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J Health Man & Info 2020, 7(1), 59–67

JHMI
Journal of Health Management and Informatics

Original Article

Efficient Resource Allocation to Social Security Organization Hospitals in Iran by Using Centralized Data Envelopment Analysis

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Abstract

Introduction: Hospitals are regarded as the largest and most expensive operational units of the health system. Also, bed is one of the most valuable hospital resources. Due to the limited resources of the health system, paying attention to efficient resource allocation is necessary. This study aimed to allocate common beds to hospitals to optimize their overall efficiency.

Methods: This is a cross-sectional and applied study. 70 Iranian hospitals affiliated to social security organizations were examined. The required data were collected from the statistical yearbook of this organization (2016). A centralized data envelopment analysis model with an input-orientation approach was used to assess the performance and bed reallocation to hospitals. The input data consist of the number of active beds, and the output data consist of bed occupancy rate, average patient stay, and survival of patients in thousand. Hospitals were clustered by k-means clustering method for analysis. The data were analyzed by GAMS and SPSS softwares.

Results: Hospitals were clustered into 4 groups of homogenous units. Based on this clustering, the number of hospitals in clusters 1 to 4 was 23, 2, 13, 32, and the overall efficiencies of them were 0.703, 1, 0.827, and 0.732, respectively. Before bed reallocation, 13 (18.6%) hospitals were efficient. After bed reallocation by Centralized data envelopment analysis, 31 (44.3%) hospitals became efficient.

Conclusion: It seems that the active bed factor can be one of the inputs influencing the overall efficiency of hospitals. However, in this regard, inclusive attention to other resources such as physicians and nurses will be necessary to achieve desirable hospital efficiency.

Keywords: Centralized Data Envelopment Analysis (CDEA), Efficiency, Hospital, k-means method.

Article History:
Received: 21 January 2020
Accepted: 12 March 2020

Please cite this paper as:
Bastani M, Ketabi S, Maddahi R, Ahari RM. Efficient Resource Allocation to Social Security Organization Hospitals in Iran by Using Centralized Data Envelopment Analysis. J Health Man & Info. 2020; 7(1): 59-67.

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Introduction

Healthcare is the fastest-growing service in both developed and developing countries. Their main goal is to offer healthcare services to people and help to improve the quality and health of their daily survival rate (1).

Due to increased environmental complexity, resource constraints and rapid increase in costs, especially in health areas, the issue of increasing the efficiency and productivity of all institutions, particularly health organizations, is at the core of the managers' attention. One of the most important principles is optimal resource allocation. Hospitals are considered as the most important consumer units in the health area and one of the main organizations to provide health services (2). Thus significant savings in healthcare costs can be obtained by improving their efficiency (3).

Besides, hospital bed management is one of the important subjects in resource allocation. Bed is one of the main resources for serving patients.

Therefore, it is important to find the best way to allocate hospital resources properly. One of the tools that can help in this field is the Operations Research models.

One of the operations research models is Data Envelopment Analysis (DEA). This model has received extensive attention in recent years, which has been used in a broad range of domains, including applications in the healthcare sector (4, 5). DEA, first introduced by Charnes, Cooper, and Rhodes (1978), is a well-known non-parametric mathematical approach applied to assess the relative efficiency of a set of similar units, referred to as Decision Making Units (DMUs) (6).

In conventional DEA models, each DMU sets its own priorities. This issue is logical when DMUs operate in a decentralized situation. The problem arises when a group of DMUs is under the control of a central decision-maker who would like to evaluate them with common priorities operating over all the systems. In this case, conventional DEA models do not make much sense (7). Therefore, it would be much more reasonable to use the Centralized Data Envelopment Analysis (CDEA) model. The CDEA model applies when all of the units are under the control of a single decision-maker in a centralized management system. This condition occurs when all the DMUs belong to the same organization.

Many applications of DEA (such as hospitals) can be included in this category. This centralized decision-maker, while interested in the efficiency of the DMUs, is also concerned with their overall consumption of the inputs and the overall production of their outputs (because conventional DEA models do not consider aggregate input consumption or aggregate output production).

Several studies have been conducted on the performance evaluation of hospitals. For example (8), used the Pabon Lasso model to assess the performance of 8 general hospitals in Tehran. Results showed these hospitals generally have low performance, as indicated by Pabon Lasso analysis. (9), Applied Stochastic Frontier Analysis (SFA) method to estimate the efficiency of 12 teaching hospitals between 1999 and 2011. The study showed a significant waste of resources in hospitals. (5), They used input-oriented DEA to investigate the efficiency of 17 Greek hospitals. In a study at Ahvaz, Iran, the efficiency of teaching and nonteaching hospitals was assessed using DEA in 2006-2010 (10). Another study in the USA calculated the efficiency scores for a sample of non-federal acute care hospitals (11). Saber Mahani et al. (12) used DEA to determine the technical efficiency of 13 teaching hospitals in Kerman University of Medical Sciences. Interested readers in this context can refer to (13, 14). (13), A study summarized all studies using DEA to evaluate the hospitals (14), studied the methods of hospital performance evaluation are used in Iran. They said DEA is the mostly used method to evaluate hospital performance in reviewed articles.

Although the above studies are considerable and address the issue related to hospital performance evaluation and resource allocation, they have failed to apply a centralized resource allocation approach that, at the same time, looked for the efficiency of the individual hospitals, aiming to minimize the total input or maximize total output.

Furthermore, various studies in developing countries such as Iran show that more than half of the healthcare resources are wasted, and limited resources are used inefficiently (15). Now, one of the major issues facing healthcare managers and officials, especially hospitals, is resource allocation and the evaluation of hospital performance.

According to what is stated, the effort to allocate optimal resources to hospitals is necessary. Many hospitals in Iran are under the control of a centralized decision-maker (e.g. the Ministry of Health or Social Security Organization). However, it seems that no study has used CDEA to assess performance and resource allocation to hospitals and this point has been neglected in many studies in the field of hospital management. Previous studies have used conventional DEA models to allocate resources to a set of hospitals even though they are under the control of a central decision-maker. However, as mentioned, it is more appropriate to apply a method for an overall evaluation of resource allocation on the performance of the hospitals. Using CDEA cause more realistic and reliable results. This study aimed to fill this research gap. Therefore, this study was an attempt to apply a centralized DEA model to determine the efficient number of beds (resource) allocated to each hospital while increasing the efficiency of all hospitals (looking for the overall improvement of the hospitals' performance) and reduce the total number of Social Security Organization hospital beds.

Based on statistics of the 2016 Social Security statistical yearbook, this organization has 70 hospitals in the country. The total number of these hospitals' active beds is 8964 (16). In this study, we consider each Social Security hospital as DMU.

Methods

This research was a cross-sectional and applied study. Social Security hospitals in Iran formed the statistical population of research. Social Security Organization is one of the largest organizations providing hospital services in Iran. Due to the expansion of Social Security hospital services and their vast contribution to Iranian community health services, it is necessary to allocate the resources to these hospitals based on their overall performance. Thus, social situation, need of the majority of people for this type of hospital and, therefore, the need for their efficiency were the inclusion criteria for selecting these hospitals. The required data were collected from the 2016 statistical yearbook of this organization (16).

DEA is the method to analyze the several inputs and outputs of the DMUs (hospitals). Table 1 shows the hospitals' inputs and outputs that are used in some studies measuring hospital efficiency using DEA. In this study, the input data consisted of the number of active beds, and the output data consisted of bed occupancy rate, average patient length of stay, and death in thousand. Death in thousand was an undesirable output, so to convert it to desirable output, we deducted its value from thousand (survived in thousand). To measure the hospitals efficiency scores before and after reallocation, the input-oriented BCC envelopment model was used, as shown below:

$$
\begin{aligned}
& Min \ \theta \\
& s.t \ \sum_{j=1}^{n} \lambda_j x_{ij} \le \theta x_{ik}, i = 1,2,\ldots,m, \\
& \sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{rk}, \ r = 1,2,\ldots,s, \qquad (1) \\
& \sum_{j=1}^{n} \lambda_j = 1, \\
& \lambda_j \ge 0, \ j = 1,2,\ldots,n.
\end{aligned}
$$

Where n is the number of DMUs, m the number of

Table 1: The inputs and outputs of DEA in studies measuring hospitals efficiency

Authors	Year	Inputs	Outputs
Kiani et al. (18)	2018	- number of beds - number of doctors - number of full-time nurses, - number of other full-time staff	- bed occupancy - average residence of patients - number of surgeries - percentage of cesarean section in total deliveries
Pirani et al. (19)	2018	- number of available beds - number of hospital admissions - number of nurses	- average of length of stay (LOS) - bed turnover interval
Ali et al. (20)	2017	- Total beds -Cost of drug supply - Total health staffs	-Outpatient department visit -Inpatient days -Number of surgery
Farzianpour et al. (21)	2017	- Specialist physician - General physician - Total staffs other than physicians - Number of active beds	- Number of outpatients - Bed occupancy rate
Jia and Yuan (22)	2017	-The actual number of beds -The actual number of staff	-The number of patients in the outpatient and emergency department -The number of discharged patients -The average days of hospitalization
Kalhor et al. (23)	2016	- Total number of full-time medical doctors - Total number of full-time equivalent nurses - Number of supporting medical personnel - Number of beds	- Number of patient days - Number of outpatient visits - Number of patients receiving surgery - The average length of stay
Wang et al. (24)	2016	- Total expenditure - Number of doctors - Number of nurses - Number of open beds	- Total revenue - Number of outpatients and emergency visits - Number of discharged patients
Cheng et al. (25)	2015	- Number of physicians - Number of nurses - The actual number of open beds	- Number of outpatient and emergency visits - Number of inpatient days
Harrison and Meyer (26)	2014	- Operating expenses - Hospital beds - Full-time employees	- Inpatient days - Surgical procedures - Outpatient visits
Yusefzadeh et al. (27)	2013	-Number of doctors -Number of active beds -Number of other personnel	-Number of patients admission - Occupied day beds
Hu et al. (28)	2012	- Number of doctors - Number of technicians - Number of staffs - Number of beds - Total fixed assets	- Emergency room visits - Total number of outpatients - Total number of inpatient days
Shahhoseini et al. (29)	2011	- Number of physicians - Number of nurses - Number of other professional - Number of active beds	- Inpatient bed days - The average length of stay - Bed occupancy rate - Outpatient visits - Number of surgeries

inputs and s the number of outputs. x_{ij} is the amount of input i used by DMU_j, and y_{rj} is the amount of output r produced by DMU_j. DMU_k is the DMU to be evaluated. Also, if the objectives function value of the above models in the optimal solution equals one, the unit under evaluation is efficient, and otherwise, it is called inefficient.

In this study, the input-oriented CDEA model proposed by Lozano and villa (17) was used. This model has two phases. In the first phase, a proportional reduction along with all inputs is sought. In the second phase, an additional reduction of any input and/or increase of any output is pursued. The first phase of the model is as follows (17):

Suppose that j, r=1,2; . . . , n, is the indexes for DMUs, i=1, 2, . . . ,m, is the index for inputs, k=1, 2, . . . , p, is the index for outputs, x_{ij}=amount of input i consumed by DMU j, y_{kj}=quantity of output k produced by DMU_j, =radial contraction of the total input vector, s_i=slack along with the input dimension i, t_k=additional increase along with the output dimension k, $(\lambda_{1r},\lambda_{2r},\ldots,\lambda_{nr})$=vector for projecting DMU_r.

$$
\begin{aligned}
& Min\ \theta \\
s.t\ & \sum_{r=1}^{n}\sum_{j=1}^{n}\lambda_{jr}x_{ij} \le \theta\sum_{j=1}^{n}x_{ij}, && \forall i \\
& \sum_{r=1}^{n}\sum_{j=1}^{n}\lambda_{jr}y_{kj} \ge \sum_{j=1}^{n}y_{kj}, && \forall k \qquad (2) \\
& \sum_{l=1}^{n}\lambda_{jr} = 1, && \forall r \\
& \lambda_{jr} \ge 0,\ \theta free
\end{aligned}
$$

By solving the first phase, θ* is obtained as the optimum value of the model, so the second phase of the model is:

$$
\begin{aligned}
& Max\ \sum_{i=1}^{m}s_i + \sum_{k=1}^{p}t_k \\
s.t\ & \sum_{j=1}^{n}\sum_{l=1}^{n}\lambda_{jr}x_{ij} = \theta^*\sum_{j=1}^{n}x_{ij} - s_i, && \forall i \\
& \sum_{j=1}^{n}\sum_{l=1}^{n}\lambda_{jr}y_{kj} = \sum_{r=1}^{s}y_{kr} + t_k, && \forall k \qquad (3) \\
& \sum_{l=1}^{n}\lambda_{jr} = 1, && \forall r \\
& \lambda_{jr}, s_i, t_k \ge 0.
\end{aligned}
$$

To solve these models, we used GAMS software.

Results

Table 2 reports a summary of the inputs, outputs, and descriptive statistics of Social Security hospitals. According to this Table, the hospitals on average have 128 beds. The mean for bed occupancy rate, average patient length of stay, and survived in thousand are 74, 2.6, and 994, respectively. Table 3 presents the hospitals' efficiency scores. According to this Table, 13 hospitals are efficient.

The standard deviation for bed is high, so we need to cluster the hospitals (13). This clustering which will cause the benchmarks for efficiency improvement of hospitals based on the number of beds, will be realistic in the relevant cluster. Hospitals have been

Table 2: Summary of descriptive of input and outputs

Type	Variable	Mean	Standard deviation	Minimum	Maximum
Input	Active bed	128.0571429	86.14172	24	448
Outputs	Bed occupancy rate	73.61142857	13.64326	18.9	104.1
	Average patient stay	2.577142857	0.707545	1	4.8
	Survived in thousand	993.7628571	4.627069	976	1000

Table 3: DEA efficiency scores before reallocation

Hospital	Efficiency	Hospital	Efficiency	Hospital	Efficiency	Hospital	Efficiency	Hospital	Efficiency
H1	0.34222	H15	1.00000	H29	1.00000	H43	0.45910	H57	0.89764
H2	0.32776	H16	0.91594	H30	0.15587	H44	0.39354	H58	1.00000
H3	0.16064	H17	1.00000	H31	0.58937	H45	0.58622	H59	0.55914
H4	0.33296	H18	1.00000	H32	0.59807	H46	0.35336	H60	0.30886
H5	1.00000	H19	0.37340	H33	0.63838	H47	0.14733	H61	0.64555
H6	0.09503	H20	0.36022	H34	1.00000	H48	0.24534	H62	0.80762
H7	0.13367	H21	0.69506	H35	0.32474	H49	0.25516	H63	1.00000
H8	0.22947	H22	0.26650	H36	0.65773	H50	0.33535	H64	0.23933
H9	1.00000	H23	0.25867	H37	0.40426	H51	0.33552	H65	0.60525
H10	0.77301	H24	1.00000	H38	0.20719	H52	0.98454	H66	0.58246
H11	0.98392	H25	0.23209	H39	1.00000	H53	0.25556	H67	0.20398
H12	1.00000	H26	0.29672	H40	0.14792	H54	0.35998	H68	0.22412
H13	0.32401	H27	0.20061	H41	0.15181	H55	0.28011	H69	0.23200
H14	1.00000	H28	0.36298	H42	0.41411	H56	0.34821	H70	0.20754

Table 4: Results of hospitals clustering

Clusters	Hospitals					
Cluster 1	H5	H9	H10	H11	H18	H21
	H24	H29	H32	H33	H34	H36
	H39	H44	H45	H52	H57	H58
	H59	H61	H62	H63	H65	
Cluster 2	H6	H15				
Cluster 3	H2	H3	H7	H16	H17	H30
	H40	H41	H47	H55	H60	H67
	H70					
Cluster 4	H1	H4	H8	H12	H13	H14
	H19	H20	H22	H23	H25	H26
	H27	H28	H31	H35	H37	H38
	H42	H43	H46	H48	H49	H50
	H51	H53	H54	H56	H64	H66
	H68	H69				

Table 5: Overall efficiency and the number of beds reallocated to cluster 1' hospitals

Cluster 1 Overall efficiency=0.703																							
Hospitals	**H5**	**H9**	**H10**	**H11**	**H18**	**H21**	**H24**	**H29**	**H32**	**H33**	**H34**	**H36**	**H39**	**H44**	**H45**	**H52**	**H57**	**H58**	**H59**	**H61**	**H62**	**H63**	**H65**	**Sum of beds**
Bed current values	46	32	39	32	75	40	36	30	74	51	32	62	24	80	52	35	34	32	54	51	40	33	55	1039
Suggested bed values	30	30	24	24	30	24.21	24	30.61	36	36	36	24	36	36	36	36	36	36	33.58	33	33	33	33	730.417

clustered into 4 groups of homogenous units based on the experts' points of view by the k-means clustering method. According to this clustering, 23 hospitals were assigned to cluster 1, 2 hospitals to cluster 2, 13 hospitals to cluster 3, and 32 hospitals to cluster 4, as shown in Table 4.

The number of beds reallocated to each cluster of hospitals and the overall efficiency of these hospitals were obtained via CDEA. Table 5-8 shows the results.

According to the results of cluster 1, for example, the number of H9 hospital beds decreased from 32 to 30, and the number of H34 hospital beds increased from 32 to36. The overall efficiency in this cluster is 0.703, and the sum of beds is 730.417. The sum of beds for these clusters decreased from 1039, 838, 3103, and 3984 to 730.417, 838, 2566.18, and 2916.288, respectively. After beds were reallocated, the hospitals' efficiency scores were calculated by the model (1). The results are presented in Table 9. According to this Table, 31 hospitals are efficient.

Discussion

Due to the lack of resources and rising costs, increasing efficiency in hospitals can lead to better

Table 6: Overall efficiency and the number of beds reallocated to cluster 2' hospitals

Cluster 2 Overall efficiency=1			
Hospitals	**H6**	**H15**	**Sum of beds**
Bed current values	390	448	838
Suggested bed values	448	390	838

Table 7: Overall efficiency and the number of beds reallocated to cluster 3' hospitals

Cluster 3 Overall efficiency=0.827													
Hospitals	**H2**	**H3**	**H7**	**H16**	**H17**	**H30**	**H40**	**H41**	**H47**	**H55**	**H60**	**H67**	**H70**	**Sum of beds**
Bed current values	299	256	254	229	247	206	224	225	246	192	256	213	256	3103
Suggested bed values	229	213.03	204.14	192	192	192	192	192	192	192	192	192	192	2566.18

Table 8: Overall efficiency and the number of beds reallocated to cluster 4' hospitals

Cluster 4 Overall efficiency=0.732																	
Hospitals	**H1**	**H4**	**H8**	**H12**	**H13**	**H14**	**H19**	**H20**	**H22**	**H23**	**H25**	**H26**	**H27**	**H28**	**H31**	**H35**	**Sum of beds**
Bed current values	96	132	140	147	152	98	103	148	125	137	145	106	160	102	88	132	
Suggested bed values	94	96	88.614	96	96	94	94	96	96	96	88	88	94	94	94	96	
Hospitals	H37	H38	H42	H43	H46	H48	H49	H50	H51	H53	H54	H56	H64	H66	H68	H69	
Bed current values	112	161	104	102	110	133	129	95	98	130	111	163	144	94	146	141	3984
Suggested bed values	88	88	88	88	88	88	88	88	95.674	88	88	88	88	88	88	88	2916.288

Table 9: DEA efficiency scores after reallocation

Hospital	Efficiency	Hospital	Efficiency	Hospital	Efficiency	Hospital	Efficiency	Hospital	Efficiency
H1	1.00000	H15	0.11107	H29	1.00000	H43	0.90849	H57	1.00000
H2	1.00000	H16	0.47685	H30	0.47685	H44	1.00000	H58	1.00000
H3	0.26843	H17	0.47685	H31	1.00000	H45	1.00000	H59	1.00000
H4	0.34222	H18	1.00000	H32	1.00000	H46	0.90849	H60	0.47685
H5	1.00000	H19	1.00000	H33	1.00000	H47	0.47685	H61	1.00000
H6	1.00000	H20	0.34222	H34	1.00000	H48	0.90849	H62	1.00000
H7	0.34284	H21	1.00000	H35	0.34222	H49	0.90849	H63	1.00000
H8	0.81508	H22	0.34222	H36	1.00000	H50	0.90849	H64	0.90849
H9	1.00000	H23	0.34222	H37	0.90849	H51	0.90849	H65	1.00000
H10	1.00000	H24	1.00000	H38	0.90849	H52	1.00000	H66	0.90849
H11	1.00000	H25	0.90849	H39	1.00000	H53	0.34866	H67	0.47685
H12	0.34222	H26	0.90849	H40	0.47685	H54	0.90849	H68	0.90849
H13	0.34222	H27	1.00000	H41	0.47685	H55	0.47685	H69	0.90849
H14	1.00000	H28	1.00000	H42	0.90849	H56	0.90849	H70	0.47685

and sustainable achievement of their strategic goals. Therefore, the purpose of this study was to reallocate Social Security hospital beds to optimize the overall efficiency of these hospitals. Reallocation of hospital beds can lead to more significant equity in service delivery and better distribution of resources. The efficient reallocation of hospital beds has a considerable impact on health management. Hospital managers make great efforts to improve treatment and patient satisfaction by optimizing the beds.

As mentioned in the centralized input-oriented model, instead of reducing the inputs of each DMU, the total consumption of DMUs decreases. For example, the sum of beds in cluster 1 should be reduced from 1039 to 730.417, according to Table 5 results. H5, H9, H10, H11, H18, H21, H24, H32, H33, H36, H44, H45, H59, H61, H62, and H65 hospitals have to reduce their beds. H29, H34, H39, H52, H57, and H58 hospitals can increase their beds in the amount of 0.6, 4, 12, 1, 2, 4 beds, respectively. H63 hospital does not need to change its number of beds. This bed reallocation was to optimize the overall efficiency of cluster 1 hospitals, and it makes all hospitals use their resources (beds) efficiently. With these proposals, the overall efficiency in this cluster would be 0.703. It is recommended that some of the patients of the hospitals that we proposed to reduce beds should be referred to the hospitals that were offered to increase their beds. The reason is that the latter hospitals' facility can improve the efficiency of serving the whole community. Before bed reallocation, 13 (18.6%) hospitals were efficient. After bed reallocation by CDEA, 31 (44.3%) hospitals were efficient according to the results shown in Table 9. There is an important point that after this reallocation, the efficiency of all hospitals increased, so this resource reallocation is efficient.

In this regard, the results of this study are similar to those of (5, 23, 25, 30, 31), which reported that less than fifty percent of the studied hospitals were efficient. However, some studies have reported that more than fifty percent of hospitals are efficient (12).

Previous studies that have used conventional input-oriented DEA which is only able to suggest the reduced use of hospital resources, but the model used in this study can also consider increasing resources when needed. As mentioned, the sum of beds must decrease in each cluster to optimize the overall efficiency. This is consistent with the result of (32), which stated that the studied hospitals owned an average of 17.66 extra beds. Also (33), it was mentioned that considering the use of extra beds in the hospital was one of the effective factors in decreasing the efficiency of hospitals.

Although most hospitals in the country are under a centralized decision-maker, conventional DEA models have been used in previous studies for efficiency evaluation. Conventional DEA models cannot be suitable because these hospitals are not private and cannot control their input variables independently. Therefore, this study can have reasonable and practical results. In the current study, all Social Security hospitals in the country were evaluated. This issue makes the findings of this study a better and more complete picture of the status of the Social Security hospitals, and the results of the current research can guide policymakers and healthcare managers for efficient resource allocation. Proposed values for beds used in the studied hospitals help the managers to reduce the waste of the bed due to its improper allocation. Given that beds are reallocated in a way that efficiency is increased, the results implicitly show the positive effect on improving the patients' satisfaction.

The findings of this study could be used for efficient resource reallocation among the hospitals. The notable point in this model is that for all hospitals, the sum of the bed variable decreased, and the sum of output variables did not decrease.

Conclusion

In this study, the CDEA model were used to reallocate Social Security hospital beds in Iran to optimize its overall efficiency. Because the hospitals were nonhomogeneous in terms of size, to achieve logical results, it was necessary to cluster hospitals. Therefore, the hospitals were clustered into 4 clusters according to the experts' points of view and statistical tests.

As expected in all clusters, the total number of beds decreased. However, the reduction of beds should be made in the form of a comprehensive plan and consideration of all aspects. Since the annual cost of each bed is higher than its income, this reduction of beds in each cluster can play an essential role in the management of hospital costs.

The research limitation of this study was that we did not have access to information about the number of physicians and nurses in the studied hospitals. It is suggested that other variables, such as the number of physicians and nurses should be used in future research. This model can be used to calculate the overall efficiency and resource reallocation of hospitals that are under the control of other centralized decision-makers such as Military and Ministry of Health. The use of different datasets, such as imprecise, uncertain, or fuzzy data, can be considered as interesting research topics. This model can be combined with other models, such as the Balanced Score Card (BSC). Other variables with qualitative nature are suggested to be studied. This model can be used to allocate extra beds.

Conflict of Interest: None declared.

References

1. Faezipour M, Ferreira S, editors. A System Dynamics Perspective of Patient Satisfaction in Healthcare. CSER; 2013.doi: 10.1016/j.procs.2013.01.016.
2. Duckett S, Willcox S. The Australian health care system. 2nd ed. Oxford: Oxford university press. South Melbourne; 2004.
3. Ketabi S, Ganji H, Shahin S, Mahnam M, Soltanolkottabi M, Moghadam SAHZ. Surgical services efficiency by data envelopment analysis. *Benchmarking: An International Journal*. 2015;22(6):978–93.
4. Cooper WW, Seiford L, Thanassoulis E, Zanakis SH. DEA and its uses in different countries. *European Journal of Operational Research*. 2004;154(2):337-44d doi: 10.1016/s0377-2217(03)00173-5 .
5. Kontodimopoulos N, Nanos P, Niakas D. Balancing efficiency of health services and equity of access in remote areas in Greece. *Health Policy*. 2006;76(1):49-57. doi: 10.1016/j.healthpol.2005.04.006.
6. Charnes A, Cooper WW, Rhodes E. Measuring the efficiency of decision making units. *European journal of operational research*. 1978;2(6):429-44. doi: 10.1016/0377-2217(78)90138-8 .
7. Mar-Molinero C, Prior D, Segovia M-M, Portillo F. On centralized resource utilization and its reallocation by using DEA. *Annals of Operations Research*. 2014;221(1):273-83. doi: 10.1007/s10479-012-1083-8 .
8. Masoumi G, Hoseini Kasnaviyeh M, Taherizade A, Panahi M, Najafi E. Hospital performance evaluation using Pabon Lasso analysis. *International Journal of Hospital Research*. 2014;3(1):267-72.
9. Goudarzi R, Pourreza A, Shokoohi M, Askari R, Mahdavi M, Moghri J. Technical efficiency of

teaching hospitals in Iran: the use of Stochastic Frontier Analysis, 1999-2011. *Int J Health Policy Manag*. 2014;3(2):91-7. doi: 10.15171/ijhpm.2014.66.
10. Najarzadeh M, Torabipoor A, Ghasemzadeh R, Salehi R. Assessment of hospitals efficiency by Data Envelopment Analysis in Ahvaz in 2006-2010. 2012. ;4(3): 77-87.
11. Nayar P, Ozcan YA. Data envelopment analysis comparison of hospital efficiency and quality. *J Med Syst*. 2008;32(3):193-9. doi: 10.1007/s10916-007-9122-8.
12. Saber-Mahani A, Gh G, Barouni M, Khakian M. Estimation of technical efficiency of general hospitals of Kerman University of Medical sciences by data envelopment analysis (DEA) method IN 2007. *Journal of Kerman University of Medical Sciences*. 2010;16(1): 59-67. Persian.
13. Jahangoshai Rezaee M, Karimdadi A, Izadbakhsh H. Road map for progress and attractiveness of Iranian hospitals by integrating self-organizing map and context-dependent DEA. *Health Care Manag Sci*. 2019;22(3):410-36. doi: 10.1007/s10729-019-09484-2.
14. Bahadori M, Izadi AR, Ghardashi F, Ravangard R, Hosseini SM. The Evaluation of Hospital Performance in Iran: A Systematic Review Article. *Iran J Public Health*. 2016;45(7):855-66.
15. Barouni M, Amiresmaieli MR, Shahravan A, Amini S. The Efficiency Assessment of Dental Units Using Data Envelopment Analysis Approach: The Case of Iran. *Iran J Public Health*. 2017;46(4):552-9.
16. Social Security Organization, Deputy of Economic and Programming. Social Security Organization statistical yearbook in 2016. Persian.
17. Lozano S, Villa G. Centralized resource allocation using data envelopment analysis. *Journal of Productivity Analysis*. 2004;22(1-2):143-61. doi: 10.1023/b:prod.0000034748.22820.33 .
18. Kiani MM, Mosavi Rigi SA, Karami H, Sepaseh F, Naghdi B, Shiravani M. Efficiency evaluation of university hospitals in Bushehr province before and after the implementation of the health system development plan. *Evidence Based Health Policy, Management and Economics*. 2018;2(1):1-11.
19. Pirani N, Zahiri M, Engali KA, Torabipour A. Hospital Efficiency Measurement Before and After Health Sector Evolution Plan in Southwest of Iran: a DEA-Panel Data Study. *Acta Inform Med*. 2018;26(2):106-10. doi: 10.5455/aim.2018.26.106-110.
20. Ali M, Debela M, Bamud T. Technical efficiency of selected hospitals in Eastern Ethiopia. *Health Econ Rev*. 2017;7(1):24. doi: 10.1186/s13561-017-0161-7.
21. Farzianpour F, Emami AH, Foroushani AR, Ghiasi A. Determining the technical efficiency of hospitals in tabriz city using data envelopment analysis for 2013-2014. *Glob J Health Sci*. 2016;9(5):42. doi: 10.5539/gjhs.v9n5p42 .
22. Jia T, Yuan H. The application of DEA (Data Envelopment Analysis) window analysis in the assessment of influence on operational efficiencies after the establishment of branched hospitals. *BMC Health Serv Res*. 2017;17(1):265. doi: 10.1186/s12913-017-2203-6.
23. Kalhor R, Amini S, Sokhanvar M, Lotfi F, Sharifi M, Kakemam E. Factors affecting the technical efficiency of general hospitals in Iran: data envelopment analysis. *J Egypt Public Health Assoc*. 2016;91(1):20-5. doi: 10.1097/01.EPX.0000480717.13696.3c.
24. Wang X, Luo H, Qin X, Feng J, Gao H, Feng Q. Evaluation of performance and impacts of maternal and child health hospital services using Data Envelopment Analysis in Guangxi Zhuang Autonomous Region, China: a comparison study among poverty and non-poverty county level hospitals. *Int J Equity Health*. 2016;15(1):131. doi: 10.1186/s12939-016-0420-y.
25. Cheng Z, Tao H, Cai M, Lin H, Lin X, Shu Q, et al. Technical efficiency and productivity of Chinese county hospitals: an exploratory study in Henan province, China. *BMJ Open*. 2015;5(9):e007267. doi: 10.1136/bmjopen-2014-007267.
26. Harrison JP, Meyer S. Measuring efficiency among US federal hospitals. *Health Care Manag (Frederick)*. 2014;33(2):117-27. doi: 10.1097/HCM.0000000000000005.
27. Yusefzadeh H, Ghaderi H, Bagherzade R, Barouni M. The efficiency and budgeting of public hospitals: case study of iran. *Iran Red Crescent Med J*. 2013;15(5):393-9. doi: 10.5812/ircmj.4742.
28. Hu H-H, Qi Q, Yang C-H. Analysis of hospital technical efficiency in China: Effect of health insurance reform. *China Economic Review*. 2012;23(4):865-77. doi: 10.1016/j.chieco.2012.04.008 .
29. Shahhoseini R, Tofighi S, Jaafaripooyan E, Safiaryan R. Efficiency measurement in developing countries: application of data envelopment analysis for Iranian hospitals. *Health Serv Manage Res*. 2011;24(2):75-80. doi: 10.1258/hsmr.2010.010017.

30. Kakeman E, Rahimi Forushani A, Dargahi H. Technical Efficiency of Hospitals in Tehran, Iran. *Iran J Public Health*. 2016;45(4):494-502.
31. Yusefzadeh H, Ghaderi H, Bagherzade R, Barouni M. The efficiency and budgeting of public hospitals: case study of iran. *Iran Red Crescent Med J*. 2013;15(5):393-9. doi: 10.5812/ircmj.4742.
32. Kazemi Z, Kiadaliri AA, Haghparast H. Estimating efficiency and optimal resource utilization in selected hospitals in east of Iran: applying the data envelopment analysis. *Payesh (Health Monitor)*. 2013;12(5):449-58.
33. Sherman HD. Hospital efficiency measurement and evaluation. Empirical test of a new technique. *Med Care*. 1984;22(10):922-38. doi: 10.1097/00005650-198410000-00005.