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# The use of resource allocation approach for hospitals based on the initial efficiency by using data envelopment analysis

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**ABSTRACT**

***Introduction:*** Recourse allocation is very important in today's highly competitive environment to enhance the quality and reduce costs due to limited resources and unlimited needs of the society. The aim of this study was to implement resource allocation in order to improve the efficiency of hospital.
***Method:*** This is a mixed method study. The data used in this paper are secondary data related to the 30 large acute and general hospitals in the US. Bed, service mix, full-time equivalent (FTE), and operational expenses are input indicators in hospital, and adjusted admissions and outpatient visits are output indicators. Using goal programming (GP) model and data envelopment analysis (DEA) model with a common weights, we suggest three scenarios for resource allocation and budget allocation. "Resource allocation based on efficiency", "budget allocation based on efficiency" and "two stage allocation of budget". The first scenario was used for allocating the resources and the second and third ones for allocating budget to decision making units (DMUs). The data were analyzed by LINGO software.
***Results:*** Before the allocation, four hospitals were efficient and the efficiency of six hospitals was less than 50%, but after allocation, in the first case of the first scenario 14 hospitals, 11 hospitals in the second case of the first scenario, 24 hospitals in the second scenario and 17 hospitals in the third scenario were efficient, and it is an important point that after the allocation, efficiency of all hospitals increased.
***Conclusion:*** This study can be useful for hospital administrators; it can help them to allocate their resource and budget and increase the efficiency of their hospitals.

***Keywords:*** Efficiency, Hospitals, Resource allocation, Budgets

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## Introduction

Health care centers and hospitals use more than 50% of the health resources (1); also, health resources are limited and there is resource shortcoming in many countries, especially in low income countries, so resource allocation is important for health care system (2). There are several methods to allocate resources in the health care centers, one of which is DEA .

DEA is a non-parametric method used to calculate the efficiency of similar DMUs. DEA was introduced by Farrell (3) and developed by Charnes, Cooper, and Rhodes for measuring the efficiency of a set of DMUs (4). Golani and Tamir allocated resources to DMUs with the goal of maximizing common outputs, and a simple programming model based on DEA was used (5). In this regard, Cook and Kress offered two-phase method. In first phase, technical efficiency of DMUs was obtained using CRS model and in the second phase, fixed resources was allocated to the DMUs, and their efficiency did not change after allocation (6). Therefore, Cook and Zhou developed two-phase method of Cook and Kress (7). Teimoori and Kordrostami proposed an alternative allocation approach based on DEA, to obtain a unique allocation, taking into account additional restrictions provided by Beasley (6, 8, 9). Du et al. proposed an iterative approach based one cross-efficiency in which all DMUs are involved with one another so as to adjust the allocation for better performance until no one can further improve (10). Also, Chih-Ching Yang developed a new approach with introducing population-based health indicator into DEA (11).

The weights from the DEA were achieved in such a way that the relevant DMUs had the highest efficiency possible. Thus, the weights chosen for input and output of each DMU can be different and efficiency of DMU can be achieved through several different ways. For example, in the DEA, a DMU can be efficient through its weight distributed equally between the different inputs and outputs or it can be efficient by taking a great weight on

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one or more factors, and assign a zero or very little weight on other factors (12). Therefore, Cook et al. introduced the common weight method to restrict the weights in DEA to be used for evaluation of highway maintenance units (13). Kousmanen et al. evaluated efficiency while price of inputs and outputs were the same for all units, using the common weight in DEA (14). Moreover, Liu and Peng suggested a method for determining common weights for performance indicators of efficient DMUs. Then, the DMUs were ranked according to the efficiency that was given to them by the CSW (Common weights analysis) (15). Amin and Toloo proposed a model to find the most efficient DMUs, using common weights (16). Li and Cui proposed a resource allocation framework consisting of variable-output model, inverse DEA, the common weight analysis and additional resource allocation algorithm (17). A model was proposed by Bi, Ding, Luo, and Liang based on DEA with common weight for resource allocation and setting of output target in parallel production systems (18). Also, Davoodi and Zhiani Rezai introduced a common weights DEA approach using a linear programming problem and multi-objective model to measure the efficiency of the DMUs (19). Hosseinzadeh Lotfi et al. also proposed a common-weights DEA approach to deal with zero-value weights (12). This method is used in our study, and they showed how resources can be assigned to the DMUs and accordingly how the expected common increase in all outputs set by the decision maker can be assigned to the DMUs adequately.

The scenarios proposed in this research are a combination of common weight, DEA and recourse allocation which has received less attention in other studies. Allocation in all scenarios based on more resources is allocated to DMU which has the higher efficiency. In the first scenario, resources are assigned and for the other two scenarios, budget is allocated.

## Methods

This is a mixed method study. To achieve the goals of this paper, we first reviewed the related literature and then proposed three allocation approaches using the common weight DEA. Also, the data used in this paper were taken from the book entitled “Health care benchmarking and performance evaluation” (20). These data are from thirty hospitals with 500 or more beds in the US which is drawn from 2011 AHA and CMS databases.

The model used in this study is a Goal Programming (GP) model to calculate common weights that followed minimum deviation of common weight from the values calculated by the DEA’s primary. The advantages of GP model are linearity, applicability, and meaningfully estimated weights. This model was presented to the allocation of resources by Lotfi et al. (13); this model with n DMU, m input and s output is explained below.

$$Min \quad \sum_{j=1}^{n} \varphi_j \tag{1}$$

$$s.t \quad \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + \varphi_j = 0, \quad j = 1, \dots n \tag{2}$$

$$\varphi_j \geq 0, \quad u_r, v_i \geq \varepsilon, \quad \forall j, r, i. \tag{3}$$

$x_{ij}$ is the amount of input i allocated DMU j, $y_{rj}$ is the amount of output r allocated DMU j, $u_r$ is weight allocated output r, $v_i$ is weight allocated input I, and $\varphi_j$ is the sum of negative and positive deviation. The efficiency of DMUs is obtained as follows, assuming the optimal value is ($u_r^*$,$v_i^*$,$\varphi_j^*$):

$$\theta_j^* = \frac{\sum_{r=1}^{s} u_r^* y_{rj}}{\sum_{i=1}^{m} v_i^* x_{ij}} = 1 - \frac{\varphi_j^*}{\sum_{i=1}^{m} v_i^* x_{ij}}, \quad \forall j. \tag{4}$$

In the next section, three scenarios are presented with the aim of improving efficiency by increasing resource.

### *1. Resource allocation based on efficiency*

The goal of this scenario is increasing the efficiency of DMUs in such a way that most resources are assigned to the DMU which has the most efficiency. The general model for this scenario is achieved with little change in the model (1).

$$Min \quad \sum_{j=1}^{n} \varphi_j \tag{5}$$

$$s.t \quad \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i (x_{ij} + \acute{x}_{ij}) + \varphi_j = 0 \quad j=1, \dots n \tag{6}$$

$$\sum_{j=1}^{n} \acute{x}_{ij} = b_i \quad i = 1, \dots m \tag{7}$$

$$\varphi_j, \acute{x}_{ij} \geq 0, \quad u_r, v_i \geq \varepsilon, \quad \forall j, r, i. \tag{8}$$

$x'_{ij}$ is a new decision variable which means the amount of the source i that is allocated to the DMU j and $b_i$ is the fixed amount of source i which is intended to be allocated to the DMUs. Each DMU’s efficiency is obtained from the following equation.

$$\theta_j^* = \frac{\sum_{r=1}^{s} u_r^* y_{rj}}{\sum_{i=1}^{m} v_i^* (x_{ij} + \acute{x}_{ij})} = 1 - \frac{\varphi_j^*}{\sum_{i=1}^{m} v_i^* (x_{ij} + \acute{x}_{ij})} \quad j = 1, \dots n \tag{9}$$

To achieve the goal of this scenario, we considered two approaches, “Resource allocation based on overall efficiency” and “Resource allocation based on input efficiency”.

In “Resource allocation based on overall efficiency”, the criterion for allocation of resource is DMUs efficiency; in other words, most resources are allocated to the DMU which has the most efficiency. Therefore, at first DMUs are arranged based on more efficiency to less efficiency, and then we compare the DMUs, two by two from top to bottom, which leads to creation of sequential constraints and these constraints are added to the model (5). Sequential constraints are as follows.

$$\theta_j^* \geq \theta_k^* \qquad \acute{x}_{ij} \geq \acute{x}_{ik} \qquad \forall i, j, k.$$

After the first resource allocation, if DMU exists and its new efficiency is lower than its initial efficiency, it indicates that in this DMU, strengthening the allocation of this resource has not worked and another resource must be allocated to it. If their efficiency increases the ratio of initial efficiency, the operation stops. Otherwise, it will continue until the last resource allocation.

In the second approach “Resource allocation based on input efficiency”, resources are allocated like the first case, with the difference that, for the allocation of each resource sequential constraints are written based on that resource efficiency. To obtain the efficiency of each resource, in the model (1) only relevant resource (input) is considered with all output, so relevant resource efficiency is obtained using the equation (4).

***2. Budget allocation based on efficiency***

In this scenario, as the previous scenario, most budgets are assigned to the DMU which has the most efficiency. Sequential constraints in this scenario that is added to model (10) are as follows.

$$\Longrightarrow \theta_j^* \geq \theta_k^* \qquad \mathrm{B}_j \geq \mathrm{B}_k \qquad \forall i,j,k$$

The proposed model for this scenario is as follows:

$$Min \quad \textstyle\sum_{j=1}^{n} \varphi_j \tag{10}$$

$$s.t \quad \textstyle\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i (x_{ij} + \acute{x}_{ij}) + \varphi_j = 0, \qquad j = 1, \dots n, \tag{11}$$

$$\textstyle\sum_{i=1}^{m} c_i * \acute{x}_{ij} = \mathrm{B_j} \qquad j = 1, \dots n, \tag{12}$$

$$\textstyle\sum_{j=1}^{n} B_j = \mathrm{B} \tag{13}$$

$$\varphi_j, \acute{x}_{ij} \geq 0, \quad u_r, v_i \geq \varepsilon, \quad \forall j,r,i. \tag{14}$$

B is assignable budget, B_jis the allocated budget to DMU j and c_i is the cost of resource i. Each DMU's efficiency is obtained from the equation (9).

***3. Two-stage budget allocation***

In the first stage, a certain amount of assignable budget is divided between all DMUs equally to allocate different resources. The allocated budget to each resource in DMUs is obtained using the model (10) (constraint (13) is deleted and B_jis fixed budget) and the efficiency of DMUs is obtained from the equation (9).

In the second stage, the remaining budget is allocated to DMUs based on the increase that DMUs had in their efficiency, in the first stage. In fact, most budgets are assigned to DMU which had the greatest increase in its efficiency. Model (10) runs for this stage with the relevant sequential constraints.

**Results**

In this research, 30 hospitals were considered with 4 inputs and 2 outputs, for allocating the resources. Bed, Service mix (The number of services provided by hospitals), FTEs (Total hours worked per week) and Operational Expenses (The operating costs per week) are inputs and Adjusted Admissions (The number of hospitalized patients per week) and Outpatient Visits (The number of outpatients per week) are the outputs.

The initial efficiency of 30 hospitals was obtained using model (1) and equation (4). The results are shown in the second column of Table 1. According to the results, 4 hospitals were efficient and 6 hospitals had an efficiency less than 0.5; the other hospitals were between the two groups.

***1. Resource allocation based on efficiency***

For allocating the beds, 29 sequential constraints were added to the model (5) based on initial efficiency, in "Resource allocation based on overall efficiency". The first and second constraints are given below.

$x'_{1,15} >= x'_{1,26} \qquad x'_{1,26} >= x'_{1,27}$

2 hospitals, No 28 and 15, which were efficient, their efficiency has fallen after allocating the beds. This shows that increasing the number of beds had not worked in these hospitals. In the second stage, model (5) was implemented only for these two hospitals for allocating service mix and sequential constraint $x'_{2,15} >= x'_{2,28}$ was added to the model (5). After allocation, the assigned service mix for both hospitals was 700 and efficiency of the hospital No.15 was 0.94 and hospital No.28 was efficient. Efficiency of hospital No.15, compared to its initial efficiency, has not still increased. In the third stage, all of the third resource, "FTEs" was allocated to this hospital and finally the fifteenth hospital was efficient.

In the second approach, "Resource allocation based on input efficiency", first the bed efficiency of all hospitals was obtained; then, 29 sequential constraints were added to the model (5), based on bed efficiency.

After allocating the beds, efficiency of all hospitals, except two hospitals No.15 and 28, increased, so service mix efficiency was calculated for these two hospitals and based on them a sequential constraint was added to the model (5) and service mix was assigned to them. Allocating service mix was the same for these two hospitals and hospital No.28 became efficient and efficiency of hospital No.15 decreased to 0.94, like the previous approach. So, allocating FTEs was considered for this hospital. Because there was a hospital for the allocation, there was no need to calculate FTEs efficiency and all of this resource was allocated to it. Finally, hospital No.15 became efficient by allocating "FTEs".

***2. Budget allocation based on efficiency***

The cost of each resource for bed was considered 20,000,000 Rial, for service mix it was 100,000,000 Rial, for FTEs 500,000 Rial and for Operational Expenses 1 Rial (Operational expenses are made of cost, so its cost is 1.)

The results of the "Budget allocation based on efficiency" are listed in Table 1. In this scenario, 24 hospitals were efficient after allocation. The average efficiency of inefficient hospitals was 0.79; also, no budget was allocated to them. 15 hospitals spent all their budgets to "Operational Expenses"; this shows their weakness in this resource and only 4 hospitals considered budget for "bed".

***3. Budget allocation in two stages***

In the first stage, 30% of the budget was divided equally between hospitals. In the second stage, sequential constraints were added to the model (10) according to the difference between efficiency of before and after allocation. Three hospitals, 7, 4 and 5, had the maximum difference between efficiency of before and after allocation. Thus, these hospitals allocated most budgets to themselves. Results of the first and second stages are presented in Table 1.

**Table 1.** The budget allocated to each resource and hospital efficiency after the allocation in "budget allocation based on efficiency" and "two stage allocation of budget"

| Hospital | Initial efficiency | Assigned Budget | | Assigned Bed | | | Assigned service mix | | | Assigned FTEs | | | Assigned Operational Expenses | | | efficiency after allocation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3.2 | 3.3.2 | 3.2 | 3.3.1 | 3.3.2 | 3.2 | 3.3.1 | 3.3.2 | 3.2 | 3.3.1 | 3.3.2 | 3.2 | 3.3.1 | 3.3.2 | 3.2 | 3.3.1 | 3.3.2 |
| H1 | 0.56 | 72244360 | 143086900 | 0 | 0 | 0 | 0 | 6 | 14 | 0 | 0 | 61.74 | 72222310 | 0 | 0 | 1 | 0.73 | 0.85 |
| H2 | 0.41 | 0 | 143086900 | 0 | 0 | 0 | 0 | 6 | 14 | 0 | 0 | 61.74 | 0 | 0 | 0 | 0.85 | 0.56 | 0.64 |
| H3 | 0.85 | 323073400 | 143086900 | 0 | 30 | 51 | 0 | 0 | 0 | 3442.251 | 0 | 52.84 | 151051300 | 0 | 3.84E+07 | 1 | 1 | 1 |
| H4 | 0.75 | 255822800 | 143086900 | 0 | 0 | 0 | 0 | 6 | 1 | 2492.18 | 0 | 1959.41 | 131160800 | 0 | 35116300 | 1 | 0.98 | 1 |
| H5 | 0.68 | 234903900 | 143086900 | 0 | 0 | 51 | 0 | 6 | 3 | 2413.15 | 0 | 28.56 | 114170000 | 0 | 9658745 | 1 | 0.91 | 1 |
| H6 | 0.63 | 76236570 | 143086900 | 0 | 0 | 0 | 0 | 6 | 14 | 0 | 0 | 61.74 | 76220200 | 0 | 0 | 1 | 0.8 | 0.93 |
| H7 | 0.63 | 90971300 | 143086900 | 0 | 0 | 23 | 0 | 6 | 0 | 0 | 0 | 1941.23 | 90954350 | 0 | 25223.82 | 1 | 0.86 | 1 |
| H8 | 0.43 | 0 | 143086900 | 0 | 0 | 0 | 0 | 6 | 14 | 0 | 0 | 61.74 | 0 | 0 | 0 | 0.89 | 0.58 | 0.67 |
| H9 | 0.85 | 323073400 | 143086900 | 0 | 0 | 2 | 0 | 0 | 4 | 3783.87 | 949.02 | 1011.33 | 133970400 | 12548990 | 4.85E+07 | 1 | 1 | 1 |
| H10 | 0.62 | 72604070 | 143086900 | 0 | 0 | 0 | 0 | 6 | 14 | 112.5893 | 0 | 61.74 | 66592840 | 0 | 0 | 1 | 0.78 | 0.91 |
| H11 | 0.69 | 255822800 | 143086900 | 0 | 0 | 70 | 0 | 6 | 0 | 0 | 0 | 11.06807 | 255770000 | 0 | 2533520 | 1 | 0.87 | 1 |
| H12 | 0.93 | 347669400 | 143086900 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 570.26 | 80.5 | 347624900 | 31487050 | 1.29E+08 | 1 | 1 | 1 |
| H13 | 0.69 | 234903900 | 143086900 | 61 | 0 | 0 | 0 | 6 | 14 | 0 | 0 | 61.74 | 113182200 | 0 | 0 | 1 | 0.81 | 0.96 |
| H14 | 0.91 | 323073400 | 143086900 | 72 | 0 | 1 | 0 | 0 | 6 | 0 | 672.74 | 163.51 | 179645100 | 26362820 | 7.29E+07 | 1 | 1 | 1 |
| H15 | 1 | 347669400 | 143086900 | 0 | 0 | 1 | 0 | 0 | 0 | 3341.38 | 245.67 | 1009.84 | 180556000 | 47716640 | 9.06E+07 | 1 | 1 | 1 |
| H16 | 0.95 | 347669400 | 143086900 | 0 | 0 | 0 | 0 | 0 | 4 | 3243.42 | 52.64 | 14.46 | 185453700 | 57367800 | 1.02E+08 | 1 | 1 | 1 |
| H17 | 0.67 | 234903900 | 143086900 | 0 | 0 | 0 | 0 | 6 | 14 | 0 | 0 | 61.74 | 234827400 | 0 | 0 | 1 | 0.79 | 0.91 |
| H18 | 0.48 | 0 | 143086900 | 0 | 0 | 0 | 0 | 6 | 14 | 0 | 0 | 61.74 | 0 | 0 | 0 | 0.93 | 0.64 | 0.74 |
| H19 | 0.38 | 0 | 143086900 | 0 | 0 | 0 | 0 | 6 | 14 | 0 | 0 | 61.74 | 0 | 0 | 0 | 0.67 | 0.47 | 0.54 |
| H20 | 0.84 | 322642400 | 143086900 | 3 | 0 | 2 | 0 | 6 | 7 | 0 | 0 | 40.92 | 317163900 | 0 | 6.70E+07 | 1 | 0.95 | 1 |
| H21 | 0.76 | 322642400 | 143086900 | 0 | 0 | 34 | 0 | 6 | 0 | 0 | 0 | 38.26 | 322584500 | 0 | 7.32E+07 | 1 | 0.94 | 1 |
| H22 | 0.62 | 72604070 | 143086900 | 0 | 0 | 0 | 0 | 6 | 14 | 46.66 | 0 | 61.74 | 69889280 | 0 | 0 | 1 | 0.77 | 0.87 |
| H23 | 0.37 | 0 | 143086900 | 0 | 0 | 0 | 0 | 6 | 14 | 0 | 0 | 61.74 | 0 | 0 | 0 | 0.66 | 0.48 | 0.54 |
| H24 | 0.66 | 186815200 | 143086900 | 0 | 0 | 0 | 0 | 6 | 14 | 0 | 0 | 61.74 | 186771000 | 0 | 0 | 1 | 0.83 | 0.96 |
| H25 | 0.41 | 0 | 143086900 | 0 | 0 | 0 | 0 | 6 | 14 | 0 | 0 | 61.74 | 0 | 0 | 0 | 0.78 | 0.54 | 0.62 |
| H26 | 1 | 347669400 | 143086900 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 347624900 | 60000000 | 143086900 | 1 | 1 | 1 |
| H27 | 1 | 347669400 | 143086900 | 0 | 0 | 0 | 0 | 0 | 0 | 277.93 | 0 | 0 | 333728400 | 60000000 | 143086900 | 1 | 1 | 1 |
| H28 | 1 | 347669400 | 50479330 | 0 | 0 | 0 | 0 | 6 | 0 | 2467.83 | 0 | 0 | 224233500 | 0 | 50479220 | 1 | 0.99 | 1 |
| H29 | 0.75 | 255822800 | 143086900 | 33 | 0 | 59 | 0 | 6 | 2 | 17.5 | 0 | 1.61 | 188895100 | 0 | 5006666 | 1 | 0.9 | 1 |
| H30 | 0.72 | 255822800 | 143086900 | 0 | 0 | 0 | 8 | 6 | 14 | 32.29 | 0 | 61.74 | 174155500 | 0 | 0 | 1 | 0.88 | 1 |

Columns 3.2 are results "Budget allocation based on efficiency" scenario, Columns 3.3.1 are first stage results of "Budget allocation in two stages" scenario and Columns 3.3.2 are second stage results of "Budget allocation in two stages" scenario.

According to Table 1, 17 hospitals became efficient after budget allocation and the average efficiency of the remaining hospitals was 0.78. In all hospitals that remained inefficient after allocation, all the budget was allocated to the "service mix", and also all funds of the three hospitals, No. 26, 27 and 28, was dedicated to the "Operational Expenses".

Discussion

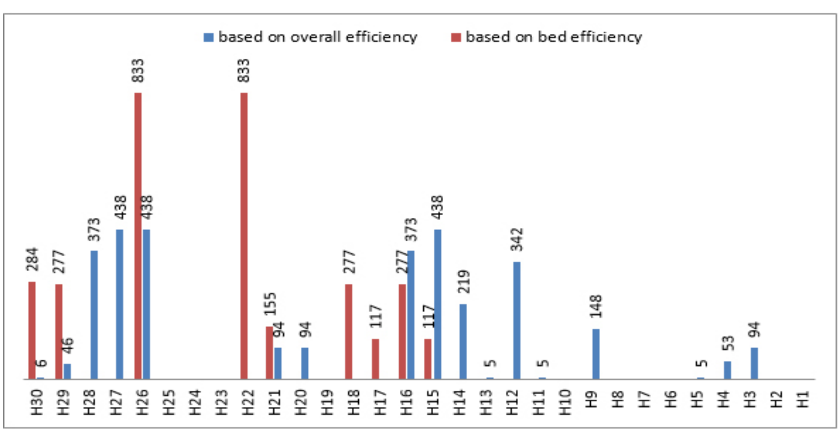
Two cases "Resource allocation based on overall efficiency" and "Resource allocation based on input efficiency" in the first scenario are compared with each other in Figure 1.

4 hospitals had high efficiency in utilizing of beds, but their efficiency was low and in the first case no bed was assigned to them. Finally in 5 hospitals, bed was given to them in both cases; this shows both efficiency and bed efficiency in them are relatively high.

Next, the correspondence between the second and third scenarios are discussed. In other words, it is specified in Figure 1 that how much budget has been allocated to any resource, in the second and third scenarios.

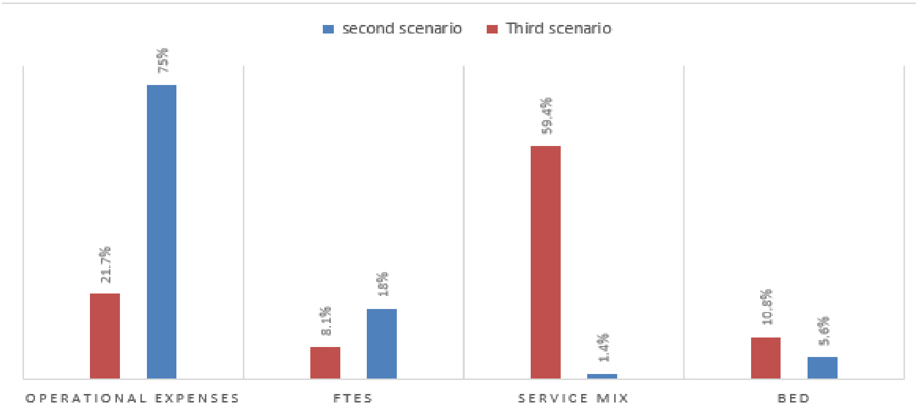
Generally, service mix efficiency is the lowest efficiency among other inputs. This causes the lowest budget to be allocated to the service mix and most to the operational expenses in the second scenario. However, as can be seen in the third scenario, most budget was allocated to service mix and lowest to the FTEs. In the third scenario, allocating budget between inputs was a little more balanced than the second scenario because in the third scenario, the budget

**Figure 1.** Bed allocation to each hospital in the two cases of first scenario




Bed is allocated to 11 hospitals in the first case; efficiency of these hospitals were relatively high, but they had poor performance in utilizing the beds. 10 hospitals were weak because both their efficiency and bed efficiency were weak and beds were not assigned to them in any two cases.

**Figure 2.** Assigned budget to each resources in second and third scenarios




was divided into two stages and in the first stage a certain budget was divided equally between all hospitals.

Generally, service mix efficiency is the lowest efficiency among other inputs. This causes the lowest budget to be allocated to the service mix and most to the operational expenses in the second scenario. However, as can be seen in the third scenario, most budget was allocated to service mix and lowest to the FTEs. In the third scenario, allocating budget between inputs was a little more balanced than the second scenario because in the third scenario, the budget was divided into two stages and in the first stage a certain budget was divided equally between all hospitals.

Hospitals in the second and third scenarios were divided into 4 clusters, based on the amount of allocated budget to their input. 4 clusters of the second scenario are as followed: 1) weak efficiency in bed and service mix: 11 hospitals have been allocated all their budgets to FTEs and operating costs, in this scenario. 2) Weak: 6 hospitals had not allocated any budget to them. 3) Good efficiency in operational expenses: 9 hospitals had allocated all their budgets to the fourth input. 4) Good efficiency in operational expenses and Beds: 4 hospitals had allocated their budgets to operational expenses and bed, on average. 4 clusters in the last scenario are as follows: 1) Good efficiency in FTEs and service mix: no budget was received for beds and operational expenses in 14 hospital. 2) Good efficiency: 8 hospitals dedicated their budget to all inputs. 3) Weak efficiency in service mix: 4 hospitals in all hospitals allocated no budget to service mix. 4) Weak efficiency in bed: In four hospitals, no budget was considered for beds.

Finally, the relationship between these two clustering is shown in Table 2.

Each row in Table 2 shows the strengths and weaknesses of the existing hospitals in the row. For example, the first row hospitals had good efficiency in the use of FTEs and weak efficiency in bed or fifth row hospitals had weak efficiency, but the two inputs FTEs and service mix had performed better than the two other inputs. Or in the hospital 26, input operational expenses had the highest efficiency and highest efficiency service mix had the lowest efficiency among its other inputs. Finally, it can be concluded from Table 2 that each organization has its own unique path which may not be emulated by other organizations. Therefore, each hospital must draw its roadmap toward increasing efficiency and improve it by analyzing its situation and the resources available.

## Conclusion

Allocation in proposed scenarios in this paper is based on the fact that each DMU has more efficiency and subsequently its resources could be better used than other DMUs; more allocation is awarded to the DMU. The significant point in the first scenario is that after allocation, 46 percent of hospitals were efficient in the first case, and 36 percent in the latter, but the average efficiency in hospitals was 0.89 and relative improvement in the efficiency was 18% in the first case and 0.91 and 20% in the second case, respectively. It can be concluded that for allocating resources, the latter is more appropriate if the purpose of hospital is improving efficiency of all units. But if the purpose of the hospital is increasing the number of efficient units in the hospital, the first case “resource allocation based on overall efficiency “ is more appropriate.

In the second and third scenarios, considering that both were related to budget allocation, after allocation, 80 percent of hospitals were efficient in the second scenario, and 56% in the third scenario. If it is important for the budget providing organization that budget is allocated to all hospitals and also the hospitals with greater efficiency receive more budgets,, the third scenario is more appropriate. But if only it is important that more budgets be allocated to hospitals with greater efficiency, the second scenario is more appropriate.

In future research, it is recommended that other approaches should be used to increase the efficiency of DMU, for example transferring resources between DMU or a combination of the transferring and allocating resources and budget. Also, other input and output factors can be considered, for example qualitative input and output factors such as customer satisfaction and employees.

A limitation of this study was lack of consideration of all hospital goals of allocating resource and budget. In this paper, the goal of allocation was increasing of hospital efficiency which is a general goal.

## Conflict of interest

None declared.

**Table 2.** The relationship between second scenario clusters and third scenario clusters

| Hospital | Second scenario clusters | Third scenario clusters |
|---|---|---|
| **H10,H22,H30** | weak efficiency in bed and service mix | Good efficiency in FTEs and service mix |
| **H5,H9** | weak efficiency in bed and service mix | Good efficiency |
| **H3,H15,H27** | weak efficiency in bed and service mix | Weak efficiency in service mix |
| **H4,H16,H28** | weak efficiency in bed and service mix | Weak efficiency in bed |
| **H2,H8,H18,H19,H23,H25** | Weak | Good efficiency in FTEs and service mix |
| **H1, H6,H17,H24** | Good efficiency in operational expenses | Good efficiency in FTEs and service mix |
| **H7,H11,H21** | Good efficiency in operational expenses | Good efficiency |
| **H26** | Good efficiency in operational expenses | Weak efficiency in service mix |
| **H12** | Good efficiency in operational expenses | Weak efficiency in bed |
| **H13** | Good efficiency in operational expenses and Beds | Good efficiency in FTEs and service mix |
| **H14,H20,H29** | Good efficiency in operational expenses and Beds | Good efficiency |

## References


1. Lotfi F, Kalhor R, Bastani P, Shaarbafchi Zadeh N, Eslamian M, Dehghani MR, et al. Various Indicators for the Assessment of Hospitals' Performance Status: Differences and Similarities. Iranian Red Crescent Medical Journal. 2014;16(4).
2. Shinjo D, Aramaki T. Geographic distribution of healthcare resources, healthcare service provision, and patient flow in Japan: A cross sectional study. Social Science & Medicine. 2012;75(11):1954-63.
3. Farrell MJ. The Measurement of Productive Efficiency. Journal of the Royal Statistical Society Series A (General). 1957;120(3):253.
4. Charnes A, Cooper WW, Rhodes E. Measuring the efficiency of decision making units. European Journal of Operational Research. 1978;2(6):429-44.
5. Golany B, Tamir E. Evaluating Efficiency-Effectiveness-Equality Trade-Offs: A Data Envelopment Analysis Approach. Management Science. 1995;41(7):1172-84.
6. Cook WD, Kress M. Characterizing an equitable allocation of shared costs: A DEA approach. European Journal of Operational Research. 1999;119(3):652-61.
7. Cook WD, Zhu J. Allocation of shared costs among decision making units: a DEA approach. Computers & Operations Research. 2005;32(8):2171-8.
8. Amirteimoori A, Kordrostami S. Allocating fixed costs and target setting: A dea-based approach. Applied Mathematics and Computation. 2005;171(1):136-51.
9. Beasley JE. Allocating fixed costs and resources via data envelopment analysis. European Journal of Operational Research. 2003;147(1):198-216.
10. Du J, Cook WD, Liang L, Zhu J. Fixed cost and resource allocation based on DEA cross-efficiency. European Journal of Operational Research. 2014;235(1):206-14.
11. Yang C-C. Measuring health indicators and allocating health resources: a DEA-based approach. Health Care Management Science. 2016.
12. Lotfi FH, Hatami-Marbini A, Agrell PJ, Aghayi N, Gholami K. Allocating fixed resources and setting targets using a common-weights DEA approach. Computers & Industrial Engineering. 2013;64(2):631-40.
13. Cook WD, Kress M. A Data Envelopment Model for Aggregating Preference Rankings. Management Science. 1990;36(11):1302-10.
14. Kuosmanen T, Cherchye L, Sipiläinen T. The law of one price in data envelopment analysis: Restricting weight flexibility across firms. European Journal of Operational Research. 2006;170(3):735-57.
15. Liu F-HF, Hsuan Peng H. Ranking of units on the DEA frontier with common weights. Computers & Operations Research. 2008;35(5):1624-37.
16. Amin GR, Toloo M. Finding the most efficient DMUs in DEA: An improved integrated model. Computers & Industrial Engineering. 2007;52(1):71-7.
17. Li X, Cui J. A Comprehensive Dea Approach for the Resource Allocation Problem based on Scale Economies Classification. Journal of Systems Science and Complexity. 2008;21(4):540-57.
18. Bi G, Ding J, Luo Y, Liang L. Resource allocation and target setting for parallel production system based on DEA. Applied Mathematical Modelling. 2011;35(9):4270-80.
19. Davoodi A, Rezai HZ. Common set of weights in data envelopment analysis: a linear programming problem. Central European Journal of Operations Research. 2011;20(2):355-65.
20. Ozcan YA, Health care benchmarking and performance evaluation: an assessment using Data Envelopment Analysis (DEA), 2nd ed. New York: Springer; 2014. P 150.