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Optimization in Internet Networks Using Data Envelopment Analysis Model with Undesirable Outputs

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Abstract The purpose of this paper is to use the decision making techniques of Data Envelopment Analysis (DEA) in order to evaluate the existing Internet networks to select the most desirable networks.To achieve this goal, we first begin by simulating a specific Internet network called Differentiated Service (DS) network that provides the quality of service to the user through the mechanism of Call Admission Control (CAC). We then evaluate and rank the networks by proposing a novel DEA model in the literature of undesirable outputs. Finally, by using the results of DEA model, we select the optimal Internet network.

Keywords Internet Network · Call Admission Control · Data Envelopment Analysis · Undesirable Outputs

Mathematics Subject Classification (2010) 65L03 · 60J74 · 60J76

1 Introduction

By developing the new services such as VoIP and video conference, using a mechanism is needed to support the quality of service of the application programs. Various models have been presented to guarantee the quality of service,

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including the Differentiated Service presented by [14] (Internet Engineering Task Force). In the architecture of the differentiated services, no admission control mechanism is considered. To guarantee the quality of service, the differentiated service network should support the admission control mechanism. In order to have the best result of the admission control mechanism, the parameters of the network should be considered to decrease the rate of loss and delay and to increase the network utilization. Therefore, due to the spontaneous evaluation of the efficiency of the different inputs and to find the best set of inputs which produce the best outputs, the Data Envelopment Analysis (DEA) is used [1].

[22] presented the optimize route in IP Networks. [20] Evaluated QoS routing in VANET. They presented a comparative QoS evaluation of two routing protocols, AODV and DSR. Also, they carried out our research by means of simulation performed using the NS2 simulation tool and implemented realistic traffic environment models using the Vanet mobiSim tool. [31] evaluated the efficiency of dynamic QoS- Aware CAC (DQA-CAC) by using broadband networks algorithm. The results of the simulation indicated that the DQA-CAC outperformed the existing CAC schemes in terms of reduced new connection blocking rate. [26] paid a considerable attention to Network optimizations in the Internet of Things. They presented a comprehensive survey on the network optimization in IoT.

Data envelopment analysis (*DEA*) gets the evaluation efficiency of decision making units (*DMUs*) with multiple inputs and multiple outputs as the ratio of weighted outputs to weighted inputs. ([5, 2]) Each *DMU* would be the most favorable weight inputs and outputs for the obtained maximum efficiency, Therefore, efficiency score obtained for each *DMU* is the best performance for it ([7]). However, the evaluation of *DMUs* based on different sets of weights is unacceptable ([33]).

Therefore, some researchers presented common weight models for the evaluation and ranking of *DMUs* using related *DEA* and some other techniques such as multi-objective programming models ([4, 8, 12, 19, 23, 33]). Recently [16] presented a common weight model using compromise solutions in multi-objective scheduling in which the efficiency of each unit is used as an ideal point and minimum distance from this point is considered as the objective to convert the multi-objective programming to a single objective one. [16] model is nonlinear. [6] presented a linear model to evaluate the efficiency of each *DMU* with a linear model that evaluated the performance of the units, which can be converted to a linear single-objective model and then can be solved. Continuing the work of [16, 33] presented a linear multi-objective model for a common weight. There is still ongoing research in this area ([30, 18]).

Sometimes undesirable outputs are among the outputs such as Greenhouse gases produced by industry. [10, 11] first presented a model for the evaluation of efficiency in the presence of undesirable outputs. [10] model was a non-linear model and it was based on increasing the desirable outputs and reducing the undesirable outputs. Then, [25] provided a linear model to evaluate the efficacy of DMUs in the presence of undesirable outputs with respect to the stability of the Fare et al.,'s model. Research is ongoing in this regard ([24, 15, 3, 32, 27, 28, 13]).

This paper presents a common weight model for the evaluation of DMUs with undesirable outputs by using [25] models. The common weight model is based on the work of [25] and the use of a multi-objective programming approach.
Because there might be undesirable outputs in the design of Internet Networks, in this paper we present a common weight model with undesirable output to evaluate and rank the Internet networks and select the most desirable network. In fact, our model is presented in two theoretical and practical parts. In the first stage, the common weight model with undesirable output is presented. Then, we simulate the computer networks and evaluate them using the common weight score. Finally, we rank the computer networks and select the most desirable network using the obtained common weight models score.

The rest of the paper is organized as follows: in the next section the issue of designing a DS network to guarantee the QoS is presented. Section 3 deals with a common weight model with undesirable output. Section 4 focuses on the selection of the most desirable Internet network using the common weight model with undesirable output as an empirical application. Finally, the conclusions and suggestions are presented in Section 5.

2 Admission Control mechanism in differentiated service network

Different networks have been presented to guarantee the quality of service among which the differentiated service is the most popular one that includes three classes of services. Expedited forwarding (EF) class was intended to offer low loss, low delay, low jitter, assured bandwidth such as VOIP, and video conference. Assured forwarding (AF) was designed to ensure that packets are forwarded with a high probability of delivery, as long as the aggregate traffic in a forwarding class does not exceed the subscribed information rate.

In order to guarantee the quality of service, the differentiated services network should support the admission control mechanism. The process of deciding to accept or reject a new request is called admission control. The Proper admission control algorithm has a significant impact on network efficiency. An algorithm which unnecessarily rejects the availability of the flows can successfully lead to an under-utilization network. Similarly, an algorithm which incorrectly accepts many flows results in violation of guaranteed quality of service.

Different algorithms have been proposed for the call admission control. In this paper, we use Parameter-Based Admission Control (PBAC) algorithm (PBAC). In this method, the admission control is based on the assumption that complete information is available from all traffic sources which can be used in any link. It is also assumed that the current number of services created is specified. This information enables the admission control to calculate the amount of the required bandwidth.

2.1 Admission Control Criteria

Admission criteria are the rules by which an admission control scheme accepts or rejects a request. Different admission control criteria have been proposed. In this paper, the equivalent capacity Cest criterion is used. In addition, in order to improve the quality of network service, the PBAC mechanism is added to the edge routers of the network. It is also assumed that through provisioning of the network and traffic engineering, the minimum total bandwidth of C_{total} is available end to end. The other assumption is that whenever a source wants to be active and sends traffic, it will inform its request to the ingress node through a reservation protocol.

In the PBAC mechanism, knowing the number of the active sources and having the peak rate of the new traffic source P_{new} and assuming that the new source is sending traffic with its peak rate, the required bandwidth for accepting the new request is computed according to equation (1).

$$C_{est} = \sum_{i=1}^{n} P_i + P_{new}, \tag{1}$$

where P_i is the pick sending rate of the active sources, and n is the number of active sources which is available in the network. Therefore, it is possible to estimate the required bandwidth to receive the new traffic according to C_{est} such that this estimation is used in the admission control criterion.

By having C_{total} and measuring C_{est}, the admission control criterion is presented according to formula (2).

$$\begin{cases} if\ C_{est} \leq C_{total}\ admit, \\ if\ C_{est} > C_{total}\ reject. \end{cases} \tag{2}$$

This scheme guarantees the QoS. Even if all the sources send traffic with the peak rate, the network will be able to deliver the desired QoS.

3 Common Weight Model for Evaluating the DMUs With Undesirable Outputs

Suppose that we have n, DMUs that by taking m inputs produce s desirable outputs and h undesirable outputs. Then according to the model proposed by Seiford and Zhou (2002), the fractional model is outputs-oriented BCC for evaluating the $\mathrm{DMU_o}$ in the presence of undesirable outputs in a linear programming model as follows:

$$
\begin{aligned}
& \min \frac{\sum_{i=1}^{m} v_i x_{io} + v_0}{\sum_{r=1}^{s} u_r y_{ro} + \sum_{t=1}^{k} \eta_t \overline{b_{to}}} \\
s.t \\
& \frac{\sum_{i=1}^{m} v_i x_{io} + v_0}{\sum_{r=1}^{s} u_r y_{ro} + \sum_{t=1}^{k} \eta_t \overline{b_{tj}}} \geq 1, \qquad j = 1, \ldots, n \\
& u_r \geq 0, v_i \geq 0, \eta_t \geq 0, v_0 \text{ free in sign}
\end{aligned} \tag{3}
$$

where $\overline{b_{tj}} = -b_{tj} + \alpha_t (j = 1, \ldots, n)$ and $\alpha_t s$ are a sufficiently large number such that all $\overline{b_{tj}} s$ are positive. Also v_i inputs weights and u_r and η_t are desirable and undesirable output weights, respectively.

Suppose that $(v^*, u^*, \eta^*, v_0^*)$ is an optimal value for the above model (model (3)), then efficiency scores of DMU_o are:

$$
E_o^* = \frac{\sum_{i=1}^{m} v_i^* x_{io} + v_0^*}{\sum_{r=1}^{s} u_r^* y_{ro} + \sum_{t=1}^{k} \eta_t^* \overline{b_{t0}}}.
$$

The above model is a nonlinear model and is always feasible and $E_o^* \geq 1$.

Definition 1 DMU_o is efficient if the optimal value of the model above is equal to 1.

Suppose that the decision unit o is efficient. According to the above definition, therefore, the target function of model (3) can be written as follows:

$$
\begin{aligned}
\frac{\sum_{i=1}^{m} v_i x_{io} + v_0}{\sum_{r=1}^{s} u_r y_{ro} + \sum_{t=1}^{k} \eta_t \overline{b_{to}}} = 1 &\Leftrightarrow \sum_{i=1}^{m} v_i x_{io} - v_0 = \sum_{r}^{s} = 1 u_r y_r o + \sum_{t=1}^{k} \eta_t \overline{b_{to}} \\
&\Leftrightarrow \sum_{i=1}^{m} v_i x_{io} - v_0 - \sum_{r=1}^{s} u_r y_{ro} + \sum_{t=1}^{k} \eta_t \overline{b_{to}} = 0
\end{aligned}
$$

In other words, if the decision making unit o is efficient, therefore, the difference between the weighted input and the weighted output will be zero. In addition, the constraints of model (3) can be written as follows:

$$
\sum_{i=1}^{m} v_i x_{io} + v_0 - \sum_{r=1}^{s} u_r y_{ro} - \sum_{t=1}^{k} \eta_t \overline{b_{tj}} \geq 0, \qquad j = 1, \ldots, n
$$

Therefore, model (3) can be considered as follows:

$$
\begin{aligned}
&\min \sum_{i=1}^{m} v_i x_{io} + v_0 - \sum_{r=1}^{s} u_r y_{ro} - \sum_{t=1}^{k} \eta_t \overline{b_{to}} \\
s.t \\
&\sum_{i=1}^{m} v_i x_{io} + v_0 - \sum_{r=1}^{s} u_r y_{ro} - \sum_{t=1}^{k} \eta_t \overline{b_{tj}} \geq 1 \qquad j = 1, \ldots, n \\
&u_r \geq 0, v_i \geq 0, \eta_t \geq 0, v_0 \text{ free in sign}
\end{aligned} \tag{4}
$$

In fact, the above model is a linear model of model (3), the optimal solution of which is the optimal solution of model (3) and vice versa. Also, if the decision making unit o is efficient, the optimal solution of model (3) will be zero. In addition, if $(v_i^*, u_r^*, \eta_t^*, v_0^*)$ is the optimal answer of model (4), the amount of the efficiency will be calculated as follows:

$$
E_0^* = \frac{\sum_{i=1}^{m} v_i^* x_{io} + v_0^* \sum_{r=1}^{s}}{u_r^* y_{ro} + \sum_{t=1}^{k} \eta_t^* \overline{b_{t0}}}.
$$

Now, according to the model above (model (4)), we present a common weight model with undesirable outputs as follows:

$$
\begin{aligned}
&\min = \sum_{i=1}^{m} v_i x_{i1} + v_0 - \sum_{r=1}^{s} u_r y_{r1} - \sum_{t=1}^{k} \eta_t \overline{b_{t1}} \\
&\min = \sum_{i=1}^{m} v_i x_{i2} + v_0 - \sum_{r=1}^{s} u_r y_{r2} - \sum_{t=1}^{k} \eta_t \overline{b_{t2}} \\
&\quad \vdots \\
&\min = \sum_{i=1}^{m} v_i x_{in} + v_0 - \sum_{r=1}^{s} u_r y_{rn} - \sum_{t=1}^{k} \eta_t \overline{b_{tn}} \\
s.t \\
&\sum_{i=1}^{m} v_i x_{io} + v_0 - \sum_{r=1}^{s} u_r y_{ro} - \sum_{t=1}^{k} \eta_t \overline{b_{tj}} \geq 0 \qquad j = 1, \ldots, n \\
&u_r, v_i \geq 0, \qquad r = 1, \ldots, s, \qquad i = 1, \ldots, m
\end{aligned} \tag{5}
$$

The above model is a multi-objective model. In multi-objective programming, several methods are presented for solving this problem ([9], [21], [17]).

One of these methods is compromise solution method that can be used. Indeed:

$$\min = \sum_{j=1}^{n}\left(E_j^* - \sum_{i=1}^{m} v_i x_{ij} - v_0 + \sum_{r=1}^{s} u_r y_{rj} + \sum_{t=1}^{k} \eta_t \overline{b_{tj}}\right)^p, \ 1 \le p \le \infty$$
$$s.t$$
$$\sum_{i=1}^{m} v_i x_{io} + v_0 - \sum_{r=1}^{s} u_r y_{ro} - \sum_{t=1}^{k} \eta_t \overline{b_{tj}} \ge 0, \quad j = 1, \ldots, n \tag{6}$$
$$u_r, v_i \ge 0, r = 1, \ldots, s, i = 1, \ldots, m$$

where $E_j^*$is efficiency values obtained in the above model for DMU_j. Now, we can present different models for the common weight with undesirable outputs with respect to different values of p. Here we use three values 1, 2 and ∞ and present three mathematical programming models. Indeed, we have three common weight models for undesirable outputs as follows:

1. If $p = 1$, then above model (model (6)) is as follows:

$$\min = \sum_{j=1}^{n}\left(\sum_{i=1}^{m} v_i x_{ij} + v_0 - \sum_{r=1}^{s} u_r y_{rj} - \sum_{t=1}^{k} \eta_t \overline{b_{tj}}\right)$$
$$s.t \quad \sum_{i=1}^{m} v_i x_{io} + v_0 - \sum_{r=1}^{s} u_r y_{ro} - \sum_{t=1}^{k} \eta_t \overline{b_{tj}} \ge 0, \quad j = 1, \ldots, n \tag{7}$$
$$u_r, v_i \ge 0, r = 1, \ldots, s, \quad i = 1, \ldots, m$$

2. If $p = 2$, then model (8) is as follows:

$$\min = \sum_{j=1}^{n}\left(E_j^* - \sum_{i=1}^{m} v_i x_{ij} + v_0 + \sum_{r=1}^{s} u_r y_{rj} + \sum_{t=1}^{k} \eta_t \overline{b_{tj}}\right)^2$$
$$s.t \quad \sum_{i=1}^{m} v_i x_{io} + v_0 - \sum_{r=1}^{s} u_r y_{ro} - \sum_{t=1}^{k} \eta_t \overline{b_{tj}} \ge 0, \quad j = 1, \ldots, n \tag{8}$$
$$u_r, v_i \ge 0, \quad r = 1, \ldots, s, i = 1, \ldots, m$$

3. If $p = \infty$, then common weight model as form:

$$\begin{aligned}
&\min = Z\\
s.t\\
&Z - \left(E_j^* - \sum_{i=1}^{m} v_i x_{ij} - v_0 + \sum_{r=1}^{s} u_r y_{rj} + \sum_{t=1}^{k} \eta_t \overline{b_{tj}}\right) \geq 0, \quad j = 1, \ldots, n\\
&\sum_{i=1}^{m} v_i x_{io} + v_0 - \sum_{r=1}^{s} u_r y_{ro} - \sum_{t=1}^{k} \eta_t \overline{b_{tj}} \geq 0 \quad j = 1, \ldots, n\\
&u_r, v_i \geq 0, \quad r = 1, \ldots, s, \quad i = 1, \ldots, m
\end{aligned} \tag{9}$$

Theorem 1 *There is at least one efficient unit for model* (4). *In fact, there is one decision making unit like k so that:*

$$E_k^* = \frac{\sum_{i=1}^{m} v_i^* x_{ik} + v_k^*}{\sum_{r=1}^{s} u_r^* y_{rk} + \sum_{t=1}^{k} \eta_t^* \overline{b_{tk}}} = 1$$

Proof By contradiction assume that no unit is efficient. Therefore, the case is as follows:

$$\sum_{i=1}^{m} v_i^* x_{ij} + v_k^* - \sum_{r=1}^{s} u_r^* y_{rj} - \sum_{t=1}^{k} \eta_t^* \overline{b_{tj}} > 0, \quad j = 1, \ldots, n.$$

In this case, there is a very small amount $\varepsilon > 0$, so that $(v_i^* + \varepsilon \mathbf{1}_a, u_r^*, \eta_t^*, v_0^*)$ is the efficient solution of problem (4). For this, the efficient solution of the target of model (4) is as follow:

$$\begin{aligned}
&\sum_{j=1}^{n} \left(E_j^* - \sum_{i=1}^{m} (v_i^* + \varepsilon \mathbf{1}_a) x_{ij} - v_0 + \sum_{r=1}^{s} u_r^* y_{rj} + \sum_{t=1}^{k} \eta_t^* \overline{b_{tj}}\right)^p\\
&\qquad < \sum_{j=1}^{n} \left(E_j^* - \sum_{i=1}^{m} v_i^* x_{ij} - v_0 + \sum_{r=1}^{s} u_r^* y_{rj} + \sum_{t=1}^{k} \eta_t^* \overline{b_{tj}}\right)^p
\end{aligned}$$

And this is in opposition with the optimizing solution $(v^*{}_i + \varepsilon \mathbf{1}_a, u_r^*, \eta_t^*, v_0^*)$. Therefore, there is at laest one efficient unit and the theory is proved.

Since the relative efficiency is calculated in data envelopment analysis, at least one of the decision making units is efficient. Therefore, the model presented in this paper will not underestimate the index of the efficiency.

This section presents the common weight models for undesirable outputs. In the next section, we show the importance using a real-world example.

4 Evaluation and selection of the most desirable Internet network

4.1 Network topology

The NS-2 simulator was used to evaluate the efficiency of the admission control algorithm in the differentiated service network. The dumbbell topology was used, as shown in figure (1).

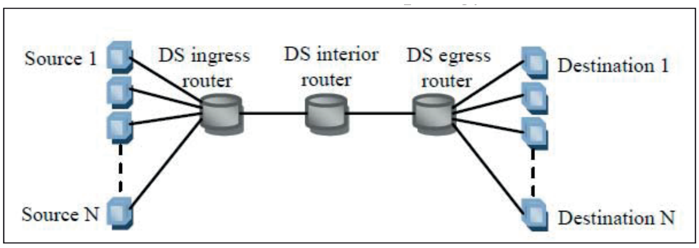

Fig. 1 Network TopologyNetwork Topology

In this paper, the simulation of two classes of network traffic was considered: the EF class and the Best-Effort (BE) class. 120 sources in the desirable topology were considered which generate traffic in the network. These sources generate two types of traffic. EF traffic is the VoIP traffic and BE traffic is the best effort traffic which produce a high percentage of Internet traffic.

4.2 The inputs and outputs of simulated DMUs

The inputs and outputs of the simulated DMUs are as follows:
The first input (I1): The number of BE sources is also changed which is equal to the difference between the numbers of the EF sources and the number of all sources. For these two traffic classes, the separate queues are used.
The second input (I2): the size of EF traffic.
The third input (I3): the amount of the link capacity allocated to EF traffic
The first output (O1): the packet loss rate related to EF traffic.
The second output (O2): the delay of the EF traffic packets from the source to the destination. The third output (O3): the network utilization.
Note that the second output (O2) is undesirable. Information on inputs and outputs is given in Table (1) below.

4.3 Simulation results

In this section, we evaluate the most desirable Internet network using the models presented in this paper. In the first step, we use model (3) and obtain

Table 1 DMUs and the input and output values

DMU	I_1	I_2	I_3	O_1	O_2	O_3
DMU_1	90	3	600	83.46	5.37	13.94
DMU_2	70	3	600	84.62	4.28	13.52
DMU_3	50	3	600	85.73	3.89	13.60
DMU_4	30	3	600	85.02	4.19	13.94
DMU_5	90	4	500	85.85	6.19	15.37
DMU_6	70	4	500	87.50	5.28	14.68
DMU_7	50	4	500	82.32	3.35	14.35
DMU_8	30	4	500	84.36	5.65	15.25
DMU_9	50	3	500	85.49	6.97	14.00
DMU_{10}	70	3	500	80.47	6.75	13.93
DMU_{11}	30	5	500	84.88	5.42	15.82
DMU_{12}	50	5	500	84.67	2.85	14.46
DMU_{13}	70	5	500	86.05	3.87	15.24
DMU_{14}	30	4	700	79.85	0.12	13.55
DMU_{15}	30	3	700	78.00	2.45	13.40
DMU_{16}	50	3	700	78.50	2.09	12.97
DMU_{17}	70	3	700	76.91	2.22	13.07
DMU_{18}	70	4	700	78.70	0.10	13.27
DMU_{19}	90	3	700	76.72	2.54	13.27
DMU_{20}	90	4	700	78.66	0.08	13.35
DMU_{21}	90	5	600	88.16	1.35	14.75
DMU_{22}	70	5	600	55.42	0.63	14.23
DMU_{23}	30	5	600	88.54	1.05	14.83
DMU_{24}	50	5	600	88.72	0.39	13.96
DMU_{25}	70	2	600	77.56	12.35	13.00
DMU_{26}	30	3	500	82.39	7.70	14.52
DMU_{27}	90	3	500	82.89	9.30	14.46
DMU_{28}	90	5	500	87.11	6.31	16.48
DMU_{29}	50	4	700	80.07	0.13	13.06
DMU_{30}	90	4	600	86.54	2.12	14.60
DMU_{31}	70	4	600	87.21	1.31	14.19
DMU_{32}	30	4	600	87.82	1.62	14.58
DMU_{33}	50	4	600	88.07	1.10	13.79

the self-evaluation efficiency, the results of which are presented in Table (2). Note that all mathematic programming models run by using Lingo 11 software.

In table (2), the efficiency scores have been shown in the second column using [25]'s model (2002) and one of the models presented in this paper, namely, model (8), as shown in the third column. As you can see from Table (2), out of 33 decision making units, 12 units have obtained the efficiency score of 1by [25] model (2002) and are efficient and the rest of the decision making units are inefficient. However, there is not such a problem in model (8) and there is just one efficient unit while the rest are inefficient. The rank of the Internet networks has been shown in the fourth column of Table (2) according to the efficiency score of model (8). As you can see, this algorithm provides a unique ranking of Internet networks, as networks of 10, 32 and 31 obtain the first to third ranks, respectively and can be good choices for selecting the most desirable network.

Table 2 The results of Self-Evaluation Using [25]'s Model and Model (8) presented in this paper.

DMU	Sieford and Zhou	Model 8	Rank by use model 8
DMU_1	0.9	0.67	10
DMU_2	0.9	0.57	26
DMU_3	0.94	0.52	30
DMU_4	1	0.68	9
DMU_5	1	0.65	14
DMU_6	1	0.62	21
DMU_7	0.95	0.60	22
DMU_8	1	0.53	27
DMU_9	1	0.62	19
DMU_{10}	0.96	1	1
6	0.69	1	DMU_{11}
DMU_{12}	0.98	0.62	20
DMU_{13}	0.98	0.58	25
DMU_{14}	0.91	0.64	16
DMU_{15}	0.93	0.65	15
DMU_{16}	0.84	0.68	8
DMU_{17}	0.77	0.67	11
DMU_{18}	0.68	0.53	28
DMU_{19}	0.78	0.73	2
DMU_{20}	0.68	0.72	5
DMU_{21}	0.83	0.59	24
DMU_{22}	0.75	0.65	13
DMU_{23}	1	0.52	29
DMU_{24}	0.86	0.50	32
DMU_{25}	1	0.51	31
DMU_{26}	1	0.45	33
DMU_{27}	1	0.67	12
DMU_{28}	1	0.69	7
DMU_{29}	0.7	0.64	17
DMU_{30}	0.84	0.59	23
DMU_{31}	1	0.73	3
DMU_{32}	1	0.76	2
DMU_{33}	0.86	0.63	18

5 Conclusion

There are two main reasons for the quality of Internet service in Iran. The first reason is the emergence of Next Generation Networks (NGNs) based on IP, which will bring a variety of services to be used in the commercial sector, such that the customers of this service are not harmed by the service providers. The second reason which is not irrelevant to the first one is the privatization and liberalization process that is hoped to provide a competitive market in the country. In such a market, the service providers will remain in competition so that they can be able to deliver guaranteed quality to the customers. Differentiated service architecture is a technology that can improve the quality of service even for the real-time services. The call admission control is needed to achieve scalability and efficient service model simultaneously.

In this paper, the admission control mechanism was added to the edge routers of the network. Then, by changing the related inputs which included buffer size, the number of the input sources, and the average service rate, the outputs including loss, delay, and utilization were obtained by the simulation method with NS-2 simulator. In this paper, an effective method was presented for optimal design of the network to achieve the highest efficiency and for optimal utilization of all network facilities, the differentiated services network was selected as the DMU and by giving different inputs, different DMUs were made. Then, the efficiency of these inputs was investigated by DEA model. This paper also provided a unique ranking of Internet networks as good options for selecting the most desirable network.

References

1. E. Alipour Chavari and M. Rostamy-Malkhalifeh, Internet network design for quality of service guarantee using Data Envelopment Analysis (DEA), international data envelopment analysis, 7, 1–14 (2019).
2. R. J. Banker, A. Charnes and W. W. Cooper, Some models for estimating technicaland scale inefficiencies in data envelopment analysis, Management Science, 30, 1078–1092 (1984).
3. A. Barzegarinegad, G. Jahanshahloo and M. Rostamy-Malkhalifeh, A full ranking fordecision making units using ideal and anti-ideal points in DEA, The Scientific World Journal, (2014).
4. V. Belton and SP. Vickers, Demystifying DEA-A visual interactive Approach based on multiple criteria analysis, J. Opl. Res. Soc., 44, 883–896 (1993).
5. A. Charnes, W. W. Cooper and E. Rhodes, Measuring efficiency of n decision making unit, Eur. J. Opl. Res., 2, 429–444 (1978).
6. Y-W. Chen, M. Larbani and Y-P. Chang, Multiobjective data envelopment analysis, J. Opl. Res. Soc., 60, 1556–1566 (2009).
7. W. Cooper, L. Seiford and T. Kaoru, Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software. Springer, (2000).
8. J. Doyle and R. Green, Efficiency and cross efficiency in DEA: Derivations, meanings and uses, J. Opl. Res. Soc., 45, 567–578 (1994).
9. M. Ehrgott, Multicriteria Optimization, Lecture Notes in Economics and Mathematical Systems, Springer-Verlag, Berlin, 491, (2000).
10. R. Fare, S. Grosskopf, C. A. K. Lovell and S. Yaiswarng, Deviation of shadow prices for undesirable outputs: a distance function approach, The Review of Economics and Statistics, 75, 374–380 (1993).
11. R. Fare, S. Grosskopf, C. A. K. Lovell, Multilateral productivity comparisons when some outputs are undesirable :a nonparametric approach, The Review of Economics and Statistics, 71, 90–98 (1989).
12. B. Golany and G. Yu, A goal programming-discriminantfunction approach to the estimation of an empirical productionfunction based on DEA results, J. Prod. Anal., 6, 171–186 (1995).
13. A. Hailu and T. Veeman, Non-parametric productivity analysis with undesirable outputs: an application to Canadian pulp and paper industry, American Journal of Agricultural Economics, 83, 605–616 (2001).
14. S. Blake, D. Black, M. Carlson, E. Davies, Z. Wang and W. Weiss, Rfc2475: An architecture for differentiated service, RFC Editor, (1998).
15. G. Jahanshahloo, F. H. Lotfi, M. Rostamy-Malkhalifeh, R. Maddahi and A. Ebrahimnejad, Ranking non-extreme efficient units based on super efficiency method in the

presence of undesirable outputs: a DEA approach, International Journal of Applied Decision Sciences, 6, 83–95 (2013).
16. C. Kao and CT. Hung, Data envelopment analysis with common weight: The compromise solution approach, J. Opl. Res. Soc., 56, 1196–1203 (2005).
17. M. Karimi and B. Karimi, Linear and conic scalarizations for obtaining properly efficient solutions in multiobjective optimization, Mathematical Sciences, 11, 319–325 (2017).
18. E. E. Karsak and N. Goker, Improved common weight DEA-based decision approach for economic and financial performance assessment, Technological and Economic Development of Economy, 26, 430–448 (2020).
19. X-B Li and GR. Reevese, A multiple criteria approach to data envelopment analysis, Eur. J. Opl. Res., 115, 507–517 (1999).
20. F. L. Lugayizi, B. M. Esiefarienrhe and A. Warren, Comparative evaluation of QoS routing in VANET, International Conference on Advances in Computing and Communication Engineering (ICACCE), Durban, 183–188 (2016).
21. M. Moeini, B. Karimi and E. Khorram, A Cross-Efficiency Approach for Evaluating Decision Making Units in Presence of Undesirable Outputs, Modelling, Computation and Optimization in Information Systems and Management Sciences, Springer, 487–498 (2015).
22. J. Rexford, Route Optimization in IP Networks. In: Resende M.G.C., Pardalos P.M. (eds) Handbook of Optimization in Telecommunications, Springer, Boston, (2006).
23. Y. Roll and B. Golany, Alternative methods of treating factor weights in DEA, Omega, 21, 99–103 (1993).
24. S. Sadri, M. Rostamy-Malkhalifeh and N. Shoja, A New Method for Optimization of Inefficient Cost units in the Presence of Undesirable Outputs, International Journal Industrial Mathematics, 10, 331–338 (2018).
25. L.M. Seiford and J. Zhu, Modeling undesirable factors in efficiency evaluation, European Journal of Operational Research, 142, 16–20 (2002).
26. N. N. Srinidhi, S. M. Dilip Kumar and K. R. Venugopal, Network optimizations in the 2333 Internet of Things: A review. Engineering Science and Technology, 22, 1–21 (2019).
27. T. Sueyoshi and M. Goto, Returns to scale vs. damages to scale in data envelopment analysis: An impact of U.S. clean air act on coal-fired power plants, Omega, 41, 164–175 (2013).
28. K. Tone, Dealing with undesirable outputs in DEA: a slacks-based measure (SBM) approach, Presentation at NAPW III, Toronto, (2004).
29. Wu, Chong, Y. Li, Q. Liu and K. Wang, A stochastic DEA model considering undesirable outputs with weak disposability, Mathematical and Computer Modelling, 58, 980–989 (2013).
30. A.P. Yekta, S. Kordrostami, A. Amirteimoori and R. K. Matin, Data envelopment analysis with common weights: The weight restriction approach, Math. Sci., 12, 197–203 (2018).
31. S. O. Yese, A. Abdulhakeem and M. Aminu, Performance Evaluation of Dynamic QoS-Aware CAC (DQA-CAC) Algorithm for Broadband Networks, European Journal of Electrical Engineering and Computer Science, 3, (2019).
32. H. Zare-Haghighi, M. Rostamy-Malkhalifeh, G. R. Jahanshahloo, Measurement of congestion in the simultaneous presence of desirable and undesirable outputs, Journal of Applied Mathematics, 2014, (2014).
33. M. Zohrehbandian A. Makui and A. Alinezhad, A compromise solution approach for finding common weights in DEA: an improvement to Kao and Hung's approach, J. Opl. Res. Soc., 61, 604–610 (2010).