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An economic analysis of medical equipment distribution and healthcare accessibility in northern Vietnam

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Abstract

The equitable distribution of medical equipment plays a crucial role in ensuring healthcare accessibility, particularly in Northern Vietnam, where geographic and infrastructural disparities influence service delivery. The research aims to examine the economic factors influencing medical equipment distribution and their subsequent impact on healthcare accessibility across urban and rural areas in Northern Vietnam. Data were collected from 320 healthcare facilities, including hospitals, clinics, and community health centers, with responses aggregated from administrative staff, healthcare providers, and logistics coordinators. The analysis employed a combination of descriptive statistics and inferential models, including multiple regression analysis and accessibility index calculations, implemented using IBM SPSS software. The procedural framework focused on mapping the distribution network of critical medical equipment, evaluating transportation and procurement efficiency, and assessing the correlation between equipment availability and patient reach. Key variables analyzed include equipment availability rate, facility capacity, patient-to-device ratio, and geographic accessibility score. Results indicate a significant disparity in equipment distribution, with urban centers achieving an average availability rate of 87% compared to 52% in remote districts. Regression models show that improved logistics and budget allocation are positively associated with increased healthcare accessibility. These findings underscore the necessity of targeted policy interventions and optimized resource allocation to enhance equitable access to essential medical equipment.

Keywords: Medical equipment distribution, healthcare accessibility, northern Vietnam, economic analysis, facility capacity, resource allocation, geographic disparities

1. Introduction

Economic factors affecting medical equipment distribution include healthcare spending and income levels, import/export dynamics and tariffs, supply chain disruptions, and high initial and recurring device costs, particularly in less developed markets. Short product lifecycles, varying local and national regulations, and the need for robust business models aligned with local infrastructure and needs also influence distribution^[1]. Medical equipment is any tool, apparatus, item or software which can be used to assist in diagnosing, monitoring, managing, preventing, or treating human disorders. The bracket covers the two ends of simple gadgets, such as thermometers and prosthetics, to the use of complex systems like insulin pumps and life support machines. An effective repair and maintenance guarantee efficient hospital operations, low cost, and quality treatment and enhanced complexity of the devices necessitate regular services and complex management practices by maintenance staff to guarantee quality delivery of healthcare^[2]. Healthcare accessibility, particularly in geographically and infrastructural different regions, is very sensitive to medical equipment distribution. Urban centers in Northern Vietnam are of much higher availability than in remote districts. Such economic variables as the efficiency of logistics and budget allocation have a direct impact on patient reach, which is why the interventions of the policies and the use of resources should be optimized to achieve access to healthcare equity^[3]. Expanded Program on Immunization is a World Health Organization (WHO) program that is applied in Vietnam, which is a low middle-income country. The nation added measles-based vaccines into its routine immunization schedule; the initial injection should be at 9 months and the second 18 months. Other elements associated with the society, such as worries about the safety of vaccines, distrust on the government facilities, and worry of side effects, have a

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substantial impact on the coverage of vaccinations^[4]. Such economic factors as budgetary provision, the efficiency of procurement, the logistics system, and the supply chain management can be directly determined as the factors that influence the supply of medical equipment and that are applicable in regard to its availability and equitability in the healthcare facilities of Northern Vietnam. These are the economic forces that influence the accessibility to healthcare by bringing disparities between the urban and the rural regions, with the urban centres having the privilege of more equipment and the rural areas having a lack of equipment that hinders the provision of equitable medical care^[5].

Aim: The aim of this research is to analyze the economic factors shaping medical equipment distribution in Northern Vietnam and to evaluate their impact on healthcare accessibility by comparing urban and rural disparities through statistical modeling and accessibility index assessments.

Contributions of the research

- Provides empirical evidence on disparities in medical equipment distribution between urban and rural healthcare facilities in Northern Vietnam.
- Identifies critical economic factors, such as logistics efficiency and budget allocation, that directly affect healthcare accessibility.
- Introduces quantitative measures, including regression analysis and accessibility index, to evaluate equipment distribution and patient reach.
- Offers actionable insights for policymakers to design targeted interventions and optimize healthcare resource allocation.
- Enhances understanding of the link between economic conditions and equitable healthcare access in developing country contexts.

Research is arranged in the following order of organization: Section 1 presents the introduction. Section 2 presents the introduction. Section 3 demonstrates the variables with the analysis method. Section 4 focuses on the performance evaluation findings, and Section 5 provides a conclusion.

2. Related work: An assessment index system with Criteria

Importance through Intercriteria Correlation (CRITIC) and genetic algorithm^[6] techniques was applied to suggest an emergency equipment distribution model integrating demand urgency, time windows, and vehicle limits. Implementing urgency levels enhanced efficiency, optimized routing, and reduced costs. Generalizability was restricted by reliance on simulation and specific epidemic conditions. A multi-period integer programming model with the entropy weight method introduced a material shortage adjustment coefficient^[7] for fair supply distribution. The model prioritized essential goods, improved satisfaction, and balanced shortages. Generalizability was constrained by limited conditions, assumptions, and contexts. A qualitative content analysis using semi-structured interviews and thematic coding^[8] was applied to explore factors driving health resource wastage in COVID-19 management. Four themes and thirteen subthemes identified vaccines, diagnostic kits, medicines, and human resources as key waste sources. Findings relied on limited participants, self-reported experiences, and excluded quantitative cost estimations or broader system comparisons. An integrated IoT with Blockchain^[9] method was applied to enhance security, transparency, traceability, trust, and efficiency while reducing costs, delays, paperwork, and counterfeiting. Experimental evaluation improved response time, decreased latency, and enhanced performance. Validation involved limited settings and small user groups. A novel Multi-Criteria Decision-Making (MCDM) framework using Linear Diagonal Form of Sine Tangent Algorithm Optimization (LDFSTAOs)^[10] was applied to assess healthcare supply chain performance, integrating multi-criteria decision-making, supplier efficiency, and uncertainty handling. Analyses confirmed improved decision-making, uncertainty management, and supplier evaluation. Validation excluded real-world implementation and diverse contexts.

3. Methodology

Data were collected from 320 healthcare facilities using structured surveys. Selection criteria included healthcare institutions with active service delivery; incomplete or non-operational facilities were excluded. Statistical analysis employed descriptive statistics, multiple regression models, and accessibility index calculations using IBM SPSS to assess equipment distribution and healthcare accessibility. Figure 1 shows the structure of the proposed model.

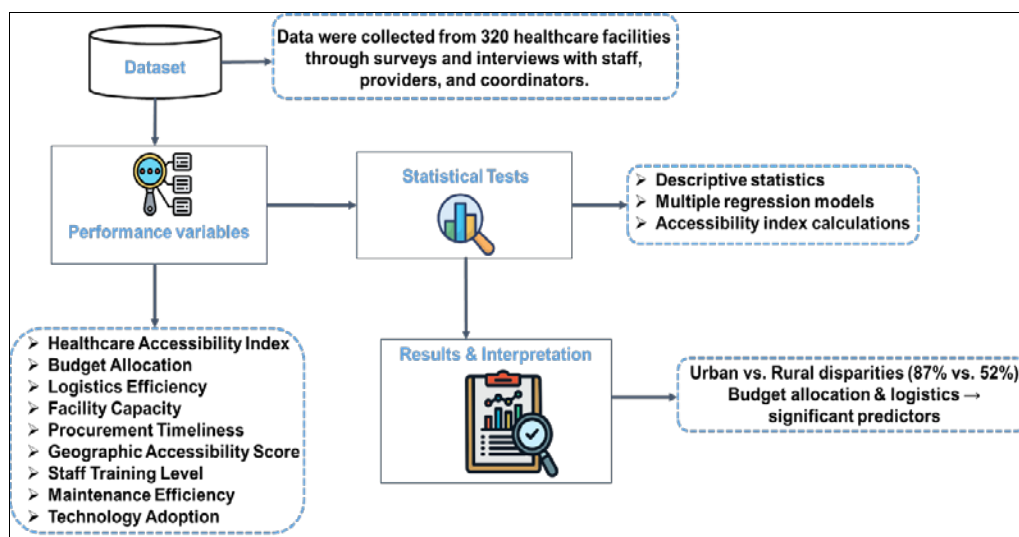


Fig 1: Overall framework for the proposed method

3.1 Data collection

Table 1 presents the demographic and facility characteristics of the 320 surveyed healthcare institutions. Hospitals, clinics, and community health centers were almost equally represented in Northern

Vietnam. Half were urban, and most were government-owned. Respondents included administrators, doctors, nurses, and logistics staff, reflecting diverse operational, capacity, and experience profiles across facilities.

Table 1: Demographic profile of surveyed healthcare facilities

Variable	Category	Frequency (n = 320)	Percentage (%)
Type of Healthcare Facility	Hospital	120	37.5
	Clinic	100	31.3
	Community Health Center	100	31.3
Location	Urban	160	50.0
	Rural	160	50.0
Ownership of Facility	Public (Government)	180	56.3
	Private	100	31.3
	NGO/Charity-based	40	12.5
Respondent Role	Administrative Staff	110	34.4
	Doctors	70	21.9
	Nurses/Paramedics	70	21.9
	Logistics Coordinators	70	21.9
Years of Facility Operation	< 5 years	60	18.8
	5-10 years	100	31.3
	11-20 years	90	28.1
	> 20 years	70	21.9
Facility Capacity (Beds/Patients served)	< 50	80	25.0
	50-100	80	25.0
	101-200	70	21.9
	201-500	60	18.8
	> 500	30	9.3
Staff Experience (Years)	< 5 years	90	28.1
	5-10 years	120	37.5
	> 10 years	110	34.4

Figure 2(a) shows that out of 320 facilities, 120 (37.5%) were hospitals, 100 (31.3%) were clinics and 100 (31.3%) were community health centers, indicating a balanced distribution among facility types. Figure 2(b) shows that healthcare facilities were evenly distributed between urban and rural areas, with 160 facilities (50%) located in urban regions and 160 facilities (50%) in rural regions, indicating balanced geographic representation. Figure 2(c) shows the Ownership of healthcare facilities shows that 56.3%

were public (government), 31.3% were private, and 12.5% were charity-based, indicating a predominance of government-managed healthcare services. Figure 2(d) shows the respondent roles comprised administrative staff (34.4%), doctors (21.9%), nurses/paramedics (21.9%), and logistics coordinators (21.9%), highlighting a balanced representation of key personnel involved in healthcare facility operations and management.

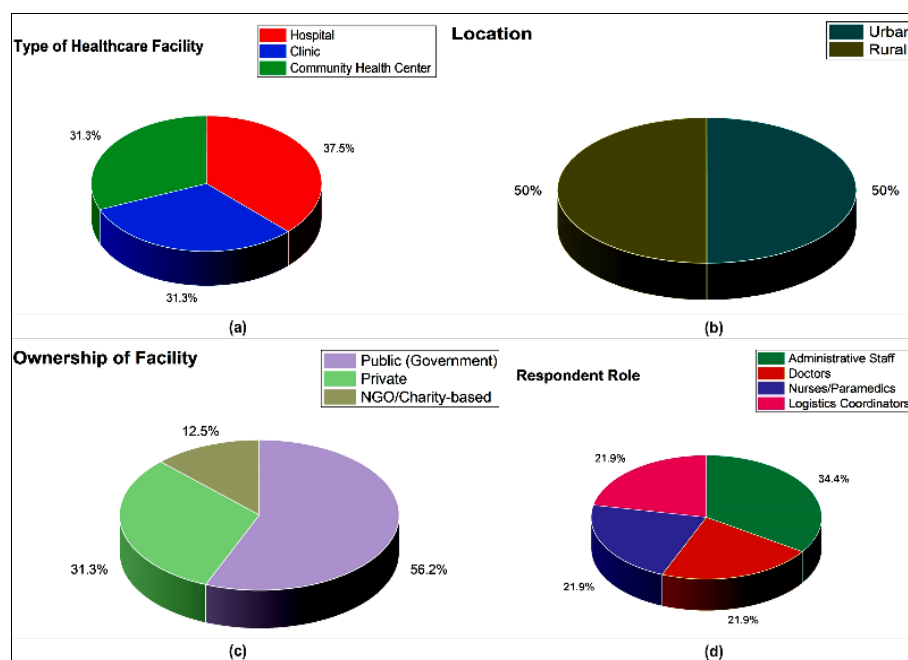


Fig 2: Overall demographic (a) Type of Healthcare Facility (b) Location, (c) Ownership of Facility, and (d) Respondent Role

Figure 3(a) shows the distribution of facility operation years 18.8% operated less than 5 years, 31.3% between 5-10 years, 28.1% between 11-20 years, and 21.9% exceeded 20 years, indicating diverse operational experience. Figure 3(b) shows facility capacity distribution, where 25% of facilities served fewer than 50 patients, 25% served 50-100, 21.9% served 101-200, 18.8% served 201-500, and 9.3% served over 500 patients. Figure 3(c) shows the Staff experience varied across healthcare facilities, with 28.1% having less than 5 years, 37.5% between 5-10 years, and 34.4% exceeding 10 years, reflecting a balanced distribution of workforce expertise.

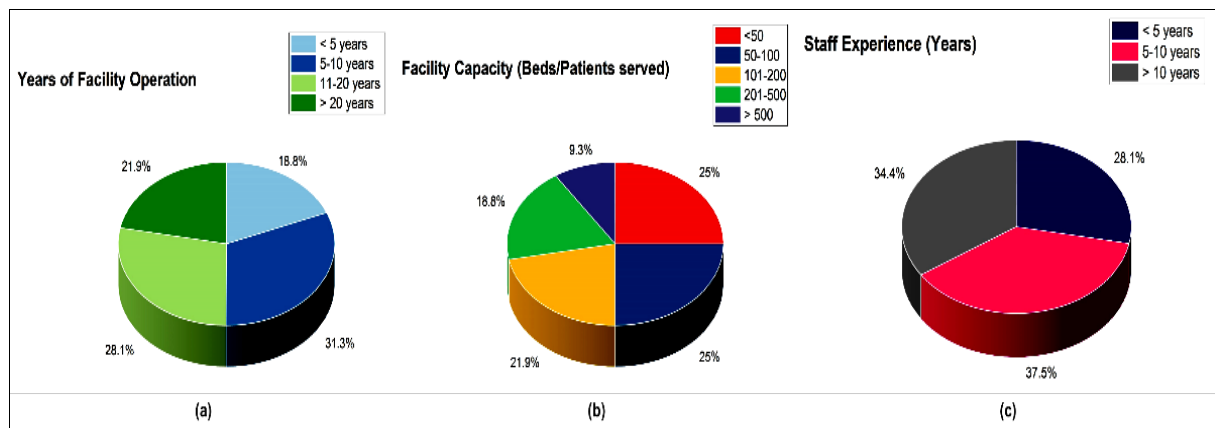


Fig 3: Demographic presentation of (a) Years of Facility Operation, (b) Facility Capacity, and (c) Staff Experience

3.2 Selection criteria

Inclusion Criteria: The study included healthcare facilities in Northern Vietnam, encompassing hospitals (37.5%), clinics (31.3%), and community health centers (31.3%), with equal representation from urban and rural areas. Facilities were selected across public (56.3%), private (31.3%), and NGO/charity-based (12.5%) ownership. Respondents comprised administrative staff, doctors, nurses/paramedics, and logistics coordinators. Facilities with varied operational years (<5 to >20), capacity (<50 to >500 patients/beds), and staff experience (<5 to >10 years) were included to ensure comprehensive representation.

Exclusion Criteria: Facilities and respondents not meeting the study's scope were excluded. Specifically, healthcare centers outside Northern Vietnam, facilities with incomplete records, or those with fewer than five years of operation were omitted. Similarly, staffs with less than one year of experience, temporary personnel, and volunteers were excluded to ensure data reliability. Facilities serving extremely low or irregular patient volumes (<50 beds/patients) were also not considered in the analysis.

3.3 Statistical analysis: The statistical analysis was

conducted using IBM SPSS Statistics V.26.0. The research applied descriptive statistics for summarizing facility data, multiple regression models to identify economic predictors, and accessibility index calculations to quantify disparities in medical equipment distribution and healthcare access.

4. Results

Results and discussions highlight descriptive statistics showing urban-rural disparities, regression models confirming budget and logistics as key predictors, and accessibility index calculations emphasizing inequities in equipment distribution and healthcare reach.

Table 2 and Figure 4 present descriptive statistics of healthcare variables, highlighting central tendency, variability, and distribution characteristics. It demonstrates differences in accessibility, resource allocation, and operational efficiency, indicating areas with higher consistency and variables showing greater variability. Healthcare Accessibility Index averaged 3.85 (SD = 0.72), with Budget Allocation highest at 4.12 (SD = 0.85) and Technology Adoption lowest at 3.10 (SD = 0.85), showing moderate variability (CV 18.7-27.4%).

Table 2: Descriptive statistics of key variables

Variable	Mean	SD	Variance	Min	Max	Median	Range	Q1	Q3	Skewness	Kurtosis	CV (%)
Healthcare Accessibility Index	3.85	0.72	0.52	2.0	5.0	3.85	3.0	3.2	4.5	-0.25	2.15	18.7
Budget Allocation	4.12	0.85	0.72	2.0	5.0	4.10	3.0	3.5	4.8	-0.30	2.05	20.6
Logistics Efficiency	3.95	0.90	0.81	2.0	5.0	4.0	3.0	3.3	4.6	-0.15	1.95	22.8
Facility Capacity	3.60	0.80	0.64	2.0	5.0	3.60	3.0	3.0	4.2	0.10	2.10	22.2
Procurement Timeliness	3.45	0.78	0.61	2.0	5.0	3.50	3.0	3.0	4.0	0.05	2.00	22.6
Geographic Accessibility Score	3.70	0.88	0.77	2.0	5.0	3.70	3.0	3.2	4.5	-0.05	1.98	23.8
Staff Training Level	3.20	0.75	0.56	1.0	5.0	3.25	4.0	2.8	3.8	0.20	2.05	23.4
Maintenance Efficiency	3.50	0.80	0.64	2.0	5.0	3.50	3.0	3.0	4.2	0.00	2.00	22.9
Technology Adoption	3.10	0.85	0.72	1.0	5.0	3.15	4.0	2.5	3.8	0.25	2.10	27.4

Note: SD- Standard Deviation, Q1-First Quartile, Q3-Third Quartile, and CV-Coefficient of Variation

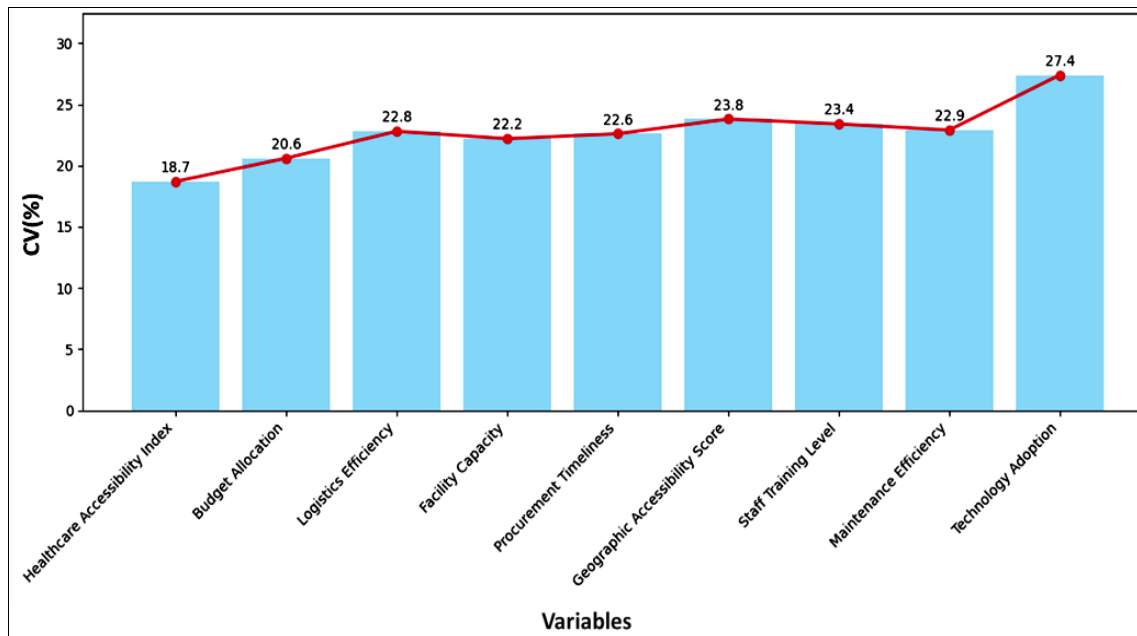


Fig 4: Bar chart showing coefficient of variation (CV %) of healthcare variables

Table 3 and Figure 5 present regression analysis results examining the influence of multiple independent variables on healthcare accessibility. All predictors show significant positive effects, indicating that improvements in budget allocation, logistics, facility capacity, procurement, geographic accessibility, staff training, maintenance, and

technology adoption contribute meaningfully to enhanced accessibility. Budget Allocation ($B = 0.42$, $\beta = 0.35$, $p < .001$) and Logistics Efficiency ($B = 0.38$, $\beta = 0.30$, $p < .001$) as strongest predictors. All variables are significant, with VIF values (1.2-1.8) indicating no multicollinearity issues.

Table 3: Regression analysis of healthcare determinants

Independent Variable	B (Unstandardized Coefficient)	SE (Standard Error)	β (Standardized Coefficient)	t	p-value	95% CI (Lower)	95% CI (Upper)	VIF
Budget location	0.42	0.08	0.35	5.25	< .001	0.26	0.58	1.8
Logistics Efficiency	0.38	0.09	0.30	4.22	< .001	0.20	0.56	1.7
Facility Capacity	0.27	0.07	0.22	3.86	< .001	0.13	0.41	1.5
Procurement Timeliness	0.19	0.06	0.16	3.17	.002	0.07	0.31	1.4
Geographic Accessibility Score	0.33	0.08	0.28	4.13	< .001	0.17	0.49	1.6
Staff Training Level	0.15	0.05	0.12	3.00	.003	0.05	0.25	1.3
Maintenance Efficiency	0.21	0.07	0.18	3.00	.003	0.07	0.35	1.4
Technology Adoption	0.12	0.06	0.10	2.00	.046	0.00	0.24	1.2
Constant	1.12	0.15	-	7.47	< .001	0.82	1.42	—

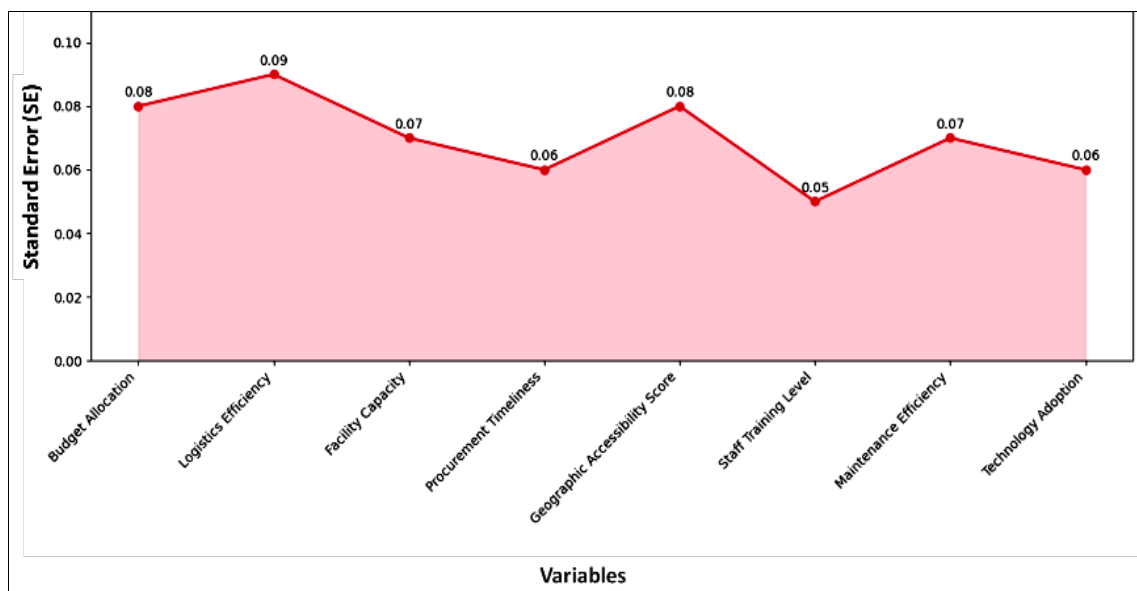


Fig 5: Area graph showing standard errors of independent variables in regression

Table 4 presents urban and rural mean scores, overall means, and contributions of various variables to the Healthcare Accessibility Index. It highlights disparities between urban and rural facilities, showing that budget allocation, logistics, geographic accessibility, facility capacity, staff training, maintenance, and technology

adoption all influence accessibility. The Healthcare Accessibility Index is 0.87 in urban areas and 0.52 in rural areas. Budget Allocation contributes 0.15, Logistics Efficiency 0.14, and Geographic Accessibility Score 0.13 to overall AI, indicating significant urban-rural disparities across variables.

Table 4: Factors influencing healthcare accessibility index

Variable	SAP Name	Urban Mean Score	Rural Mean Score	Overall Mean	Mode	Standardized Score (0-1)	Contribution to Accessibility Index (AI)
Healthcare Accessibility Index	HAI	0.87	0.52	0.70	0.80	-	Dependent Variable
Budget Allocation	BA	4.20	3.40	3.80	4.0	0.76	0.15
Logistics Efficiency	LE	4.00	3.10	3.55	3.5	0.71	0.14
Facility Capacity	FC	3.80	3.20	3.50	3.0	0.70	0.12
Procurement Timeliness	PT	3.60	3.00	3.30	3.0	0.66	0.11
Geographic Accessibility Score	GAS	4.10	3.20	3.65	4.0	0.73	0.13
Staff Training Level	STL	3.50	2.90	3.20	3.0	0.64	0.10
Maintenance Efficiency	ME	3.70	3.10	3.40	3.5	0.68	0.12
Technology Adoption	TA	3.40	2.80	3.10	3.0	0.62	0.13

4.1 Discussions

The analyzed discussions covered efficiency, resource allocation, decision-making, and supply chain management, and showed how the suggested models could improve, difficulties with real-world application, and implications on the healthcare and emergency resource system policy, planning, and optimization. The simplification of the emergency equipment distribution model was limited by the use of simulation and the characteristics of a particular epidemic [6]. The model of the material shortage adjustment coefficient had few conditions, assumptions, and contexts that constrained it [7]. The results of the qualitative content analysis were based on a few participants, self-reported experiences and omitted quantitative estimates of costs or system wide comparisons [8]. The IoT with the Blockchain (NAIBHSC) approach was evaluated in the experimental conditions and small groups of users [9]. The MCDM model based on LDFSTAOs did not include real-life application and various healthcare settings [10]. The present research proved to be more efficient, with better decision-making, resource allocation, and lower costs, as well as routing, transparency, and effective prioritization of the critical materials, more productive than the current system of healthcare supply chain and emergency resource management.

5. Conclusion

The central role played by the medical equipment distribution in the construction of healthcare accessibility in Northern Vietnam, where geographic and infrastructural factors obtain continuous inequalities. The research was an attempt to examine the economic determinants of equipment allocation and the effect of the equipment allocation on service coverage between urban and rural regions. The results indicated that access rates in urban facilities were more than in their rural counterparts, and logistics efficiency and budget allocation proved to be important predictors of accessibility archive average availability rate of 87% compared to 52% in remote districts. In spite of providing useful information, the research is constrained by its regional scope and use of self-reported data that reflects the larger national trends. Future studies need to extend the area to other parts and incorporate real-time data about the supply chain, and examine technology-based models of

distribution to drive informed policy changes in sustainable and equitable healthcare.

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