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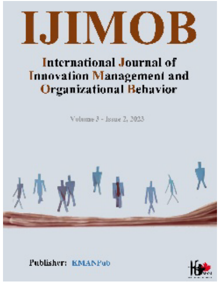

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Evaluating the Performance of Health Supply Chains Using Network Data Envelopment Analysis Model Under Uncertainty Conditions in Selected Tehran Hospitals

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ABSTRACT

Objective: Objective: The objective of this research is to expand the models of Network Data Envelopment Analysis with approaches to uncertainty for evaluating the performance of supply chains.

Method: The method used in this research is descriptive and, in terms of outcome, falls under applied research. From a strategic research perspective, it is descriptive and cross-sectional retrospective based on an analytical approach, conducted through fieldwork and a survey method in the research community. A census method was employed.

Findings: In this study, Razi Hospital, with a score of 0.99, has the highest average efficiency in outpatient services, while Sina Hospital, with a score of 0.139, has the lowest level of average outpatient efficiency among multi-specialty hospitals. Additionally, Yas Hospital, with an average efficiency of 0.99 in inpatient sections, has the highest efficiency, whereas Razi Hospital with a score of 0.58 has the lowest efficiency. Bahrami Hospital among children's hospitals is in a better condition.

Conclusion: Based on the findings of the research, it was determined that the use of the fuzzy Network Data Envelopment Analysis model with variables such as the number of doctors, the number of healthcare workers, active beds, total inpatient days, the number of outpatient visits, and the number of inpatients, can compare the performance of selected decision-making units providing services in the studied medical centers from the perspective of inputs and outputs and across the entire health service supply chain. In the long term, it serves as a suitable tool for officials and policymakers of the selected centers for continuous performance evaluation of these services.

Keywords: *Data Envelopment Analysis, Fuzzy, Performance Evaluation, Supply Chain, Hospital*

1 Introduction

A supply chain encompasses all activities related to the flow of products and information from the point of raw materials to the final delivery to consumers. Health supply chains are composed of various components such as vendors, manufacturers, hospitals, blood centers, and pharmacies in a network structure with the goal of meeting required needs and providing high-quality services to patients. The first tier of healthcare supply chains typically involves suppliers of equipment and medical devices, and the last tier involves patients. Each level in the health supply chain plays a key role as any mistake or disruption can threaten human lives and also lead to irreversible outcomes. Health supply chains are distinguished from other supply chains in terms of complexity, diversity, service types, uncertainty, and objectives. Investigating potential opportunities for new advanced models for effective management of health supply chains has been a novel subject for researchers and health managers (Azadi et al., 2023).

The ultimate goal of a health supply chain is to provide patient care services. The performance of a hospital supply chain must be evaluated to ensure that the patient safety goal within the chain is achieved (Battini et al., 2009).

In the study by Ozcan (1998), it is mentioned that as interest in efficiency in the health service provision process has increased, remedial actions for inefficient medical institutions should be offered by examining the most efficient methods (Ozcan & Smith, 1998). Moreover, the efficiency of a health supply chain can reduce hospital operational costs by 2 to 8 percent (Haavik, 2000).

Holmberg (2000) points out that the performance of all sections in an interconnected system is directly or indirectly related, making it difficult or even impossible to evaluate the performance of a section separately (Holmberg, 2000).

Over the years, the cost of hospital services has significantly increased, thereby requiring special attention towards reducing these costs while maintaining and improving efficiency (Ebadi et al., 2005) and the best way to increase efficiency is the correct and rational use of available resources (Salehzadeh & Ketabi, 2011). The Data Envelopment Analysis method, with its ability to measure efficiency through multiple inputs and outputs, facilitates this possibility (Khodabakhshi et al., 2017).

One of the best methods that can calculate and measure the efficiency of decision-making units by considering the efficiency of all decision-making units is the Data Envelopment Analysis method. The advantage of this method over other methods is that it does not require a specific production function, and consequently, no parameters are estimated. This method can also calculate the efficiency of units separately, using both constant and variable returns to scale assumptions, and present the most efficient ones ranked (Parker, 2000).

Classic Data Envelopment Analysis evaluates decision-making units based solely on final inputs and outputs. The classic approach does not allow the analyst to identify the strengths and weaknesses of each. However, in the Network Data Envelopment Analysis approach, details are analyzed. Therefore, the stages at which the supply chain is inefficient/defective can be identified in advance (Kim & Kim, 2019).

Data Envelopment Analysis models still have a "post-event" nature, meaning that the Data Envelopment Analysis evaluation is based on the past performance of decision-making units. However, in a performance evaluation, for example, in a health supply chain, it is necessary to calculate efficiency under conditions of uncertainty. On the other hand, in Data Envelopment Analysis models, input and output values are estimated with precise values. But in examining practical issues, such a thing is not always possible in the real world, and in many cases, data are imprecise and vague (Kachouei et al., 2022).

Professor Zadeh introduced fuzzy sets for the first time in 1965 (Zadeh, 1965). These sets laid the foundation for a successful method for modeling uncertainty and ambiguity. Fuzzy systems have membership functions with degrees of attachment. Fuzzy logic, unlike Aristotelian logic (which is considered a two-valued logic), is a multivalued logic. It does not view phenomena with a value of one or zero but can determine an infinite number of values between zero and one. They do not have clear lines and defined boundaries. In classic set theory, an element is either a member of the set or not. In fact, membership of elements in a set follows a two-valued pattern (zero and one), but fuzzy set theory extends this concept and replaces it with graded membership. Thus, an element can be a member of a set to varying degrees. In fuzzy logic, the function U(x) is a continuous function. When the sum of the U values is continuous, it means gradual changes in the value degree of different members of a set. Fuzzy logic deals with imprecise facts and refers to the limits and degrees of a reality (Ekin et al., 2016; Nasiri & Masoodi, 2017).

IJIMOB
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Given the above, this study used the Network Data Envelopment Analysis model under uncertainty conditions to evaluate selected public hospitals in Tehran.

2 Methods and Materials

The methodology of this study was descriptive and, in terms of outcomes, it was of the applied research type. Strategically, it was comparative research and, from a temporal perspective, it was retrospective based on an analytical method that was conducted through fieldwork and via a survey in the research population. The execution process of this research was quantitative, utilizing quantitative principles such as sampling calculations with precise census data. The necessary data for this research were collected from the annual statistics units of the Treatment Deputy and the Deputy of Development and Support at the University of Medical Sciences. Theoretically, this research is aligned with the standard model of Data Envelopment Analysis, has a deductive logic, and from the perspective of data collection logic from the research population, it employs inductive reasoning. The research data pertain to the years 2015-2016-2017, which were collected at a specific point in time (2023). The reason for selecting these years is that they were before the COVID-19 pandemic era since the conditions in hospitals were different during the pandemic, and the criteria and factors affecting their efficiency were in different conditions. Therefore, it was necessary to ensure the validity of the data and uniform environmental conditions of the decision-making units as one of the important conditions for employing the Data Envelopment Analysis method, the study period should be before the start of the epidemic and the relative stability of inputs in the supply chain for the entire target population. Since the study of performance with the Data Envelopment Analysis method requires studying all samples, sampling was not performed, and a census method was employed. To construct a DEA model for performance evaluation, it is necessary that the input and output variables be studied, and considering the network nature of the model and its fuzziness, in phase two, inpatients and outpatients were studied and criteria were determined and examined over three consecutive years.

The supply chain studied in this research consists of selected public hospitals in Tehran, which were evaluated and includes both inpatient and outpatient sections, with variables in the inpatient sections including the total number of healthcare workers, active beds in hospital inpatient sections, the total number of inpatients, and total hospital bed-days in the inpatient sections of the hospital, and in outpatient units, the total number of doctors in clinics, healthcare workers, and the total number of outpatient visits to the hospital. These hospitals provide medical services to patients. In this plan, the statistical population includes 12 public hospitals in Tehran, each of which acts as a decision-making unit.

In this plan, inpatient referrals include all inpatients through direct referrals, emergency, clinics, and super-specialty clinics, and referrals from other hospitals. Outpatient referrals include all outpatient visits to emergencies, clinics, counseling, paraclinical and diagnostic therapeutic (paramedical) sections.

The data collection method initially involved library studies, collection through library methods by visiting libraries, studying related materials and articles, books, the internet, and magazines, and reputable domestic and international databases, and fieldwork through a checklist tool that was prepared and used after library study and consultation with experts.

The methods of data analysis involved the use of Data Envelopment Analysis models and data analysis tools, with the Frontier Analyst software for analyzing the results of fuzzy Data Envelopment Analysis models. After collecting quantitative information related to the criteria, the CCR model was executed 50 times using Frontier Analyst software.

3 Findings and Results

In this study, to determine appropriate indicators for evaluating the health supply chain in selected Tehran hospitals through study, identification, and extraction of effective criteria for performance evaluation and their selection, initially, through research and studies conducted in the field of hospital performance evaluation, the most important performance evaluation criteria were identified. Following the reviews conducted after consultation and interviews with experts and based on accessible information, certain items were specified and selected as inputs and outputs. These included the number of doctors, the number of healthcare workers, active beds, total inpatient days, the number of outpatient visits, and the number of inpatients. The results were recorded in Table 1 and Table 2, categorized by outpatient and inpatient services.

IJIMOB
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Table 1

Input and output data for inpatient sections in selected public hospitals in Tehran

Hospital	Inpatient			
	Active Beds	Personnel	Total Inpatients	Total days in hospital
	Input	Input	Output	Output
1	1020,1048,1054	204,621,722,269	49862,52577,54401	307734,335878,347282
2	190,210,220	336,401,416	13499,14302,16897	38971,46849,55900
3	233,244,269	476,501,539	19417,20118,20437	75447,80297,80475
4	121,122,124	219,231,239	8700,9341,9341	37599,40609,41048
5	122,125,128	276,310,339	14787,15760,16451	29349,37625,42116
6	463,486,497	9,039,721,098	22534,24256,24892	150528,159944,161071
7	69,69,69	131,133,149	4143,4328,4649	11364,11940,12239
8	217,217,220	518,560,570	47090,47618,47090	56298,56664,57934
9	411,422,454	655,742,808	24548,26151,27057	100538,101002,108291
10	138,142,143	239,294,296	13352,13577,13961	39401,40041,42379
11	285,314,333	595,651,711	16332,17348,25417	92253,94849,104577
12	118,124,132	172,185,208	10501,10767,11082	21685,25695,29723

Table 2

Input and output data for outpatient sections in selected public hospitals in Tehran

Hospital	Outpatient		
	Total Doctors	Total Personnel	Total Clients
	Input	Input	Output
1	551,536,542	204,621,722,269	752130,781049,1008319
2	54,66,86	336,401,416	238005,242798,287192
3	74,75,80	476,501,539	467578,612471,814370
4	41,48,52	219,231,239	128132,135375,197547
5	52,52,141	276,310,339	207080,217513,311260
6	284,320,460	9,039,721,098	430986,468041,616722
7	106,106,124	131,133,149	452753,448560,484812
8	271,308,347	518,560,570	945754,1061306,1087641
9	106,109,113	655,742,808	238435,240703,554872
10	97,102,103	239,294,296	608087,628034,764892
11	168,205,215	595,651,711	430169,382071,743987
12	44,46,66	172,185,208	148021,176483,230326

After collecting quantitative information related to the criteria using Frontier Analyst software, the CCR model was executed 50 times. The results of evaluating the performance of the health supply chain using the Network Data Envelopment Analysis model under conditions of uncertainty (fuzzy) in selected public hospitals in Tehran are presented in Table 3. Subsequently, using Excel, the efficiency of hospitals was calculated based on inpatient and outpatient patients and overall. The results are presented in Table 4. Then, multi-specialty hospitals and children's hospitals were ranked separately based on inpatient and outpatient patients, and the results are presented in Tables below:

IJIMOB
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Table 3

Efficiency levels (fuzzy) of inpatient and outpatient sections in selected public hospitals in Tehran

Hospital	Inpatient	Outpatient
1	80-96.3-100	15.8-23.2-36.7
2	55.5-72.5-100	43.3-47.6-65.2
3	80.1-99.8-100	85.1-100-100
4	88.8-100-100	31-41.3-72.7
5	72.6-98.1-100	39.1-49.9-54.7
6	82.5-98.9-100	17.6-30.3-100
7	48.2-59.2-67.6	94.1-100-100
8	69.7-100-100	29.9-30.2-51.2
9	67-80.1-100	9.4-13-22.1
10	82.9-88.9-100	23-31.9-97
11	79.7-90.7-100	7.6-9.6-25.6
12	97-100-100	16.7-19.2-36.4

Table 4

Efficiency table for inpatient, outpatient, and overall sections in selected multi-specialty public hospitals in Tehran

Hospital	Inpatient	Outpatient	Total Efficacy
1	94.20	24.22	22.812
2	74.25	49.82	36.989
3	96.55	97.50	94.136
4	98.13	44.82	43.980
5	94.17	48.90	46.048
6	96.35	39.80	38.347
7	58.77	99.02	58.189
8	94.95	33.65	31.951
9	74.68	13.92	10.393
10	89.75	61.90	55.555
11	90.42	11.93	10.790
12	99.50	21.65	21.542

Table 5

Efficiency ranking for each phase of inpatient and outpatient services in selected public children's hospitals in Tehran

Hospital	Rank	Outpatient	Total Efficacy	Rank
4	98.13	44.82	43.980	1
11	90.42	11.93	10.790	2

Table 6

Efficiency ranking table for outpatient sections in selected multi-specialty public hospitals in Tehran

Hospital	Outpatient	Rank
7	99.02	1
3	97.50	2
10	61.90	3
2	49.82	4

IJIMOB
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5	48.90	5
6	39.80	6
1	24.22	7
12	21.65	8
9	13.92	9

Table 7

Efficiency ranking table for inpatient sections in selected multi-specialty public hospitals in Tehran

Hospital	Inpatient	Rank
12	99.50	1
3	96.55	2
6	96.35	3
1	94.20	4
5	94.17	5
10	89.75	6
9	74.68	7
2	74.25	8
7	58.77	9

Table 8

Overall efficiency ranking table in selected multi-specialty public hospitals in Tehran

Hospital	Total Efficacy	Rank
3	94.14	1
7	58.19	2
10	55.56	3
5	46.05	4
6	38.35	5
2	36.99	6
1	22.81	7
12	21.54	8
9	10.39	9

The efficiency of both stages of the service supply chain in selected public hospitals in Tehran was calculated separately for inpatient and outpatient services, and the overall efficiency for each of the hospitals under study was determined.

Finally, in the tables below, based on the variable under study in the inpatient and outpatient sections of each hospital, the required increase or decrease in each case to reach the efficiency frontier was examined and shown in below tables:

Table 9

Efficiency frontier determination table (fuzzy) for sections in selected public hospitals in Tehran by variable

Hospital	Personnel Frequency	Real	Goal	Potential
1	Doctors Frequency	2046-2172-2269	1984-2046-2188	(-3.57)-0-(-8.64)
	Clients Frequency	46862-52577-54401	54401-80241-93463	0-52.62-87.44
	Personnel Frequency	307734-335878-347282	347282-348838-384550	0-3.86-24.96
	Doctors Frequency	524-1048-1048	524-1048-1048	0-0-0
2	Clients Frequency	336-401-416	336-401-416	0-0-80.24
	Personnel Frequency	13499-14302-16897	16897-19727-24331	0-37.93-80.24
	Doctors Frequency	38971-46849-55900	55900-64619-70243	0-37.93-80.24

IJIMOB
E-ISSN: 3041-8992

	Clients Frequency	210-210-220	201-210-220	(-4.42)-0-0
3	Personnel Frequency	501-539-539	469-539-539	(-6.36)0-0
	Doctors Frequency	20118-20437-20437	20163-25507-25507	0.22-24.81-24.81
	Clients Frequency	75447-75447-80297	80475-94162-94162	0.22-24.81-24.81
	Personnel Frequency	233-269-344	233-244-269	0-0-0
4	Doctors Frequency	219-231-239	219-231-239	0-0-0
	Clients Frequency	8700-9341-9341	9341-9341-9800	0-0-12.64
	Personnel Frequency	37599-40609-41048	40609-41048-42353	0-0-12.64
	Doctors Frequency	121-122-124	121-122-124	0-0-0
5	Clients Frequency	276-310-339	268-276-287	(-15.39)-(-13.58)-0
	Personnel Frequency	14787-15760-16451	16063-16451-20367	0-1.92-37.74
	Doctors Frequency	29349-37625-42116	38348-40424-42116	0-1.92-37.74
	Clients Frequency	122-125-128	122-125-128	0-0-0
6	Personnel Frequency	903-972-1098	903-920-1038	(-5.5)-(-5.33)-0
	Doctors Frequency	22534-24256-24892	24892-37211-44324	(-5.33)-0-96.7
	Clients Frequency	150528-159944-161071	161071-161770-182368	0-1.14-21.15
	Personnel Frequency	463-486-497	463-486-497	0-0-0
7	Doctors Frequency	131-133-149	131-133-149	0-0-0
	Clients Frequency	4143-4328-4649	6874-7306-8597	47.86-68.81-107.51
	Personnel Frequency	11364-11940-12239	18097-20156-23582	47.86-68.81-107.51
	Doctors Frequency	69-69-69	64-69-69	(-7.01)-0-0
8	Clients Frequency	518-560-570	459-518-560	(-19.42)-0-0
	Personnel Frequency	4709-47618-49025	19620-47618-49025	0-0-316.65
	Doctors Frequency	56298-56664-57934	56664-57934-80726	0-0-43.39
	Clients Frequency	217-217-220	217-217-220	0-0-0
9	Personnel Frequency	655-742-808	655-742-808	0-0-0
	Doctors Frequency	24548-26151-27057	27057-32634-36637	0-24.79-49.25
	Clients Frequency	100538-101002-108291	108291-126041-150051	0-24.79-49.25
	Personnel Frequency	411-422-454	384-411-450	(-9.1)-(-0.91)-0
10	Doctors Frequency	239-294-296	239-290-296	0-0-(-1.34)
	Clients Frequency	13352-13577-13961	13961-15277-16108	0-12.52-20.64
	Personnel Frequency	39401-40041-42379	42379-45055-47533	0-12.52-20.64
	Doctors Frequency	138-138-142	138-138-142	0-0-0
11	Clients Frequency	595-651-711	595-595-659	(-8.67)-(-7.25)-0
	Personnel Frequency	17348-16332-25417	20496-24042-25417	0-25.49-38.58
	Doctors Frequency	92253-94849-104577	104518-104577-115772	0-10.19-25.49
	Clients Frequency	285-314-333	285-314-333	0-0-0
12	Personnel Frequency	172-185-208	172-185-208	0-0-0
	Doctors Frequency	10767-10767-11082	11082-11094-15398	0-3.04-43.01
	Clients Frequency	21685-25695-29723	23477-31012-29723	0-3.04-43.01
	Personnel Frequency	118-124-132	86-106-118	(-30.4)-(-19.78)-0

Table 10

Efficiency frontier determination table for inpatient units in selected public hospitals in Tehran by variable

Hospital	Variable	Real	Goal	Potential
1	Personnel Frequency	2167.17	2059.33	-3.82
	Doctors Frequency	51928.50	78138.00	49.65
	Clients Frequency	333088.00	354530.67	6.73
	Active Beds	960.67	960.67	0.00
2	Personnel Frequency	392.67	392.67	13.37
	Doctors Frequency	14600.67	20022.67	38.66
	Clients Frequency	47044.50	64103.17	38.66
	Personnel Frequency	211.67	210.17	-0.74
3	Doctors Frequency	532.67	527.33	-1.06
	Clients Frequency	20383.83	24616.33	20.71
	Personnel Frequency	76255.33	91880.83	20.71
	Doctors Frequency	275.50	246.33	0.00
4	Clients Frequency	230.33	230.33	0.00
	Personnel Frequency	9234.17	9417.50	2.11

	Doctors Frequency	40180.50	41192.33	2.11
	Clients Frequency	122.17	122.17	0.00
5	Personnel Frequency	309.17	276.50	-11.62
	Doctors Frequency	15713.00	17039.00	7.57
	Clients Frequency	36994.17	40360.00	7.57
	Personnel Frequency	125.00	125.00	0.00
6	Doctors Frequency	981.50	2481.83	-4.47
	Clients Frequency	24075.00	36343.33	15.23
	Personnel Frequency	203974.75	165086.50	4.29
	Doctors Frequency	484.00	484.00	0.00
7	Clients Frequency	135.33	135.33	0.00
	Personnel Frequency	4350.67	7449.17	71.77
	Doctors Frequency	11893.83	20383.83	71.77
	Clients Frequency	69.00	68.17	-1.17
8	Personnel Frequency	554.67	515.17	-3.82
	Doctors Frequency	40701.00	43186.17	48.51
	Clients Frequency	56814.67	61521.00	7.23
	Personnel Frequency	217.50	217.50	0.00
9	Doctors Frequency	738.50	738.50	0.00
	Clients Frequency	26034.83	32371.67	24.74
	Personnel Frequency	102139.50	127084.33	24.74
	Doctors Frequency	425.50	413.00	-2.12
10	Clients Frequency	285.17	282.50	-0.22
	Personnel Frequency	13603.50	15196.17	11.79
	Doctors Frequency	40324.00	45022.00	11.79
	Clients Frequency	138.67	138.67	0.00
11	Personnel Frequency	651.67	605.67	-6.28
	Doctors Frequency	18015.50	23680.17	23.42
	Clients Frequency	96037.67	106433.00	11.04
	Personnel Frequency	312.33	312.33	0.00
12	Doctors Frequency	186.67	186.67	.
	Clients Frequency	10819.50	11809.33	9.20
	Personnel Frequency	25698.00	29541.33	9.20
	Doctors Frequency	124.33	104.67	-18.25

Table 11

Efficiency frontier determination table (fuzzy) for outpatient units in selected public hospitals in Tehran by variable

Hospital	Variable	Real Value	Goal	Potential
1	Personnel Frequency	2046-2172-2269	2046-2172-2269	0-0-0
	Doctors Frequency	536-536-542	536-536-542	0-0-0
	Clients Frequency	752130-781049-1008319	2749489-3365923-4758199	172.68-330.95-532.63
2	Personnel Frequency	336-401-416	321-336-401	(-22.76)-0-0
	Doctors Frequency	54-66-86	54-66-86	0-0-0
	Clients Frequency	238005-242798-287192	440298-510343-549700	110.19-130.96-533.31
3	Personnel Frequency	476-501-539	172-476-501	(-68.14)-0-0
	Doctors Frequency	74-75-80	74-75-80	0-0-0
	Clients Frequency	467578-612471-814370	549534-612471-814370	0-0-17.53
4	Personnel Frequency	219-231-239	219-231-239	0-0-0
	Doctors Frequency	41-48-52	41-48-52	0-0-0
	Clients Frequency	128132-135375-197547	271850-327625-413609	37.61-142.01-222.8
5	Personnel Frequency	276-310-339	276-309-310	(-8.73)-0-0
	Doctors Frequency	52-52-141	52-52-141	0-0-0
	Clients Frequency	207080-217513-311260	397824-5293341-624292	82.9-100.57-155.62
6	Personnel Frequency	903-972-1098	903-972-1098	0-0-0
	Doctors Frequency	32-284-460	32-284-460	0-0-0
	Clients Frequency	430986-468041-616722	2037610-2442063-468041	0-0-230.39
7	Personnel Frequency	131-133-149	131-133-149	0-0-0
	Doctors Frequency	106-106-124	64-106-124	(-39.42)-0-0
	Clients Frequency	448560-452753-484812	452753-476857-484812	0-0-6.31

8	Personnel Frequency	518-560-570	518-560-570	0-0-0
	Doctors Frequency	271-308-347	271-308-347	0-0-0
	Clients Frequency	430977-446353-945754	1440143-1848827-1479134	95.49-231.38-234.16
9	Personnel Frequency	655-742-808	631-655-742	(-21.94)-0-0
	Doctors Frequency	106-109-113	106-109-113	0-0-0
	Clients Frequency	83749-238435-8486800	654335-893909-1079040	352.55-671-967.37
10	Personnel Frequency	239-294-296	239-294-296	0-0-0
	Doctors Frequency	97-102-103	97-102-103	0-0-0
	Clients Frequency	127819-149822-608087	469315-554859-627201	3.14-213.25-334.1
11	Personnel Frequency	595-651-711	595-651-711	0-0-0
	Doctors Frequency	168-205-215	168-205-215	0-0-0
	Clients Frequency	87929-97337-382071	1013763-1158320-1491240	290.30-941.5-1217.34
12	Personnel Frequency	172-185-208	172-185-208	0-0-0
	Doctors Frequency	44-46-66	44-46-66	0-0-0-
	Clients Frequency	48122-59045-148021	287859-307420-407090	175.02-420.65-498.19

Table 12

Efficiency frontier determination table for outpatient units in selected public hospitals in Tehran by variable

Hospital	Variable	Real Value	Goal	Potential
1	Personnel Frequency	2162.33	2162.33	0.00
	Doctors Frequency	538.00	538.00	0.00
	Clients Frequency	847166.00	3624537.00	338.19
2	Personnel Frequency	384.33	352.67	-3.79
	Doctors Frequency	68.67	68.67	0.00
	Clients Frequency	255998.33	500113.67	194.56
3	Personnel Frequency	505.33	383.00	-11.36
	Doctors Frequency	76.33	76.33	0.00
	Clients Frequency	631473.00	658791.67	2.92
4	Personnel Frequency	229.67	229.67	0.00
	Doctors Frequency	47.00	47.00	0.00
	Clients Frequency	153684.67	337694.67	138.08
5	Personnel Frequency	308.33	298.33	-1.46
	Doctors Frequency	245.00	245.00	0.00
	Clients Frequency	245284.33	517152.33	106.80
6	Personnel Frequency	991.00	991.00	0.00
	Doctors Frequency	258.67	258.67	0.00
	Clients Frequency	505249.67	1649238.00	38.40
7	Personnel Frequency	11.47	11.47	0.00
	Doctors Frequency	112.00	98.00	-6.57
	Clients Frequency	462041.67	471474.00	1.05
8	Personnel Frequency	549.33	549.33	0.00
	Doctors Frequency	308.67	308.67	0.00
	Clients Frequency	607694.67	1589368.00	209.20
9	Personnel Frequency	735.00	676.00	-3.66
	Doctors Frequency	109.33	109.33	0.00
	Clients Frequency	2936328.00	875761.33	667.32
10	Personnel Frequency	276.33	276.33	0.00
	Doctors Frequency	100.67	100.67	0.00
	Clients Frequency	295242.67	550458.33	198.37
11	Personnel Frequency	652.33	652.33	0.00
	Doctors Frequency	196.00	196.00	0.00
	Clients Frequency	189112.33	1221107.67	878.94
12	Personnel Frequency	188.33	188.33	0.00
	Doctors Frequency	52.00	52.00	0.00
	Clients Frequency	85062.67	334123.00	392.64

4 Discussion and Conclusion

In this research, the Network Data Envelopment Analysis model was used to evaluate the performance of selected Tehran hospitals' supply chains. In this model, input and output data are entered as triangular fuzzy numbers, and the model's output is a triangular fuzzy number for each decision-making unit, indicating the performance of the respective supply chain. This model, considering the fuzziness of the output data, is much closer to human thinking.

This study examined 12 public hospitals in two phases: inpatient and outpatient services. For inpatients, active bed count and total healthcare personnel were considered as inputs, and the number of inpatients and total bed-days as outputs. For outpatients, the number of doctors and total healthcare personnel were inputs, and the number of outpatient visits was the output.

Hospitals play a crucial role in the country's health sector; this study was conducted in the hospital community segment. Utilizing the fuzzy Data Envelopment Analysis model, this research succeeded in evaluating performance in uncertain environments. Data from the years 2015, 2016, and 2017 from 12 hospitals covered by selected public hospitals in Tehran were used to determine the efficiency level of the hospitals and take a significant step towards continuous performance improvement through Network Data Envelopment Analysis. All information used in this research, categorized by inpatient and outpatient patients, is mentioned in Tables 1 and 2, and the research results are presented in Tables 3 and 4.

This study calculated the efficiency of each stage for every hospital and presented it according to Tables 3 and 4. According to Table 5, children's hospitals showed that Hospital 4 has a higher efficiency level in both inpatient and outpatient situations. Also, according to Table 6, Hospital 7 with an efficiency of 0.99 has the highest outpatient efficiency, and Hospital 9 with 0.139 has the lowest outpatient efficiency. Furthermore, according to Table 7, Hospital 12 with an efficiency of 0.99 has the highest inpatient efficiency, and Hospital 7 with 0.583 has the lowest. Additionally, according to Table 8, Hospital 3 with 0.94 has the highest overall efficiency, and Hospital 9 with 0.103 has the lowest. Hospital 4 with efficiencies of 0.98, 0.44, and 0.43 for inpatients, outpatients, and overall efficiency, respectively, ranks higher than the children's medical center hospital.

Hospitals are similar in terms of hardware and software facilities, and hospitals with more specialized medical facilities have more resources. Therefore, after interviewing experts, inputs and outputs were determined for each stage. The most important performance evaluation criteria were identified through research and studies on hospital performance evaluation. After consultations and interviews with experts and based on accessible information, items were specified and selected as inputs and outputs, including the number of doctors, the number of healthcare workers, active beds, total inpatient days, the number of outpatient visits, and the number of inpatients.

Ekin (2016) concluded in a study on fuzzy decision-making in healthcare that some U.S. military hospitals are efficient, while others are not. This research also found that some hospitals are efficient at certain times. Efficiency can be increased in two ways: first, by reducing the level of input resources, and second, by achieving more results without changing the resources used (Ebadi et al., 2005). Habib et al. (2022), Kim et al. (2019) and Moons et al. (2019) showed that correctly employing this concept helps hospitals manage and satisfy all stakeholders in the industry. They only believe that using such a concept helps them reduce the overall costs of hospitals (Habib et al., 2022; Kim & Kim, 2019; Moons et al., 2019).

This study, by determining the efficiency of each hospital at each stage, identified the strengths and weaknesses at each stage. The aim of this research is to evaluate hospital performance, assisting managers in identifying and addressing their weaknesses if they have low performance. This study can help hospital managers increase efficiency by possibly reducing inputs like active hospital beds or excess healthcare and medical personnel, or by seeking ways to properly use facilities and increase patient satisfaction, thereby increasing outpatient and inpatient visits to the hospital.

Based on the above, the following recommendations are made:

- Study decision-making units in all departments of the hospitals under study, accurately identify and enumerate work processes, and implement inputs and outputs in collaboration with unit staff.
- Identify redundancies and parallel work in each process in work units in the hospital with an approach to process improvement and development.
- Economic studies and analysis of supply chain costs with a focus on reducing unnecessary costs in tangible and intangible areas (human resources).

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- Analyze hospital workflow or flow to increase the speed of admitting and discharging inpatients and outpatients and to make more optimal use of existing infrastructure, improving occupancy bed-day and inpatient-day indicators while maintaining service quality throughout process execution.
- Develop performance management with a process-oriented approach in hospitals by conducting specialized training classes.
- Enhance the capability and performance of efficient and specialized human resources as one of the effective factors in improving hospital efficiency.
- Identify strengths and weaknesses of human resources and take effective action to improve human resource performance.
- Reorganize with work measurement and time study, optimal allocation of suitable tasks.
- Properly arrange human resources in organizational structures, making appropriate use of official, contractual, and project personnel to optimize human resource costs across different work shifts.
- Use forces correctly and appropriately at the right time and place, and if necessary, use forces such as compulsory service human resources.
- Use experienced, professional, and specialized managers to increase the efficiency of hospitals.
- Identify strengths and weaknesses of the supply chain in providing services in hospitals and take necessary actions to improve hospital performance.
- Creating a unified hospital information system in the country can help solve research workflow problems.
- Review and offer suitable solutions according to the type of service to increase outpatient and inpatient visits to hospitals.

Future research on the following topics is also suggested:

- Investigate the efficiency of the supply chain of selected hospitals in Tehran considering the role of mediating and intervening variables.
- Examine the efficiency of the supply chain of selected hospitals in Tehran with more detailed and precise stages and compare private hospitals with public ones.
- Study and investigate the efficiency of logistics sections of hospital supply chains.
- Investigate the efficiency of the health supply chain of selected hospitals in Tehran from the initial stage of producers, distributors, etc.
- Examine the efficiency of hospital supply chains using other efficiency evaluation methods (to be able to present new fuzzy models for supply chain efficiency evaluation).
- Regarding research limitations, this study was conducted in the geographical realm of selected hospitals in Tehran; therefore, caution should be exercised in generalizing its results to other regions and universities. There is always an inherent limitation in research tools.
- Access to required information and the incompleteness of some necessary information, which required the researcher to spend more time, can be stated as limitations. There is a limitation in selecting hospitals due to the lack of information and a unified information system for hospitals in the years under study.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Authors Contributions

All authors have contributed significantly to the research process and the development of the manuscript.

Ethics principles

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were observed.

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