International Journal of Innovative Research and Scientific Studies, 8(1) 2025, pages: 2364-2373

IJIRSS
International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Using data-driven weightings to construct the provincial healthcare system index

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Abstract

The healthcare system is essential in delivering services that enhance the quality of life and contribute to the Sustainable Development Goals (SDGs) worldwide. Thus, measuring the effectiveness of healthcare systems is important. This study introduces a Provincial Healthcare System Index (PHSI) as a composite index that integrates macro- and micro-level data to assess the readiness and capacity of provincial healthcare systems, with an application to Vietnam, an emerging economy. Importantly, principal component analysis was used to derive data-driven weightings for the PHSI instead of a priori subjectively defined ones. The empirical results show that the average 2021 PHSI in Vietnam is notably low at 0.199, indicating a significant lack of preparation and capacity in converting healthcare resources into outcomes. The marked disparity among neighboring provinces suggests that their healthcare systems are still disconnected. The study highlights the need for Vietnamese policymakers to enhance the resources and outcomes of its provincial healthcare system. Improving provincial connectivity could significantly enhance the overall efficiency of the regional and national healthcare systems in Vietnam. Such implications could be further extended to other emerging economies.

Keywords: Composite indices, Healthcare management, Provincial, Sustainable development goals, Vietnam.

DOI: 10.53894/ijirss.v8i1.4993
Funding: This study received no specific financial support.
History: Received: 2 January 2025 / **Revised:** 5 February 2025 / **Accepted:** 15 February 2025 / **Published:** 28 February 2025

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Publisher: Innovative Research Publishing

1. Introduction

The healthcare system is essential for maintaining and improving the health of individuals and communities. It includes hospitals, clinics, and healthcare professionals such as doctors and nurses, which generally provide critical healthcare services such as disease prevention, treatment, and management. In addition to individual health, a robust healthcare system contributes significantly to public health initiatives, addressing issues such as sanitation, nutrition, and health education. These efforts promote community well-being and can lead to long-term reductions in healthcare costs.

Economically, the healthcare sector generates jobs and drives innovation, supporting a productive workforce that contributes to economic growth. Thus, the effectiveness of healthcare systems directly impacts overall health outcomes and the quality of life within society [1, 2]. The United Nations has, therefore, defined healthcare as a crucial component of the Sustainable Development Goals (SDGs), including the SDG3 Good Health and Well-being, SDG5 Gender Equality, and SDG11 Sustainable Cities and Communities [3].

There are various attempts to examine and evaluate the healthcare systems across countries and regions [4, 5]. While most of them agreed on the importance of healthcare, its evaluation is inconclusive, mainly due to two reasons. Firstly, the healthcare system has only been analyzed either at the national [5, 6] or hospital level [7, 8]. Since data (and research models) of the cross-country and country-specific approaches are different, it may lead to conflict findings: for instance, Mujasi, et al. [7] found that Ugandan hospitals are generally performing well with a 91.4% level of technical efficiency whilst Kim and Kang [6] found that the healthcare system in Uganda only scored a low value of 29.8% in terms of efficiency. Secondly, the popular method of evaluation in healthcare assessment is Data Envelopment Analysis (DEA) [9] such a method can only measure the relative performance of the units (e.g., countries or hospitals) involved. Therefore, DEA results are dependent and constrained on the cross-country or country-specific samples.

As discussed in Gerami, et al. [10] and Boubaker, et al. [11] among others, a composite index (CI) would be of better use because (i) it does not require the categorization of data into inputs and outputs, (ii) it is simpler to calculate, and (iii) it has the characteristics of an absolute measurement. This study contributes to the literature as the first to use province-level data (e.g., the number of hospitals, doctors and nurses) to construct a provincial healthcare system index (PHSI). In this sense, it is also the first study to evaluate the healthcare system in Vietnam empirically – the country was chosen as a case study thanks to its resilience in the recent COVID-19 pandemic [12, 13] but our findings could still be extended to other emerging economies.

The remainder of the paper is organized as follows. Section 2 provides a brief review of the relevant literature on the examination and evaluation of the healthcare system. Section 3 presents the methodology and data. Section 4 reports and discusses the empirical findings while Section 5 concludes the paper.

2. Literature Review

2.1. Healthcare system: Cross-country evaluation

The study of Kim and Kang [6] employed bootstrap DEA to evaluate healthcare system efficiency across 170 countries based on data from the World Bank. In this sense, each country was considered an independent healthcare system utilizing two key inputs (Schooling years and Public health expenditure) to provide two important health outcomes (Life expectancy and Child mortality rate). The findings revealed that most countries struggled to maximize healthcare outcomes, given their inputs, with only 16.7% performing efficiently. High-income countries generally exhibited higher efficiency, while Asian countries outperformed others across all categories. The study consequently recommended that countries with inefficient healthcare systems should formulate practical strategies by adopting best practices from their regional peers. It was also noted that simply increasing public expenditure on healthcare may not always yield the desired outcomes, as there is a weak correlation between public spending and health status [14, 15].

In a similar vein but utilising a different approach, Basu, et al. [16] systematically reviewed previous studies and reports on the healthcare system in middle- and low-income countries, published from January 1980 to August 2011. Data from 102 relevant articles (out of 1178 initial ones) were organized into six WHO health system themes, including Accessibility and responsiveness; Quality; Outcomes; Accountability, transparency, and regulation; Fairness and equity; and Efficiency. The review highlighted that private healthcare is not necessarily more efficient than public healthcare, noting that while the private sector provides significant outpatient services, it often violates medical standards and yields poorer outcomes. The public sector, on the other hand, is criticized for lacking timeliness and hospitality towards patients and facing resource limitations. Competition between healthcare sectors may help reduce drug prices, but the private sector can also increase costs due to unnecessary treatments and higher drug prices. Overall, the review suggested that healthcare quality improvement is still important for both the public and private sectors, particularly in terms of medical education, addressing the conflict of interest for physicians and drug store owners, regulation and consumer education, transparency in public medical subsidies, and so on.

Morgan, et al. [17] deepened the systemic review in Basu, et al. [16] by looking at 51 studies on the performance of private healthcare providers. The authors highlighted the varying role of the private sector in achieving universal health coverage, noting that performance is contingent on quality, access equity, and efficiency. The study also emphasized that government interventions should address the entire private sector rather than individual providers because, in the healthcare system, the performance of the private sector is closely linked to the structure of the public sector. It, therefore, raised concerns about equity, as private providers often cater to wealthier populations, while informal providers dominate care for the poor in low-income countries. Inefficiencies arising from overprescribing and weak regulation are also identified, alongside the need for comprehensive regulatory responses. The authors concluded that addressing the private sector's performance is essential for improving the overall healthcare system outcomes, with larger facilities potentially enhancing quality and efficiency, particularly under favourable economic conditions.

Uyar, et al. [18] employed the fixed-effects panel data regression analysis to investigate the relationship between corporate social responsibility (CSR), board structure, and firm performance in the healthcare sector for 2644 firm-year observations (2011-2018) of nearly 90 thousand companies trading across more than 120 countries. The findings highlight the positive impact of female directors on healthcare firms' performance and emphasize that CSR activities enhance reputation and stakeholder relations. The research, therefore, underscored the significant influence of board structure on both financial and CSR performance, filling a literature gap in healthcare governance. However, as the study focused on firm-level performance, it did not examine the differences across countries and no macro-level implication nor recommendation was suggested.

2.2. Healthcare System: Country-Specific Evaluation

As previously introduced, DEA is a popular tool for healthcare and hospital performance evaluation. Sikka, et al. [4] employed DEA to measure the efficiency of hospital-based clusters of American hospitals in 2004. Accordingly, it evaluated 412 multihospital systems across 638 clusters, finding that only 20 clusters (5.8% of the sample) received the highest possible efficiency score of 100% while the sample's average efficiency score was 73%. Therefore, it was suggested that there is room for capacity improvement in the US healthcare system. Recommendations for such improvements included hospital expansion, particularly in terms of the number of hospital beds and urban hospitals. Meanwhile, Mujasi, et al. [7] studied the efficiency of Ugandan referral hospitals in 2012-2013 employing a two-stage Data Envelopment Analysis (DEA) and Tobit regression approach. Particularly, the study evaluated how Ugandan hospitals utilized inputs (medical staff and hospital beds) to provide healthcare services (outpatient visits and inpatient days). The authors found that the average technical efficiency score of the hospitals was 91.4%, indicating a high level of performance in the Ugandan healthcare system. The paper consequently recommended that Ugandan policymakers should aim at improving the performance of low-efficiency hospitals by reducing their size and accordingly the bed occupancy rates. Other studies employing DEA (or other frontier methods such as Stochastic Frontier Analysis and Free Disposal Hulls) to evaluate the performance of hospitals include [19] for 101 Vietnamese hospitals during the 1998-2006 period, Flokou, et al. [20] for 107 Greek NHS hospitals between 2009-2013, Ho and Huang [21] for 538 US hospitals in 2013, and so on.

Grigoroudis, et al. [22] followed another method, the Balanced Scorecard (BSC), to evaluate the performance measurement of the Provisional Governmental Hospital of Didimoticho (GHD), a public secondary-level hospital providing healthcare services to the local population under poverty surrounding Didinmoticho, a northeastern town of Greece. Particularly, the study examined how the GHD performed in relevant to its strategic objectives including the Financial, Customer, Internal business, and Learning and growth aspects. The results of this analysis showed that, while there was a substantial improvement in the Learning and growth dimension from 0.197 in 2006 to 0.738 in 2007, improvements in the other three dimensions were marginal and thus, there was a need for revision in the implementation of the GHD strategy.

Cinaroglu [23] employed a path analytic approach to examine the health resource allocation in Turkey, utilizing data from hospitals across 81 Turkish provinces. In this sense, the study assessed the interrelationships between health service variables, particularly hospital beds and health professionals, in contributing to health outcomes. The findings reveal a strong connection between the number of beds and health outcomes, emphasizing that optimal capacity planning is crucial for sustainable health services in Turkey. However, high bed occupancy rates may negatively affect physician (ratio) numbers and reduce the productivity/efficiency of the healthcare workforce, which later mitigates the contribution of health professionals to health outcomes. Consequently, the study underscores the importance of effective health workforce planning and the interrelationships between hospital size and service utilization in Turkey.

2.3. Healthcare System: Composite Indices Evaluation

The early work of Berndt, et al. [24] tried to evaluate the inequities of the healthcare system using the Gini index at the ZIP code level. Particularly, a Healthcare Gini Index was constructed based on over 300 health and social indicators for roughly 875 ZIP codes throughout Florida. It then compared those data against the state's average and the peer community's average to inform policymakers about healthcare disparities. By incorporating economic and social justice perspectives into healthcare analysis, the Healthcare Gini Index effectively quantified health-related burdens inequities, such information is valuable for policymakers and local stakeholders to reduce wealth-related variations in the healthcare system.

Dönmez, et al. [25] developed a Global Healthcare Competitiveness Index (GHCI) using statistical analysis and nonlinear optimization models. The GHCI was constructed based on 2019 national-level data on GDP, GDP per capita, life expectancy, and other healthcare system characteristics such as the number of beds, nurses, midwives, and physicians. It covered 53 middle- and high-income countries with a GDP per capita of over $10,000, and the resulting GHCI had an average of 2.4758 but most countries (46 out of 53 or nearly 87%) were under the optimum GHCI values. As such, it was suggested that those countries need to improve their GHCI scores immediately by focusing on economic development and consequently, the national healthcare expenditures. The study, therefore, provided a foundation for future research on healthcare competitiveness, although the study acknowledges limitations, such as insufficient data on hospitals.

The work of Barua [26] is the closest to the recent study since it also constructed a provincial healthcare index, particularly for Canada in 2010. Specifically, the index was constructed from 46 healthcare indicators of 10 Canadian provinces, covering four dimensions: Availability of resources, Use of resources, Access to resources, and Clinical performance. The calculation of the index followed a simple Min-Max approach to normalize the overall scores of the four dimensions across the 10 provinces, i.e., each dimension was treated equally and accounted for 25% of the weight of the index. The findings suggested that Quebec was the top while Prince Edward Island was the bottom performer.

2.4. Summary

- Cross-countries studies on the healthcare systems use either macro-level (panel) data analysis, mainly via the econometrics and DEA methods, or systemically review the previous literature.
- Country-specific studies are dominated by DEA and mostly focused on hospitals, i.e., the micro-level.

- Composite index studies are still limited, with specific indices on the provincial healthcare systems even rarer. The provincial healthcare index proposed by Barua [26] followed an equal weights approach, which is subjective and may lead to inaccurate results because each province should evaluate each dimension differently and thus, they should have different weights depending on their circumstances. It may explain why the index was a one-off study and no further update was sighted.
- Therefore, it is important to construct a PHSI that stands between macro- and micro-levels utilizing objective and data-driven weights to evaluate the readiness and capacity of the healthcare systems in Vietnamese provinces.

3. Research Methodology

The OECD [27] Handbook argued that a CI can provide simple comparisons between the analysed units (often countries) in terms of more complex (and sometimes elusive) aspects in wide-range fields such as economy, society, technology, and environment. In addition, a CI is more understandable by a large society without any specific knowledge requirement, compared to other academic measurements such as the DEA efficiency scores. The Handbook also presented several methods to construct a composite index, alongside their pros and cons; the cons arise when the construction is incorrect, e.g., untransparent or missing indicators [27]. As such, when properly constructed, a CI is a simple but useful analytic measurement that stands between narratives and analysis in providing information for policymakers and managers. In this study, for the first time, a PHSI is constructed to measure the readiness and capacity of the Vietnamese healthcare system at the provincial level. The construction of the PHSI, following the CI literature [25-28] is illustrated in Figure 1. The following sub-sections discuss the particular steps involved in this study.

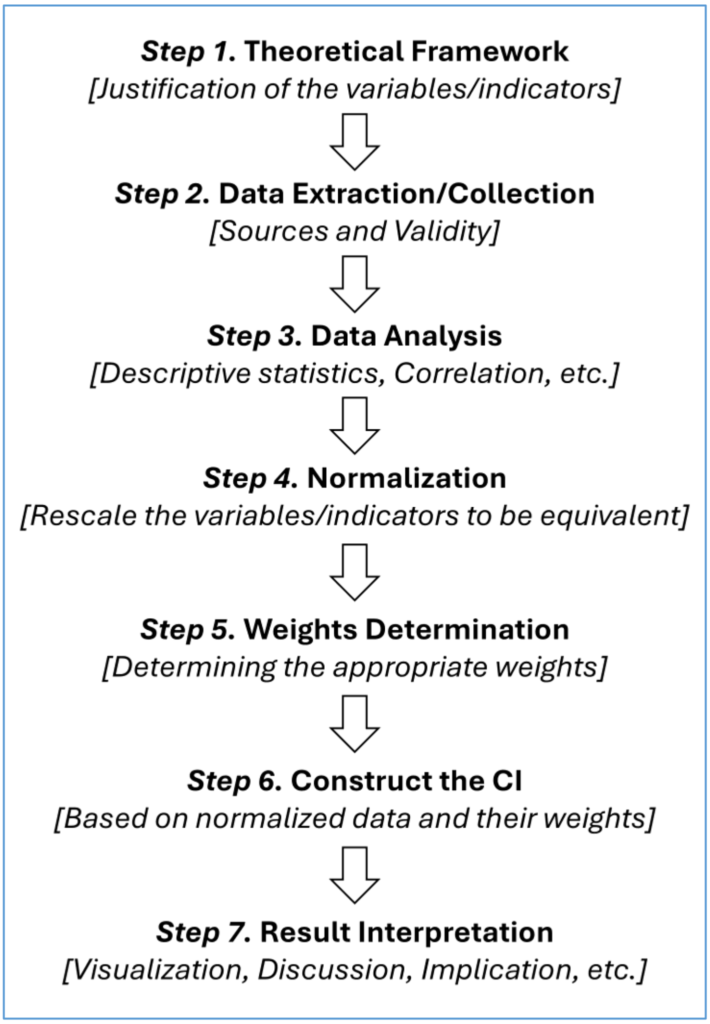

Figure 1.
Basic steps for CI construction [27].

3.1. Theoretical Framework of the PHSI

As summarized in Section 2.4, the purpose of the PHSI is to evaluate the readiness and capacity of Vietnamese provincial healthcare systems utilizing hybrid micro- and macro-level data. Among other factors, the readiness and accessibility of the healthcare system are reflected in the system of health establishments in both cross-country and country-specific studies Cantor and Poh [9] and Barua [26] and thus, the number of hospitals and medical clinics is utilized in this study as an important indicator. Consequently, the number of doctors and nurses, and the availability of clinical beds are important capacity indicators of the healthcare system, affecting how the system can provide healthcare services to the population, as examined in Mujasi, et al. [7]

and Cinaroglu [23] among others. For the outcome, the capacity also is reflected in the number of outpatients [8, 14]; in this study, it is measured by the number of those who were health examined, tested, and treated in each province. The measurements and codes for the indicators of the PHSI are further presented in Table 1.

Table 1.
The indicators of PHSI.

Indicator	Code	Definition/Measurement	Role in PHSI
Establishments	E	Number of polyclinics, special clinics, family doctors, and health centers	Resource
Doctors	D	Number of Doctors in health establishments	Resource
Nurses	N	Number of Nurses and other types of employment in health establishments	Resource
Beds	B	Number of real hospital beds in health establishments	Resource
Patients	P	Number of those who were health examined, tested, and treated in health establishments	Outcome

3.2. Data Collection, Analysis, and Normalization

Our data was extracted from the recent report entitled "Vietnam Health – Figures and Assessments from the Economic Census 2021" published by the General Statistics Office of Vietnam [29]. It provides the most updated information on the provincial healthcare system in Vietnam, with data broken down at the provincial level for 63 provinces – their list is provided in Appendix 1. While the report showed that between 2016 and 2021, the Vietnamese healthcare system had achieved some positive results (e.g., the increase in health establishments, and the enhancement in infrastructure and human resources to provide healthcare services), it did not provide a deeper evaluation at the provincial level.

Table 2.
Descriptive statistics of the indicators.

Indicator	Unit	Mean	Standard deviation	Min	Max
E	Establishments	543.00	622.22	89.00	4390.00
D	Thousand persons	1.75	2.53	0.49	16.81
N	Thousand persons	7.38	10.30	1.48	72.91
B	Thousand beds	7.24	8.77	1.33	56.58
P	Million persons	5.44	13.40	0.48	87.50

The descriptive statistics of the five indicators of PHSI are reported in Table 2. Table 3 further presents the correlation between them, showing that they are highly correlated with each other and thus, justifying the requirement for the PHSI 's components [26, 27].

Table 3.
Spearman's ranking correlation analysis

E				
0.6462	**D**			
0.7747	0.9162	**N**		
0.5956	0.9323	0.8910	**B**	
0.8090	0.7812	0.8732	0.6717	**P**

Note: All are significant at1% level.

Normalization using a Min-Max approach is a way to rescale all indicators into equivalent measurements that can be aggregated into the PHSI [26]. For instance, Table 2 shows that indicator P is measured in million patients while indicator D is in thousand doctors – a direct combination of the two into the PHSI will be difficult and inaccurate [28]. The normalization follows the equation of

$$X^* = \frac{X - X_{min}}{X_{max} - X_{min}} \quad (1)$$

where X^* denotes the normalized value; X represents the indicators E, D, N, B, and P, respectively; X_{min} is the minimum while X_{max} is the maximum value of X, respectively. After the normalization, all indicators are thus rescaled into the [0,1] intervals.

Consequently, the PHSI is calculated as

$$PHSI_j = w_E E_j + w_D D_j + w_N N_j + w_B B_j + w_P P_j \quad (2)$$

Subject to

$$w_E + w_D + w_N + w_B + w_P = 1 \text{ or } 100\% \quad (3)$$

where w_1, w_2,.., w_5 are the appropriate weights assigned for each indicator E, D, N, B, and P, respectively; and j ranges from 1 to 63 representing the province under examination.

3.3. A Data-Driven Approach for the Weights of PHSI Variables: The Principal Component Analysis

There are various ways to determine the weights of a composite index OECD [27] and Hammami, et al. [30]. Decancq and Lugo [28] and Boubaker, et al. [11] among others, argued that it would be better to have the weights subjectively data-driven. The recent development of big data and artificial intelligence [31-33] also contributes to the justification of the data-driven weights for our PHSI.

Among several data-driven methods of weights determination [see, for example, Decancq and Lugo [28]], we follow the statistical approach to examine the appropriate weights of our PHSI. In statistics, the principal component analysis (PCA) is an unsupervised machine learning method to simplify a dataset into smaller sets or components while maintaining significant information from the source dataset [34]. Accordingly, the principal components generated by PCA are a few linear combinations of the original variables that account for the maximum variance of all the variables [35]. It is, therefore, argued that such combinations reflect the importance of each variable in the original dataset and thus, they can be used as the weights for the composite index constructed from the same data [36, 37].

Specifically, consider our original dataset X as a matrix of 63 rows (representing the provinces) and five columns (representing the indicators).

$$X = \begin{pmatrix} E_1 & D_1 & N_1 & B_1 & P_1 \\ E_2 & D_2 & N_2 & B_2 & P_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ E_{63} & D_{63} & N_{63} & B_{63} & P_{63} \end{pmatrix} \tag{4}$$

PCA aims to transform it into a new matrix Y using the vector of load factor P (p_E, p_D, p_N, p_B, p_P), so that

$$Y = PX = \begin{pmatrix} p_E E_1 & p_D D_1 & p_N N_1 & p_B B_1 & p_P P_1 \\ p_E E_2 & p_D D_2 & p_N N_2 & p_B B_2 & p_P P_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ p_E E_{63} & p_D D_{63} & p_N N_{63} & p_B B_{63} & p_P P_{63} \end{pmatrix} \tag{5}$$

For our sample, the first generated principle component accounts for about 83% cumulative information of the original data with a corresponding eigenvalue of 4.15 (see Table 4), suggesting that it is a strong and meaningful 'compression' of the data [34, 35].

Table 4.
PCA results.

Part A. The principal components.

Component	Eigenvalue	Difference	Proportion	Cumulative
Component 1	*4.1538*	*3.5291*	*0.8308*	*0.8308*
Component 2	0.6247	0.4378	0.1249	0.9557
Component 3	0.1869	0.1591	0.0374	0.9931
Component 4	0.0278	0.0209	0.0056	0.9986
Component 5	0.0068	---	0.0014	1.0000

Part B. The weights

Weight	Component 1	Component 2	Component 3	Component 4	Component 5
E	0.4525	0.0480	-0.8901	0.0117	0.0242
D	0.4815	-0.1954	0.2103	-0.1278	-0.8182
N	0.4766	-0.2296	0.2349	-0.6467	0.4967
B	0.4729	-0.2650	0.2438	0.7513	0.2868
P	0.3357	0.9146	0.2212	0.0274	0.0317

Accordingly, the relationship between the factors P (p_E, p_D, p_N, p_B, p_P) within Component 1 will represent the importance of each indicator E, D, N, B, and P. Given the constraint in Equation (3), P is transformed into the appropriate weights of our PHSI as follows.

$$w_i = \frac{p_i}{p_E + p_D + p_N + p_B + p_P} \tag{6}$$

where i runs from 1 to 5 representing the indicators E, D, N, B, and P, respectively.

Utilizing the first column of Part B in Table 4, we calculated that $w_E = 0.2039$, $p_D = 0.2170$, $p_N = 0.2148$, $p_B = 0.2131$, and $p_P = 0.1513$; they are used to construct the PHSI for further analysis.

4. Empirical Results

4.1. The PHSI for Vietnamese Provinces

Table 5 reports the summary statistics of the PHSI for 63 Vietnamese provinces in 2021, indicating that the provincial healthcare systems were averagely at low readiness and capacity regarding their resources and outcomes. More importantly, disparities occurred across provinces, regions, and quantiles: the worst performers concentrated in the Northern and Central Highlands (in both minimum and average PHSI values) while the top performers are in the Red River Delta and Southeast regions.

Table 5.
The PHSI of Vietnam in 2021

Variable	Mean	SD	Min	Q1	Q2	Q3	Max.
PHSI	0.199	0.322	0.001	0.068	0.132	0.205	2.043
In which							
Red River Delta	0.343	0.568	0.046	0.139	0.155	0.228	2.043
Northern	0.079	0.051	0.001	0.050	0.065	0.120	0.160
Central Coast	0.174	0.142	0.030	0.087	0.129	0.200	0.504
Central Highlands	0.097	0.065	0.022	0.035	0.120	0.132	0.174
Southeast	0.445	0.627	0.090	0.102	0.178	0.381	1.696
Mekong River Delta	0.157	0.072	0.068	0.104	0.144	0.212	0.291

Note: SD, standard deviation; Q1, Q2, Q3 represent the 1st, 2nd, and 3rd quartiles, respectively.

We further illustrate the disparities in terms of PHSI and its indicators between the top and bottom provinces in Figure 2. In the first part of Figure 2, we accordingly observe that the Top-5 provinces, on average, had their PHSI twelve times higher than that of the Bottom-5 thanks to their superiority in terms of resources (E, D, N, ad B) and outcomes (P), which were about 14 to 30 times larger. Importantly, we also found that the efficiency of converting resources into outcomes of the Top-5 was much higher than its counterpart, with the positions of the values for B, N, D, and E are relatively similar for the two groups but the position of P was much higher for the case of the Top-5.

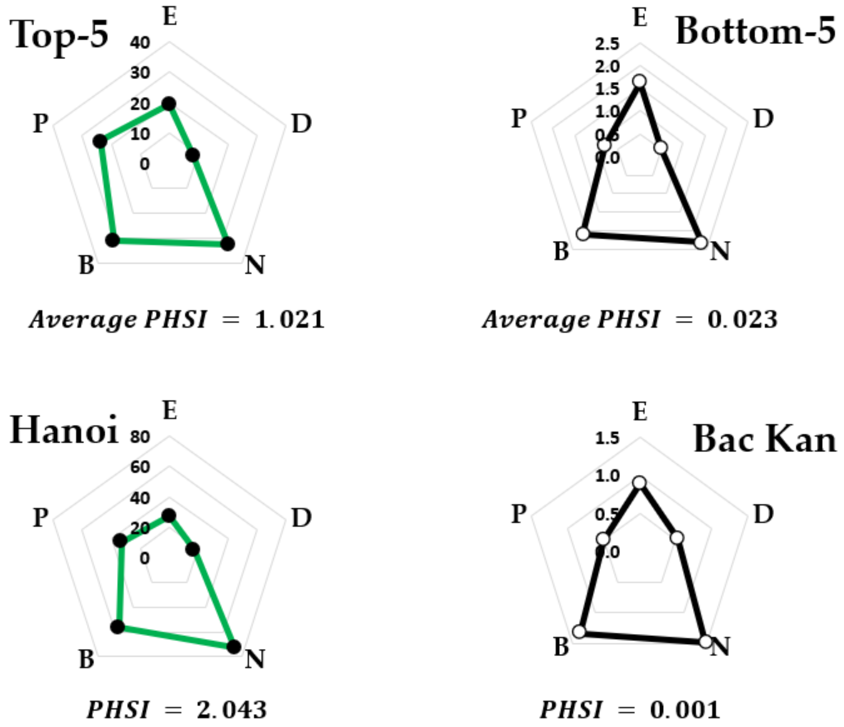

Figure 2.
PHSI for the top and bottom provinces.
Note: E, number of healthcare establishments (in thousand); D, number of doctors (in thousand); N, number of nurses (in thousand); B, number of hospital beds (in thousand); and P, number of patients (in million).

The second part of Figure 2 further compares the best (i.e., Hanoi) and the worst (i.e., Bac Kan) provinces in terms of PHSI. Similarly, we found that the position of P for Hanoi was relatively higher than that of Bac Kan, while the relative positions of B, N, and D are similar between the two provinces. However, regarding indicator E, its position in the case of Bac Kan was relatively higher than in the case of Hanoi, suggesting a certain level of concentration and development in terms of the healthcare establishment network in the Northeast province, although it was not effective enough to bring its PHSI higher.

4.2. Discussions and Implications

The low levels of the 2021 PHSI reveal the problems in the Vietnamese healthcare system, especially at the provincial level. While the disparity of PHSI across provinces is explainable given the provinces' geographical socioeconomic characteristics [29, 38, 39] the findings still suggest that Vietnamese policymakers should pay more attention to improving the resources and outcomes of its healthcare system.

Since the disparity occurs even between provinces in the same region, it suggests that the connection across the provincial healthcare systems in Vietnam was still low. In well-connected regions, patients from one province could benefit from the healthcare system of not only the province they are living in but also from nearby provinces, therefore, the overall efficiency of the regional and national healthcare systems could be improved. For example, a patient from Bac Kan may suffer from its own province's lack of doctors but they can move to the neighbouring provinces of Thai Nguyen or Ha Giang (see Appendix 2) to enjoy the healthcare services there, only if these provinces are connected.

Accordingly, it is crucial to improve the efficiency of the Vietnamese healthcare system. For instance, it is not only about 'how much' resources (e.g., hospital establishments and staff) can be utilized but more importantly, 'how efficient' those resources could be converted into healthcare outcomes, like in the case of Bac Kan province.

5. Conclusions

The healthcare system is crucial in providing health services to improve the quality of life within society, contributing to the SDGs targets on countries across the globe [3]. This study developed a PHSI that bridges macro- and micro-level data to evaluate the readiness and capacity of the Vietnamese provincial healthcare systems. Empirically, the average value of the 2021 PHSI in Vietnam remains low at 0.199, indicating that provincial healthcare systems are underprepared and lack capacity in terms of resources (clinical establishments and staff) and outcomes (outpatients). Significant disparities existed among provinces, regions, and quantiles, in which the top five provinces, on average, have PHSI scores twelve times higher than the bottom five. Importantly, the efficiency of converting resources into outcomes is a major problem for the healthcare systems of many Vietnamese provinces.

While the disparities in PHSI among provinces can be attributed to their geographical and socioeconomic characteristics, these findings indicate that Vietnamese policymakers need to focus more on enhancing both the resources and outcomes of the healthcare system. Such disparities also suggest a lack of connectivity among provincial healthcare systems in Vietnam, especially for neighboring provinces. By improving this connectivity, one can enhance the overall efficiency of the national and regional healthcare systems. Importantly, the efficiency of utilizing healthcare resources to provide the maximum services and outcomes should be prioritized.

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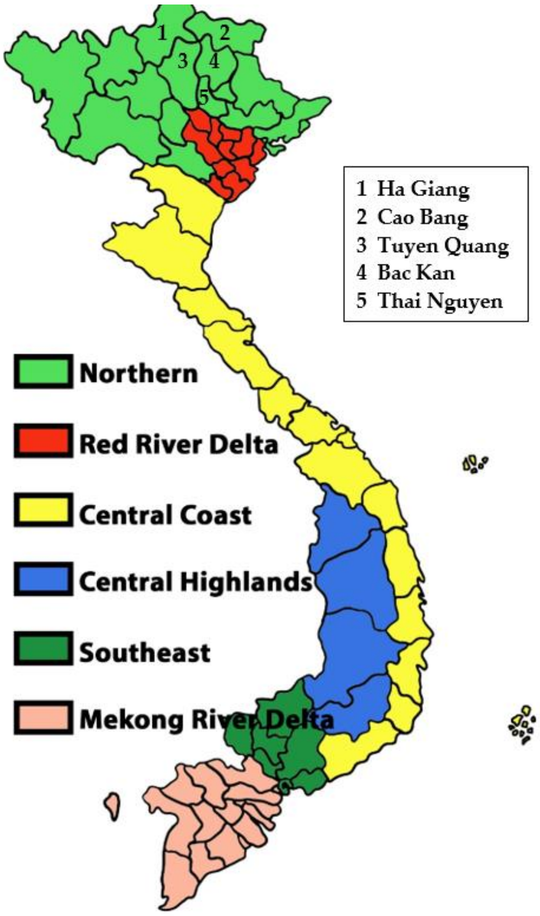
Appendix 1.
The Vietnamese provinces.

No.	Province	Region	No.	Province	Region
1	Ha Noi	1	33	Quang Nam	3
2	Vinh Phuc	1	34	Quang Ngai	3
3	Bac Ninh	1	35	Binh Dinh	3
4	Quang Ninh	1	36	Phu Yen	3
5	Hai Duong	1	37	Khanh Hoa	3
6	Hai Phong	1	38	Ninh Thuan	3
7	Hung Yen	1	39	Binh Thuan	3
8	Thai Binh	1	40	Kon Tum	4
9	Ha Nam	1	41	Gia Lai	4
10	Nam Dinh	1	42	Dak Lak	4
11	Ninh Binh	1	43	Dak Nong	4
12	Ha Giang	2	44	Lam Dong	4
13	Cao Bang	2	45	Binh Phuoc	5
14	Bac Kan	2	46	Tay Ninh	5
15	Tuyen Quang	2	47	Binh Duong	5
16	Lao Cai	2	48	Dong Nai	5
17	Yen Bai	2	49	Ba Ria - Vung Tau	5
18	Thai Nguyen	2	50	Ho Chi Minh City	5

19	Lang Son	2	51	Long An	6
20	Bac Giang	2	52	Tien Giang	6
21	Phu Tho	2	53	Ben Tre	6
22	Dien Bien	2	54	Tra Vinh	6
23	Lai Chau	2	55	Vinh Long	6
24	Son La	2	56	Dong Thap	6
25	Hoa Binh	2	57	An Giang	6
26	Thanh Hoa	3	58	Kien Giang	6
27	Nghe An	3	59	Can Tho	6
28	Ha Tinh	3	60	Hau Giang	6
29	Quang Binh	3	61	Soc Trang	6
30	Quang Tri	3	62	Bac Lieu	6
31	Thua Thien-Hue	3	63	Ca Mau	6
32	Da Nang	3			

Notes: Vietnam has six regions of Red River Delta (Region=1), Northeast (Region=2), Central Coast (Region=3), Central Highlands (Region=4), Southeast (Region=5), and Mekong River Delta (Region=6).



Appendix 2.
Bac Kan province and its neighbourhood.