO (2024), health is not merely the absence of disease but also includes physical, mental, and social well-being. Building on this idea, the OECD (2023) selects, compiles, and organizes indicators into three analytical dimensions related to health system performance.

a. *Resources* (inputs). These indicators reflect the capacity of health systems, including infrastructure, personnel, and equipment. Resources represent the state's operational capacity and define the system's potential to respond to health needs. The database provides the following resource indicators (per 1 000 inhabitants): Active physicians, Nurse practitioners, and Beds. The OECD (2023) also includes hospital discharges in this dimension. This indicator is excluded from this analysis because it does not directly measure health resources. High or low rates of hospital discharges do not necessarily indicate better health care resources; they should be interpreted alongside results and system efficiency.

b. *Status* (results) are indicators that measure the overall outcome of the system in terms of population health. Health status reflects the population's health condition and shows accumulated achievements or deficits in longevity, mortality, and morbidity. The most representative indicators of a population's health status are life expectancy and mortality (Bhattacharya, Hyde, Tu, 2014). The database includes life expectancy at birth, crude mortality rate, age-adjusted mortality rate, and infant mortality rate.

c. *Risk* (determinants). These indicators represent individual or societal factors that increase the likelihood of illness or early death. They are social and behavioral determinants of health. Risks serve as probabilistic predictors of changes in health status, especially when combined. The database includes the Obesity rate, Population exposure to fine particulate matter (PM2.5), Mortality rate from respiratory diseases, and Mortality rate from circulatory diseases.

The operational nature of the OECD approach is flexible enough to accommodate various theoretical perspectives, but it does not fully align with all of them. For example, Sen's (1985) capabilities methodological procedure and OECD health resources (physicians, nurses, and beds) agree that a well-funded health system is essential not only for preventing disease but also for enabling people to develop their abilities and lead fulfilling lives.

The OECD approach also connects to Marmot's social determinants of health framework (Marmot, 2015; Marmot et al., 2020). Both the OECD and Marmot aim to incorporate social and structural factors into health analysis. However, they differ in focus and scope: the OECD emphasizes measuring resources, status, and risks for comparison and policy development, whereas Marmot promotes an equity and social justice agenda focused on changing the structural conditions that create the social gradient in health.

1.2 Recent literature on the case study and the advantages of the performance interval

Mexico's health system exhibits profound subnational heterogeneity, necessitating analytical frameworks that capture disparities and guide social policy. Composite indices are promising tools for empirical assessment, yet methodological limitations constrain their diagnostic utility in addressing regional inequities. Gómez-Dantés et al. (2016) used Global Burden of Disease data to analyze the geographic pattern of cancer. They found a discordant health transition across Mexican states from 1990 to 2013, thereby demonstrating geographic disparities and producing regional rankings showing southern states lagging their northern counterparts in mortality and disease burden.

Empirical measurements of health systems are vital for identifying specific areas that require intervention. However, these measurements also present additional complexities that demand careful interpretation. Urquieta-Salomon and Villarreal (2016) documented the evolution of health coverage, showing progress while highlighting structural challenges in the Mexican health system.

Socioeconomic factors influence performance metrics, thereby affecting the overall assessment of the system's effectiveness. Smith and Goldman (2007) identified socioeconomic disparities in health among older adults. Barraza-Llorens et al. (2002) examined income-related inequalities from 2000 to 2006 and found that health care utilization varied significantly by socioeconomic status.

Together, these studies show that although coverage has expanded, equity remains elusive. The current literature indicates that composite indices fail to capture the social segmentation and institutional fragmentation of Mexico's health system (Meneses-Navarro, 2025). Segmentation refers to the classification of the population, primarily by formal or informal labor market status, whereas fragmentation refers to the diversity of institutions serving the segmented population (e.g., IMSS, ISSSTE, SEDENA, MARINA, PEMEX, health institutions associated with unions, such as universities) (Becerril-Montekio et al., 2024). The combination of segmentation and fragmentation creates a "sanitary apartheid" characterized not only by the divide between those who have and those who lack access to the health system but also by disparities in health resources and in the quality of medical care among those who already have health services (Knaul et al., 2012).

Critical methodological gaps persist in the composite index literature: single-value indices blend uniformly low performance with highly variable performance, leading to mismatched interventions; compensatory aggregation obscures indicator substitution, thereby masking fragmentation; and existing typologies stratify states by average scores alone, ignoring organizational styles (institutional fragmentation across different sectors of the population). The performance interval approach addresses these gaps by quantifying and combining midpoint and amplitude to suggest a regional health typology. This two-dimensional diagnosis enables precision in public policy and prevents the uniform allocation of resources across and within states for indicators.

2 METHODOLOGY

The current study uses health indicators from the OECD-Explorer (Health Statistics – Regions) for Mexico's 32 federal entities. The database groups these indicators into three dimensions: resources, status, and risk. The methodology combines these indicators using the performance interval approach in five steps. A final sixth step extends the interval approach to developing a typology that supports the creation of territorial strategies for decision-making and policy development.

a. *Normalization*. This research employs vector normalization, the most stable among the normalization options used in decision-making methods, such as TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) (Bouhedja, Bouhedja, Benselhoub, 2024), which aligns with the typology described in this methodology:

$$z = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^2}}, \qquad \text{Eq. (1)}$$

Where x_{ij} is the value of indicator j in observation i in the input data matrix; the sum of squares is calculated for each indicator (per column). This normalization does not change the shape of the distribution of the original values (i.e., the same skewness and kurtosis).

b. *Negative polarity*. Indicators with an inverse relationship (negative correlation) with the composite index have ~~a~~ negative polarity, meaning they need to be inverted to align with it. Negative polarity can be reversed by applying any standardization or normalization procedure for negative indicators, linear operations (subtracting from the maximum value), or non-linear procedures (reciprocal transformation), as detailed in Alaimo (2023). In this research, indicators with negative polarity are reversed following Mulliner, Malys, Maliene (2016):

$$x_i^{'} = max + min - x_i. \qquad \text{Eq. (2)}$$

c. *Weighting*. There are objective and subjective weightings. Objective weighting is based on data-driven criteria such as variability, statistical properties, or optimization procedures. Subjective weighting involves value judgments or preferences by experts, stakeholders, or index designers. This research assigns equal weights based on the number of indicators in each dimension, as explained in the case study.

d. *Aggregation*. All indicators are synthesized using the performance interval approach (Mazziotta and Pareto, 2020). This method builds a composite index that considers both the midpoint and the range of each interval, offering a synthetic and reliable view of the health situation by state. This approach identifies for each territorial unit the minimum (LB) and maximum (UB) of the normalized and weighted values that define the performance interval. In the case study, the UB (upper bound) of the interval is the arithmetic mean of the normalized, equally weighted values for each row (Mexican state).

The amplitude of the interval (A) is the difference between the maximum and minimum values of the indicators in each observation:

$$\text{A} = \text{UB} - \text{LB} \qquad \text{Eq. (3)}$$

And the midpoint (MP) of this interval is:

$$\text{MP} = (\text{LB} + \text{UB})/2 \qquad \text{Eq. (4)}$$

The midpoint (MP) of this interval is a composite index that considers both the average value and its relative stability (variability). The MP is a partially compensatory index, like other single-value indices (e.g., geometric mean), that determines the hierarchy of performance in each state. The interval approach simultaneously accounts for both the midpoint performance value and the internal variation of each state, offering a more detailed view than a traditional index based solely on averages.

e. *Importance of normalized indicators, Z_i*. It is assessed through an iterative process that involves repeatedly calculating the MP by removing one indicator at a time and adjusting the weights w_i for the remaining indicators. This method is based on the idea that the indicator whose removal results in a lower correlation is the most important, as its absence has a greater effect on the observation hierarchy. This same simulation process is applied to the weighted geometric mean for normalized data. The study uses the multiplicative version, denoted as GM_w^{Π} (there is also an additive version that produces the same result):

$$GM_w^{\Pi} = \left(\prod_{i=1}^{j=7} z_i^{w_i} \right)^{\frac{1}{\sum_{i=1}^{j=7} w_i}} \qquad \text{Eq. (5)}$$

The number seven in Eq. (5) represents the count of indicators in this research. When the sum of the weights equals one, the formula simplifies to multiplication inside parentheses:

$$GM_w^{\Pi} = \prod_{i=1}^{j=7} z_i^{w_i} = z_1^{w_1} * z_2^{w_2} * z_3^{w_3} \ldots z_7^{w_7} \qquad \text{Eq. (6)}$$

f. *Typology*. The combination of MP and A creates a typology of health performance for the states. The key to developing this typology is to calculate an interval arithmetic (interval average) using the mean of all minimums (LB) on one side and the mean of all maximums (UB) on the other, considering all individual intervals (Drago and Gatto, 2023; Drago, 2021). The significant points of the interval average are the midpoint ($\overline{MP}$) and the amplitude (Ā):

$\overline{MP} = \left(\overline{LB} + \overline{UB}\right)/2$; and $\bar{A} = \overline{UB} - \overline{LB}$. These values allow the states to be classified into four groups:

a. High performance, low variability (MP > $\overline{MP}$ & A < Ā): States with effective healthcare systems and stable indicators. Policy: Continue current measures and enhance innovation.
b. High performance, high variability (MP > $\overline{MP}$ & A ≥ Ā): Successful states with internal imbalance in indicators. Policy: focus interventions in areas with unbalanced indicators.
c. Low performance, low variability (MP ≤ $\overline{MP}$ & A < Ā): States with poor results but internally balanced indicators. Policy: restructure general policy and increase resources.
d. Low performance, high variability (MP ≤ $\overline{MP}$ & A ≥ Ā): States with low performance and unbalanced indicators. Policy: implement institutional reform and emphasize territorial equity with balanced indicators.

This typology emphasizes the unique challenges of each group of states, allowing for the creation of policies tailored to each one. The approach supports the principles of territorial equity and institutional efficiency, which are vital for reaching health goals across various geographical settings (Kruk et al., 2015).

MP and A can be divided into any number of strata to develop more detailed typologies. Different stratification methods can be used for this purpose, such as natural breaks or intervals around the mean or median. However, as the number of categories or types increases, interpretation becomes more complicated.

3 HEALTH INDICATORS IN THE MEXICAN STATES

Data are represented by variables that, when combined, form indicators. Health indicators in the OECD are categorized into three dimensions, as mentioned earlier: resources, status, and risk (Table 1). The number of indicators varies by dimension and may sometimes include missing data. These characteristics lead to the following decisions:

a. Indicators with missing information for specific states were retrieved from alternative sources instead of being omitted. For example, obesity data for Mexico does not appear in the OECD database. The data show the percentage of the population with overweight and obesity by state in 2018, available on the Mexican website for the 2030 Agenda.
b. The Hospital discharges indicator has been removed from the analysis because it does not effectively measure resources.
c. The data for the indicators are averages from recent years to avoid short-term effects and to update lagging data. The exceptions are the PM2.5 and Obesity indicators, as they are available only for 2020 and 2018, respectively. The remaining indicators are averages for the periods 2020-2022, 2023, or 2024.
d. Indicators with a coefficient of variation less than 10% are excluded from the study because they lack sufficient discriminatory power between states. This includes the indicators Infant mortality and Life expectancy in the Status dimension, and Obesity in the Risk dimension.

Once the previous operational decisions were made, the input matrix was ready to be used in the performance interval procedure. The final matrix has seven indicators grouped into three dimensions, covering the 32 states of Mexico (Table 1 and Table 2).

Table 1 Health indicators, by dimension, polarity, and description.

Dimensions (polarity)	Abbreviation and description
Resources	
Physicians (+). Per 1 000 habts.	*Physicians.* General practitioners who assume responsibility for providing ongoing care to individuals and families, or specialists such as pediatricians, obstetricians-gynecologists, psychiatrists, medical specialists, and specialist surgeons.
Nurses (+). Per 1 000 habts.	*Nurses.* They provide direct patient care services, including professional nurses, nurse practitioners, and foreign nurses licensed to practice and actively practicing in the country. Midwives are excluded, unless they work primarily as nurses.
Beds (+). Per 1 000 habts.	*Beds*. They are hospital beds with regular maintenance and staffing, immediately available for the care of admitted patients. They include beds in all hospitals, including general hospitals, mental health and substance abuse hospitals, and other specialty hospitals; occupied and unoccupied beds.
Status	
Crude mortality rate. (-). Per 1 000 habts.	*MortR*. It is the ratio of deaths during the year to the average population of that year.
Risk	
Population exposure to fine particles PM2.5	*PM2.5*. Population exposure to PM2.5
Respiratory system diseases mortality rate (-)*	*RespiraM*. Number of deaths from diseases of the respiratory system, for 100 000 habts.
Circulatory system diseases mortality rate (-)*	*CirculaM*. Number of deaths from diseases of the circulatory system, for 100 000 habts.

Source: Based on OECD data explorer (https://data-explorer.oecd.org/).
* The OECD, in its country-level analysis, examines circulatory and respiratory diseases under Health status (OECD Health at a Glance, 2023, Chapter 3). However, in its database, both indicators are reported in the health risk classification at the level of regions (Data Explorer-Health statistics - Regions). Since the main data source in this research is at the regional level (TL2), the classification of health indicators is the same as that used in the OECD Data Explorer.

Table 2 Selected health indicators. Input data (decision matrix)

States	Resources			Status	Risk		
	Physicians	Nurses	Beds	MortR	RespiraM	CirculaM	PM2.5
Aguascalientes (Ags)	1.35	1.8	1.0	5.97	57.4	125.27	13.8
Baja California (BC)	0.90	1.2	0.9	7.08	57.4	163.13	16.4
Baja California Sur (BCS)	1.78	1.4	1.1	5.87	46.6	133.88	10.9
Campeche (Cam)	1.50	1.6	1.1	7.04	52.8	177.69	15.6
Coahuila (Coa)	1.28	1.4	1.2	7.28	55.8	190.69	13.5
Colima (Col)	1.70	1.7	1.2	8.27	65.5	171.58	12.3
Chiapas (Chis)	0.83	1.3	0.6	6.30	49.0	166.80	18.0
Chihuahua (Chih)	1.20	1.8	1.1	8.45	70.7	213.85	13.2
Ciudad de Mexico (CdMx)	2.45	3.2	2.3	9.28	76.9	234.64	17.2
Durango (Dgo)	1.18	1.3	1.0	6.71	60.7	209.09	13.1
Guanajuato (Gto)	1.00	1.5	1.0	7.66	57.3	203.31	14.3
Guerrero (Gro)	1.15	1.4	0.8	6.62	42.6	158.77	13.1
Hidalgo (Hgo)	1.03	1.2	0.8	6.71	45.1	187.43	16.0
Jalisco (Jal)	1.03	1.5	1.2	7.37	79.0	179.28	12.9
Mexico (Mex)	0.88	1.1	0.8	7.32	58.6	169.84	17.3
Michoacan (Mich)	1.00	1.1	1.0	7.66	60.3	192.25	13.2
Morelos (Mor)	1.15	1.2	0.8	9.04	65.5	224.37	14.8
Nayarit (Nay)	1.35	1.2	0.7	6.79	62.0	162.14	11.5
Nuevo Leon (NL)	0.95	1.6	1.1	6.84	64.8	189.81	14.1
Oaxaca (Oax)	0.88	1.0	0.7	7.90	51.3	213.59	14.6
Puebla (Pue)	0.83	1.0	0.8	7.82	61.9	220.14	15.7
Queretaro (Qro)	0.95	1.1	0.8	6.09	48.8	145.65	15.3
Quintana Roo (QRoo)	1.03	1.4	0.7	5.26	36.1	94.67	13.8
San Luis Potosi (SLP)	0.80	1.2	1.0	7.78	68.9	217.33	14.8
Sinaloa (Sin)	1.35	1.5	1.0	6.73	64.8	180.23	11.9
Sonora (Son)	1.48	1.5	1.2	7.97	75.6	211.23	13.2
Tabasco (Tab)	1.48	1.6	0.9	7.31	51.4	195.83	17.4
Tamaulipas (Tam)	1.23	1.8	1.3	6.91	56.6	188.82	14.2
Tlaxcala (Tla)	1.15	1.2	0.7	7.44	89.2	185.92	16.2
Veracruz (Ver)	1.00	1.1	0.8	8.51	61.4	250.32	15.7
Yucatan (Yuc)	1.25	1.6	1.1	7.15	66.5	211.21	14.1
Zacatecas (Zac)	1.33	1.6	0.9	8.03	71.3	192.13	13.0
Mean	1.200	1.439	0.986	7.285	60.371	186.277	14.409
Stdev	0.339	0.403	0.295	0.907	11.341	32.713	1.787
CV	0.283	0.280	0.299	0.125	0.188	0.176	0.124

Source: OECD-explorer. Data averaged for the recent period (2020, onwards)—indicator abbreviations in Table 1.

The performance interval approach differs from studies on value intervals in the input matrix because it produces both compensatory and non-compensatory measurements from a single continuous-value matrix. It is not tied to indices based on input ranges, underscoring the difficulty of accurately representing aspects such as individual preferences through value ranges (Jahanshahloo, Lotfi, Izadikhah, 2006).

The original performance interval procedure is not applied in its original form; instead, it is applied with four variations and two extensions, indicated when appropriate. Variations are common because the original version's main purpose is to develop composite indices using the performance interval method. It is important, however, to mention them to avoid claims of distorting or falsifying the original procedure. Extensions are needed for a more effective graphical representation of the interval method and to develop the typology proposed in this research. Among the variations and extensions, the study incorporates observations from the original approach into the graphical representation of the interval. The study lists all steps, variations, observations, and extensions in order. The first four steps involve adaptations or variations:

1. *Vector normalization instead of rescaled standardization in the original version* (Table 2). This step is essential to make indicators expressed in different units of measurement comparable. There are several standardization procedures, with varying effects on the composite index (OECD, 2008; Talukder, Hipel, Vanloon, 2017). The original version uses the z standardization multiplied by 10, and ± 100. The version applied in this research employs vector normalization, as explained in the methodology.

2. *Revert indicators with negative polarity* so that higher values indicate better performance (see Table 3). The methodology details this procedure.

Table 3 Normalized matrix with reversed negative indicators

States	Physicians	Nurses	Beds	Polarity reversal= (max + min) - xi			
				MortR	RespiraM	CirculaM	PM2.5
Ags	0.1916	0.2093	0.1719	0.2064	0.1953	0.2055	0.1839
BC	0.1277	0.1382	0.1605	0.1794	0.1954	0.1701	0.1522
BCS	0.2519	0.1658	0.1834	0.2087	0.2265	0.1974	0.2192
Cam	0.2129	0.1935	0.1834	0.1806	0.2086	0.1565	0.1620
Coa	0.1810	0.1619	0.2063	0.1747	0.1999	0.1443	0.1875
Col	0.2413	0.2014	0.2063	0.1508	0.1722	0.1622	0.2022
Chis	0.1171	0.1501	0.1032	0.1982	0.2197	0.1666	0.1327
Chih	0.1703	0.2172	0.1948	0.1464	0.1571	0.1226	0.1912
CdMx	0.3477	0.3791	0.3897	0.1266	0.1393	0.1032	0.1425
Dgo	0.1668	0.1580	0.1719	0.1885	0.1858	0.1271	0.1924
Gto	0.1419	0.1777	0.1719	0.1655	0.1956	0.1325	0.1778
Gro	0.1632	0.1658	0.1375	0.1906	0.2381	0.1741	0.1924
Hgo	0.1455	0.1422	0.1375	0.1885	0.2310	0.1473	0.1571
Jal	0.1455	0.1737	0.2063	0.1725	0.1333	0.1550	0.1948
Mex	0.1242	0.1303	0.1318	0.1738	0.1919	0.1638	0.1413
Mich	0.1419	0.1303	0.1719	0.1655	0.1872	0.1428	0.1912
Mor	0.1632	0.1382	0.1318	0.1323	0.1722	0.1128	0.1717
Nay	0.1916	0.1382	0.1261	0.1865	0.1822	0.1710	0.2119
NL	0.1348	0.1856	0.1891	0.1853	0.1741	0.1451	0.1802
Oax	0.1242	0.1185	0.1203	0.1597	0.2129	0.1229	0.1741
Pue	0.1171	0.1145	0.1375	0.1617	0.1824	0.1167	0.1607
Qro	0.1348	0.1343	0.1375	0.2033	0.2201	0.1864	0.1656
QRoo	0.1455	0.1658	0.1261	0.2234	0.2567	0.2341	0.1839
SLP	0.1135	0.1461	0.1719	0.1626	0.1624	0.1194	0.1717
Sin	0.1916	0.1816	0.1776	0.1880	0.1741	0.1541	0.2070
Son	0.2093	0.1816	0.2063	0.1581	0.1431	0.1251	0.1912
Tab	0.2093	0.1935	0.1547	0.1739	0.2126	0.1395	0.1400
Tam	0.1739	0.2132	0.2235	0.1837	0.1977	0.1460	0.1790
Tla	0.1632	0.1422	0.1261	0.1709	0.1040	0.1488	0.1547
Ver	0.1419	0.1264	0.1375	0.1451	0.1839	0.0885	0.1607
Yuc	0.1774	0.1895	0.1834	0.1778	0.1691	0.1251	0.1802
Zac	0.1881	0.1895	0.1490	0.1567	0.1555	0.1429	0.1936

Source: Abbreviations and calculations based on Table 2.

3. *Equal weighting by dimension* (Table 4). Equal weighting is used when there is no strong reason to consider one dimension or indicator more important than others (the principle of insufficient reason or the principle of indifference). Segmenting the weights helps prevent dominance by dimensions with the most indicators. The indicators in this research represent the social right to health. There are no convincing arguments that one social right is more important than another, nor that one indicator of the social right to health is more important than others. In the absence of a firm argument for differential weighting, these indicators are weighted equally, as suggested by the literature (Babbie, 2021; Mothupi et al., 2021; Nguefack-Tsague, Klasen, Zuchini, 2011; UNICEF, n.d.). This weighting strategy also prioritizes conceptual clarity and policy transparency. Unlike expert-weighting (vulnerable to stakeholder capture) or statistical weighting (opaque to non-technical audiences), equal weighting by dimension provides a defensible, auditable baseline that highlights trade-offs rather than obscuring them.

Table 4 Normalized and equally weighted matrix according to the number of indicators by dimension

States	Resources (1/3)			Status (1/3)	Risk (1/3)		
	Physicians	Nurses	Beds	MortR	RespiraM	CirculaM	PM2.5
Weighting	0.11111	0.1111111	0.11111	0.33333	0.11111	0.11111	0.11111
Ags	0.0213	0.0233	**0.0191**	0.0688	0.0217	0.0228	0.0204
BC	**0.0142**	0.0154	0.0178	0.0598	0.0217	0.0189	0.0169
BCS	0.0280	**0.0184**	0.0204	0.0696	0.0252	0.0219	0.0244
Cam	0.0237	0.0215	0.0204	0.0602	0.0232	**0.0174**	0.0180
Coa	0.0201	0.0180	0.0229	0.0582	0.0222	**0.0160**	0.0208
Col	0.0268	0.0224	0.0229	0.0503	0.0191	**0.0180**	0.0225
Chis	0.0130	0.0167	**0.0115**	0.0661	0.0244	0.0185	0.0147
Chih	0.0189	0.0241	0.0216	0.0488	0.0175	**0.0136**	0.0212
CdMx	0.0386	0.0421	0.0433	0.0422	0.0155	**0.0115**	0.0158
Dgo	0.0185	0.0176	0.0191	0.0628	0.0206	**0.0141**	0.0214
Gto	0.0158	0.0197	0.0191	0.0552	0.0217	**0.0147**	0.0198
Gro	0.0181	0.0184	**0.0153**	0.0635	0.0265	0.0193	0.0214
Hgo	0.0162	0.0158	**0.0153**	0.0628	0.0257	0.0164	0.0175
Jal	0.0162	0.0193	0.0229	0.0575	**0.0148**	0.0172	0.0216
Mex	**0.0138**	0.0145	0.0146	0.0579	0.0213	0.0182	0.0157
Mich	0.0158	**0.0145**	0.0191	0.0552	0.0208	0.0159	0.0212
Mor	0.0181	0.0154	0.0146	0.0441	0.0191	**0.0125**	0.0191
Nay	0.0213	0.0154	**0.0140**	0.0622	0.0202	0.0190	0.0235
NL	**0.0150**	0.0206	0.0210	0.0618	0.0193	0.0161	0.0200
Oax	0.0138	**0.0132**	0.0134	0.0532	0.0237	0.0137	0.0193
Pue	0.0130	**0.0127**	0.0153	0.0539	0.0203	0.0130	0.0179
Qro	0.0150	**0.0149**	0.0153	0.0678	0.0245	0.0207	0.0184
QRoo	0.0162	0.0184	**0.0140**	0.0745	0.0285	0.0260	0.0204
SLP	**0.0126**	0.0162	0.0191	0.0542	0.0180	0.0133	0.0191
Sin	0.0213	0.0202	0.0197	0.0627	0.0193	**0.0171**	0.0230
Son	0.0233	0.0202	0.0229	0.0527	0.0159	**0.0139**	0.0212
Tab	0.0233	0.0215	0.0172	0.0580	0.0236	**0.0155**	0.0156
Tam	0.0193	0.0237	0.0248	0.0612	0.0220	**0.0162**	0.0199
Tla	0.0181	0.0158	0.0140	0.0570	**0.0116**	0.0165	0.0172
Ver	0.0158	0.0140	0.0153	0.0484	0.0204	**0.0098**	0.0179
Yuc	0.0197	0.0211	0.0204	0.0593	0.0188	**0.0139**	0.0200
Zac	0.0209	0.0211	0.0166	0.0522	0.0173	**0.0159**	0.0215

Source: Calculations based on Table 3. Numbers in bold indicate the lowest value in each row. Abbreviations for the states correspond to Table 2.

4. *High correlation between MP and geometric mean for weighted data (GMw)*. The original version by Mazziotta and Pareto (2020) states that MP and GM are highly correlated. The difference in this research is the use of weighted GM for standardized data. This change is necessary because the original version does not group the indicators by subcomponents. In contrast, the calculations in this study use equally weighted data based on the number of dimensions and indicators in each.

The MP is calculated as the average of the lower limit (LB) and the upper limit (UB) of the interval. LB represents the minimum value of each observation (state), while UB is the average of the entire row (Table 5). Additionally, the methodology provides a formula for determining the geometric mean of weighted values (GMw). The case study confirms the original claim of a high rank correlation between MP and GMw (0.96, $p < 0.001$). This strong correlation not only demonstrates that the MP is a partially compensatory index but also, unlike GMw, is preferable because it includes information about the interval's amplitude and the balance of indicators in each observation.

Table 5 Performance intervals for health indicators in the states

State	Min (LB)	MP	Mean (UB)	Amplitude (A)	GMw	Rank MP	Rank GMw	MP-GM	MP	Interval
Ags	0.0191	0.0237	0.0282	0.0091	0.1970	2	2	0	High	Narrow
BC	0.0142	0.0189	0.0235	0.0093	0.1633	22	23	−1	Low	Narrow
BCS	0.0184	0.0241	0.0297	0.0113	0.2065	1	1	0	High	Wide
Cam	0.0174	0.0219	0.0263	0.0089	0.1834	4	5	−1	High	Narrow
Coa	0.0160	0.0208	0.0255	0.0094	0.1774	8	10	−2	High	Narrow
Col	0.0180	0.0220	0.0260	0.0080	0.1796	3	9	−6	High	Narrow
Chis	0.0115	0.0175	0.0236	0.0121	0.1600	26	25	1	Low	Wide
Chih	0.0136	0.0187	0.0237	0.0101	0.1635	24	22	2	Low	Wide
CdMx	0.0115	0.0207	0.0299	0.0184	0.1815	9	7	2	High	Wide
Dgo	0.0141	0.0195	0.0249	0.0108	0.1729	16	13	3	Low	Wide
Gto	0.0147	0.0192	0.0237	0.0090	0.1650	20	20	0	Low	Narrow
Gro	0.0153	0.0207	0.0261	0.0108	0.1807	9	8	1	High	Wide
Hgo	0.0153	0.0198	0.0242	0.0089	0.1671	14	19	−5	High	Narrow
Jal	0.0148	0.0195	0.0242	0.0094	0.1682	16	17	−1	Low	Narrow
Mex	0.0138	0.0180	0.0223	0.0085	0.1544	25	26	−1	Low	Narrow
Mich	0.0145	0.0188	0.0232	0.0087	0.1612	23	24	−1	Low	Narrow
Mor	0.0125	0.0165	0.0204	0.0079	0.1416	30	31	−1	Low	Narrow
Nay	0.0140	0.0195	0.0251	0.0111	0.1736	16	11	5	High	Wide
NL	0.0150	0.0199	0.0248	0.0099	0.1728	13	14	−1	High	Narrow
Oax	0.0132	0.0173	0.0215	0.0083	0.1474	27	29	−2	Low	Narrow
Pue	0.0127	0.0168	0.0209	0.0081	0.1441	29	30	−1	Low	Narrow
Qro	0.0149	0.0201	0.0252	0.0103	0.1735	12	12	0	High	Wide
QRoo	0.0140	0.0211	0.0283	0.0143	0.1932	7	3	4	High	Wide
SLP	0.0126	0.0172	0.0218	0.0092	0.1510	28	27	1	Low	Narrow
Sin	0.0171	0.0217	0.0262	0.0091	0.1828	5	6	−1	High	Narrow
Son	0.0139	0.0191	0.0243	0.0104	0.1679	21	18	3	Low	Wide
Tab	0.0155	0.0202	0.0249	0.0094	0.1727	11	15	−4	High	Narrow
Tam	0.0162	0.0215	0.0267	0.0105	0.1859	6	4	2	High	Wide
Tla	0.0116	0.0165	0.0215	0.0099	0.1484	30	28	2	Low	Narrow
Ver	0.0098	0.0150	0.0202	0.0104	0.1393	32	32	0	Low	Wide
Yuc	0.0139	0.0193	0.0247	0.0108	0.1721	19	16	3	Low	Wide
Zac	0.0159	0.0198	0.0236	0.0077	0.1644	14	21	−7	High	Narrow
Int. avg	**0.0145**	**0.0195**	**0.0245**	**0.0100**						

Source: Calculations based on Table 4. Abbreviations for the states correspond to Table 2.

The case study verifies the following details listed in the original version:

a. The MP values are lower than those of the GMw because the minimum value penalty is higher in the interval version. The case study confirms this in the original version (Table 5).

b. The absolute difference highlights the significant impact of the minimum value penalty in the MP-GMw ranking. The MP-GMw difference shows that the states with the highest penalties, due to their lower standardized and weighted minimum values, are Colima (Col), Hidalgo (Hgo), and Zacatecas (Zac) (Table 5).

5. *Identification of the most important indicators at the midpoint (MP) and the weighted geometric mean (GMw)*. This task is not addressed in the original version of the performance interval. The rank correlation shows that the two most important indicators (lowest correlation) in the MP simulation are respiratory system diseases mortality rate (RespiraM) and circulatory system diseases mortality rate (CirculaM), with $r = 0.847$, $p < 0.001$, and $r = 0.842$, $p < 0.001$, respectively. The simulation for the GMw confirms the higher relevance of these indicators but adds PM2.5. Another interesting fact is that omitting an indicator has a greater impact on the GMw than on the MP (Table 6).

Table 6 Identification of the most important variables in MP and GMw by rank correlation

Simulation for MP

All indicators		**Without**						
		Physicians	**Nurses**	**Beds**	**MortR**	**RespiraM**	**CirculaM**	**PM2.5**
All indicators	1.000	0.932	0.927	0.929	0.942	**0.847**	**0.842**	0.901
Simulation for GMw								
All indicators	1.000	0.724	0.724	0.724	0.773	**0.597**	**0.597**	**0.597**

* All rank correlation coefficients are significant for $p < 0.001$.

6. *Graph of the intervals and interpretation*. In the interval graph, the states are displayed in descending order of performance summarized in the MP (Figure 1). The gray rectangle, which is not included in the original version, represents the interval average, and the dotted line shows its MP. The original version emphasizes the following aspects in the interval chart:

a. The graph illustrates the hierarchy across three levels of compensation: LB and UB, representing the full non-compensatory and full compensatory extremes, respectively. MP is partially compensatory. The full non-compensatory approach prevents strong performance in one indicator from concealing poor results in others. The MP, like the GMw, is partially compensatory because it allows some degree of trade-off between indicators. UB is full compensatory (it is an average) because an excellent performance in one indicator can offset low performance in another, and it treats essential indicators as if they were completely interchangeable. Full compensatory indices are recommended for public reports or communications due to their simplicity. Full non-compensatory and partially compensatory indices are intended for specialists supporting decision-making, as they require greater technical expertise (El Gibari, Cabello, Gómez, and Ruiz, 2021).

b. One state may perform better than another from a non-compensatory perspective (LB), but do poorly from a full compensatory viewpoint (UB lower). This is the case, for example, with Colima (Col) and Campeche (Cam). The interval of Col is entirely within the interval of Cam.

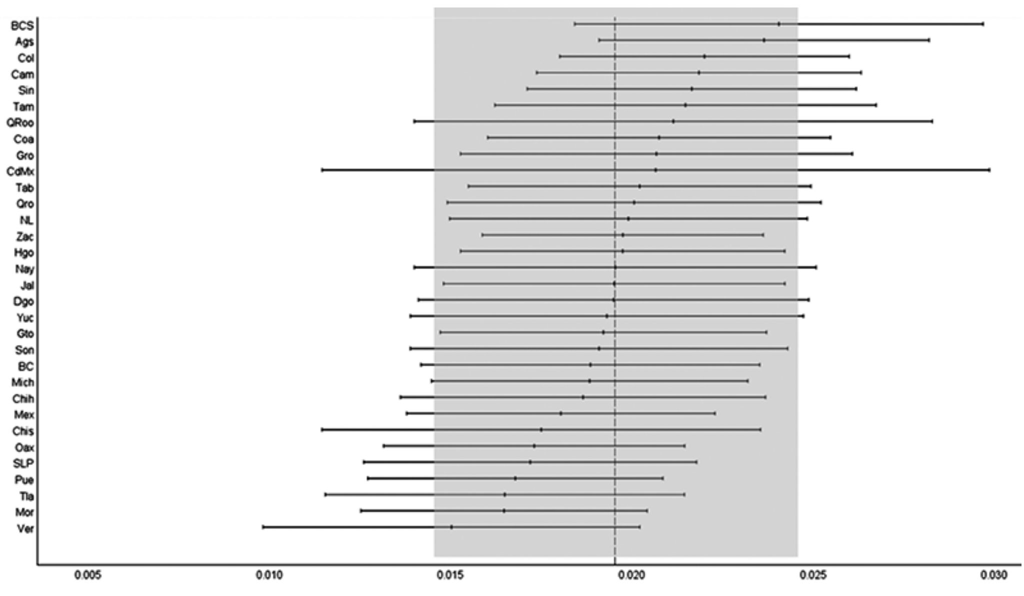
c. A state may be considered a better performer if its LB is higher than the UB of another, regardless of its degree of compensation. There are no cases related to this health situation in the states of Mexico.

d. The narrower the amplitude, the more stable the performance of a state. For example, Mexico City (CdMx) performs better than Tabasco (Tab), but it is less balanced, as shown by its wider amplitude.

7. *Typology based on MP and interval amplitude,* as outlined in the study methodology. This task is not part of the original interval approach but complements it and provides greater clarity. Figure 1 illustrates the components of the individual intervals and their average. The fundamental elements of the interval average—lower limit, upper limit, midpoint, and amplitude—serve as references for evaluating the MP and A of each observation. States to the right of the dotted line perform at higher levels. Segments outside the gray rectangle fall above or below the average rectangle's boundaries. One way to integrate both criteria, MP and A, is to use the interval average to develop a typology for decision-making, as recommended in the methodology. The gray rectangle in Figure 1 helps locate the MP and A of each characterized state within the typology cells.

The average interval allows for the stratification of MP and A, as outlined in the methodology. Combining these stratifications into a cross-tabulation categorizes states into four main groups, each with specific policy recommendations (Table 7).

Figure 1 Performance interval of health indicators.



Source: Table 5. The gray area indicates the interval average, and the dotted line shows its midpoint (MP). Each horizontal line represents a state's interval, with the central mark indicating the MP. The states are ordered by MP in descending order. Abbreviations for the states correspond to Table 2.

The four-group typology in Table 7, derived from performance (MP) and amplitude (A) metrics, provides a starting point for designing targeted interventions to address institutional fragmentation in Mexico's federal health system. Rather than merely redistributing resources, the amplitude metric diagnoses coordination failures across subsystems, including IMSS, ISSSTE, and state *Secretarías de Salud*, enabling precision equity by aligning intervention design with each state's institutional reality.

Table 7 Typology and public policy suggestions for states

Typology	State (minimum value)	Public policy suggested
Robust state with consolidated performance (Midpoint high + narrow interval)	Ags (Beds) Cam (CirculaM) Coa (CirculaM) Col (CirculaM) Hgo (Beds) NL (Physicians) Sin (CirculaM) Tab (CirculaM) Zac (CirculaM)	*Maintain and enhance current performance*: Continue supporting existing programs and consider expanding successful policies to additional states. *Invest in innovation:* Use stability to test advanced programs (e.g., digital health services). *Prepare for future risks:* Strengthen resilience against unexpected shocks, since current performance remains stable.
State with good performance, but unstable or uneven indicators (Midpoint high + wide interval)	BCS (Nurses) CdMx (CirculaM) Gro (Beds) Nay (Beds) Qro (Nurses) QRoo (Beds) Tam (CirculaM)	*Addressing inequality*: Interventions should target intra-state disparities, supporting weaker indicators. *Monitoring and evaluation*: Enhancing data collection and skills to better understand the causes of internal variability. *Responsive programs*: Create flexible policies customized to varied local needs (e.g., health programs).
State with weak but consistent system (Low midpoint + narrow interval)	BC (Physicians) Gto (CirculaM) Jal (RespiraM) Mex (Physicians) Mich (Nurses) Mor (CirculaM) Oax (Nurses) Pue (Nurses) SLP (Physicians) Tla (RespiraM)	*Basic support*: Broad investments in health. *Incremental improvement*: Interventions can be implemented and scaled consistently thanks to uniformity of conditions. *Capacity building*: Strengthen administrative and institutional ability to adopt and carry out reforms.
State with severe risks and a high degree of uncertainty (Low midpoint + wide interval)	Chis (Beds) Chih (CirculaM) Dgo (CirculaM) Son (CirculaM) Ver (CirculaM) Yuc (CirculaM)	*High priority for intervention*: These are the most vulnerable regions that require immediate and adequately resourced actions. *Tailor-made approaches*: There is no one-size-fits-all solution; craft local policies. *Local involvement*: Engage community members to identify particular issues and encourage participatory growth.

Group 1: Robust states with consolidated performance (Aguascalientes, Zacatecas, Nuevo León) exhibit high MP and narrow amplitude, signaling systemic coherence in which resources, status, and risks align. This reflects successful cross-institutional coordination. The operational pathway positions these states as integration laboratories: formalize cross-institutional referral protocols through state *Comisiones de Salud*, building on Aguascalientes' integrated electronic records system; target municipal peripheries where amplitude begins to widen by deploying mobile non-communicable disease (NCD) clinics funded by the federal catastrophic expenditure fund; and monitor amplitude stability over time, using widening A as an early warning signal for preemptive coordination even when overall performance remains steady.

Group 2: High-performing but unstable states (Mexico City, Quintana Roo, Baja California Sur) show high MP but wide amplitude, indicating institutional decoupling, in which resource concentration fails to reduce mortality due to coverage gaps. Mexico City's paradox (high physician density yet the worst circulatory mortality rates) stems from residents' reliance on underfunded state services despite their proximity to inaccessible IMSS facilities. The pathway implements outcome-linked coordination: redirect a portion of IMSS-Bienestar transfers to fund a shared NCD registry jointly managed by the federal SSA and the city government, with facility bonuses tied to cross-institutional verification of patient outcomes; send promotores to high-pollution, high-informality *colonias populares* to conduct screenings and escort patients to the nearest facilities regardless of affiliation, supported by transportation vouchers; and apply *Fondo de Aportaciones para los Servicios de Salud* (FASSA) flexibility clauses to permit spending on cross-institutional coordination rather than facility-specific inputs, directly addressing the resource-outcome decoupling.

Group 3: Weak but consistent states (Oaxaca, Puebla, Guerrero) show low MP and narrow amplitude, indicating uniform underdevelopment (all indicators move together at low levels) and signaling systemic capacity deficits rather than misalignment. The pathway prioritizes limited infrastructure: channel *Programa de Fortalecimiento para la Salud* (PROSA) funds toward integrated primary care units that combine physician staffing, NCD screening equipment, and air quality monitors to address all three dimensions simultaneously and prevent new resources from replicating fragmentation; focus on indigenous municipalities where narrow amplitude masks ethnic inequities, embedding bilingual community health workers within PROSA units to ensure culturally competent care without creating parallel systems; and avoid quick-win mortality interventions that could widen amplitude by improving outcomes without strengthening local resources, thereby creating dependency and future volatility.

Group 4: States with severe risks and high uncertainty (Veracruz, Chiapas, Chihuahua) show low MP and wide amplitude, signaling a structural crisis in which indicators move in opposing directions due to institutional collapse in specific domains. The pathway implements emergency triage with accountability: activate the federal *Early Warning Mechanism* to declare health system emergencies in critical municipalities, enabling direct SSA management while rebuilding coordination capacity; use amplitude as a targeting metric, prioritizing municipalities where A exceeds the state average (e.g., by over 30%), and deploy mobile surgical units for acute mortality spikes while negotiating ad hoc institutional protocols; and establish a clear exit strategy, transitioning back to state management only after amplitude narrows (e.g., below 0.010) for two consecutive years, ensuring stability precedes autonomy.

This operationalization shows that amplitude is not merely diagnostic but also a tool for intervention design. Traditional rankings would misguide policy: deprioritizing Mexico City despite its fragmentation crisis, or treating Oaxaca and Veracruz as identical low performers, even though they require opposite interventions. Critically, all pathways rely on existing Mexican institutional mechanisms (FASSA flexibility, *Comisiones de Salud*, PROSA) rather than proposing politically infeasible system-wide integration. This transforms the analysis from a methodological exercise into an applied, actionable tool for SSA policymakers addressing Mexico's documented segmentation crisis, advancing both theoretical innovation and practical implementation to strengthen equitable health systems.

4 DISCUSSION

The performance interval approach reveals critical dimensions of Mexico's health system that conventional single-value indices obscure, particularly the internal heterogeneity of state-level health systems and the policy implications of that heterogeneity. Performance intervals bound composite indices between non-compensatory (e.g., minimum value) and fully compensatory (e.g., arithmetic mean) extremes, with the midpoint approximating partial compensability, as with geometric means. Averages or single indices assume fixed substitutability, which can over-penalize or over-compensate unbalanced units; intervals quantify this range explicitly. This approach also reveals how conventional composite indices obscure the critical heterogeneity of indicators within jurisdictions.

Key findings reveal severe resource-outcome decoupling in Mexico's health system, exemplified by Mexico City. Ranking 9th by midpoint, Mexico City exhibits the nation's widest amplitude, indicating extreme disparity between abundant resources (physicians, nurses) and the worst mortality outcomes. This paradox highlights institutional fragmentation rather than scarcity. Among low-performing states, Veracruz shows chaotic imbalance (wide amplitude), requiring targeted rebalancing, while Oaxaca displays uniformly weak performance (narrow amplitude), demanding broad capacity-building. These distinctions are lost in conventional rankings. Sensitivity analysis further shows that Mexico's imbalance stems from inefficient resource-to-outcome conversion rather than input scarcity. By diagnosing why systems underperform, the approach enables precision equity: directing institutional reform to volatile systems (Veracruz), innovation investments to stable, high-performing systems (Aguascalientes), and emergency triage to states with both low performance and high uncertainty (Chiapas). This moves health economics beyond ranking-based resource allocation toward balanced, indicators-aware policy.

A possible explanation for wide intervals in high-resource states is institutional decoupling rather than resource scarcity. This paradox reflects institutional fragmentation within an urban epidemiological transition, not resource scarcity. This dissociation arises from four interacting mechanisms:

a. *Segmented coverage*: Mexico City illustrates the consequences of institutional fragmentation and social segmentation. Despite its exceptional health infrastructure, it has the nation's highest circulatory mortality (Table 2). About 38% of Mexico City's population relies on underfunded state-level services (Secretaría de Salud capitalina), while federal regimes (IMSS/ISSSTE) serve formal-sector workers, creating access gaps even with near resources (Gómez-Dantés et al., 2023).

b. *Urban risk concentration*: Daily PM2.5 exposure (17.2 μg/m^3), above the WHO 24-hour limit (15 μg/m^3).

c. *Cost-sharing barriers and geographic segregation within the metropolis*: obesogenic environments exacerbate the non-communicable disease (NCD) burden among informal workers and marginalized colonias, where proximity to resources does not translate into use.

d. *Outcome accountability gaps*: Mexico's historical focus on input metrics (beds, personnel) in performance evaluation emphasizes infrastructure investment without linking it to mortality outcomes, precisely why amplitude exposes what averages conceal. Quintana Roo exhibits a mirror pattern: tourism-driven resource concentration (hospital infrastructure for visitors) coexists with population-level vulnerability to respiratory mortality (36.1/100 000), revealing how economic specialization fragments health systems within states.

Why does circulatory/respiratory mortality dominate composite performance? The sensitivity analysis (Table 6) shows that respiratory ($r = 0.847$) and circulatory ($r = 0.842$) mortality are the most influential indicators, reflecting Mexico's advanced epidemiological transition but uneven institutional adaptation across and within states. Unlike resource indicators (physicians, beds) that measure system capacity, these mortality metrics capture system effectiveness, which is fragmented across Mexico's institutional system. This explains why amplitude becomes policy-relevant: it quantifies the gap between capacity and effectiveness created by fragmentation, making visible the institutional failures that single-value indices cannot capture.

Policy implications. As detailed in the typology, wide intervals in resource-rich states signal not a need for more inputs but for integration mechanisms, such as shared electronic records across national and local facilities, unified referral protocols for NCDs, and outcome-based financing that penalizes institutional fragmentation. Conversely, narrow intervals in low-performing states (Oaxaca, Puebla) reflect uniformly weak systems, where input expansion remains necessary but insufficient without parallel governance reforms to prevent new resources from merely replicating existing fragmentation in wide-interval states. The amplitude metric thus shifts the policy question from 'how much should be invested?' to 'which institutional arrangements are most effective at converting resources into mortality reduction? and 'which institutional system will convert resources into mortality reduction?' This diagnostic precision is essential for addressing Mexico's documented segmentation crisis.

CONCLUSION

The performance interval approach used for the indicators selected for Mexican states is an innovative and statistically reliable tool for assessing regional health. This method combines average performance with the indicators' internal variability. This dual focus offers a more comprehensive view of health, highlighting states with consistent, balanced performance; those with good conditions but internal disparities; and those with weak systems and high uncertainty.

The method used shows that it is important to consider both average results and the balance of internal indicators for a full diagnosis. The performance range measures the overall effectiveness and consistency of the health system, highlighting aspects that traditional methods, such as averages or rankings, might overlook.

The methodology goes beyond traditional approaches by analyzing all three compensation levels simultaneously within the performance interval. This improves the technical interpretation and clear communication of the results, making it suitable for application in other public policy sectors and for public health officials in Mexico.

The study also emphasizes that mortality rates from respiratory and circulatory diseases are most critical for estimating the partially compensatory composite index (MP). This finding underscores the need to target these indicators to improve population health without neglecting institutional fragmentation.

Moreover, the strong correlation between the midpoint and the weighted geometric mean confirms the index's consistency. At the same time, the interval's width highlights the states with the greatest internal imbalance, a key consideration for fair resource distribution.

This study advances the health economics literature by reframing regional health system inequality not only as a gradient of resource scarcity but also as an internal imbalance among indicators. Interval-based findings, such as performance intervals in composite indices, reveal imbalances across indicators that single-value averages or rankings often mask, leading to more cautious policy decisions. A policy focused on the internal heterogeneity of indicators within each state targets imbalances, such as low life expectancy despite high income, whereas average-based rankings might uncritically place high-income units at the top. Analytically, the interval methodology reframes health policy to prioritize equilibrium (short intervals) over interventions that inadvertently reinforce spatial imbalances by overcompensating weak indicators with strong ones.

Rather than generic prescriptions to address inequality, the interval approach shows that Mexico's state-level indicator imbalances may stem not only from resource scarcity but also from institutional decoupling across parallel health subsystems, including IMSS (formal-sector workers), ISSSTE (public employees), and *Secretaría de Salud* (uninsured/residual population).

Operationalization pathway. The federal Ministry of Health (SSA) and the states should co-design an outcome-based referral protocol to address current imbalances in indicators. First, implement the 2023 General Health Law reforms by establishing joint coordination councils to create a unified non-communicable disease (NCD) registry across public health institutions (e.g., IMSS, ISSSTE, and SSA) to ensure continuity of care. Second, redirect a percentage (e.g., 15%) of IMSS-Bienestar transfers toward outcome-linked payments, rewarding facilities for achieving 80% disease control rather than consultation volume, focusing on mortality reduction over inputs. Third, deploy public community health workers to marginalized areas with high levels of informal employment to conduct door-to-door screenings and escort patients to the nearest facilities using state-funded transport vouchers, regardless of institutional affiliation. Finally, measure success by the reduction in amplitude, narrowing the gap between resource indicators and catastrophic disease outcomes. A target of a 20% reduction in amplitudes over three years would indicate effective institutional integration. This strategy prioritizes impact over indices, incentivizing results rather than system saturation while ensuring excluded populations have access to care.

This intervention fundamentally differs from single-value approaches. For example, traditional single-value indices might classify Mexico City as moderately performing (MP rank 9) and deprioritize it for resource allocation. In contrast, amplitude diagnostics highlight its institutional fragmentation, which calls for coordination mechanisms instead of additional resources. Notably, the proposed approach suggests using Mexico's existing legal framework, such as coordination councils and IMSS-Bienestar transfers, rather than pursuing impractical system-wide integration due to current federalism and political limitations.

Future research should examine how the sensitivity of the performance interval varies across different normalization or weighting criteria for indicators. It is also advisable to investigate the included and excluded indicators separately, examine the relationship between the composite index and economic variables such as GDP, and relate the index results to the types of health programs implemented in each state.

AUTHOR STATEMENT

Jesus A. Trevino-Cantu. The author was solely responsible for the conception and design of the study, data acquisition and analysis, adaptation and extension of the composite index methodology, interpretation of results, and preparation and revision of the manuscript, including intellectual content.

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