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An Efficiency Measurement of E-Government Performance for United Nation Ranking Index

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Abstract**—**In order to serve the society in an electronic manner, many developing countries have launched tremendous e-government projects. The strategies of development and implementation e-government system have reached different levels, and to ensure consistency of development, the governments need to evaluate e-government performance. The United nation has design e-government development ranking index (EGDI) that rely on three indexes, Online service index (OSI), Telecommunication Infrastructure index (TII), and human capital index(HCI) which are not reflecting the interaction between a government and their citizens. Based on data envelopment analyses (DEA) technique, we are using E-participating index (EPI) as an output of government effort to evaluate the performance of e-government system. Therefore, the ranking index can be achieved in efficiency manner.

Keywords**—**E-government, DEA, efficiency measurement, EGDI.

I. Introduction

IN modernization activities, many countries have launched tremendous e-government initiatives to enhance the quality of public service [1], Governments across the word have adopted a variety of models and often developed their own customized frameworks and application that fit their country or organizational situations best, resulting in the variety of e-government system design [2]. Enhancing the quality of public services, transparency and accountability, cost-effective service provision and government operation, reduced corruption, and citizen's engagement in public matters are benefits and values that have been recognized by developed countries as well as emerging countries [3]-[5]. Regarding literature review, a few types of research have been embraced for evaluating the e-government system development, mapping practical tools to theoretical foundations [6]. Some of that research focuses on success factors, and some were assessing e-government web portals services [7]-[9]. In 2012, and in order to rank the performance of e-government development, the United Nations department of economics and social affaire (UNDESA) through its division for public administration and development management (DPADM) has lunch a new index named e-government development index (EGDI). But the gaps in assessing effectiveness and efficiency in EGDI's composites led us to look into those indexes, and Base on government web portals, Hsieh et al, and Jie et al, used the method of data envelopment analysis (DEA) to evaluate e-government performance, the finding was the measured efficiency of various e-government websites in different region for providing web service. And this is quit far from a concrete efficiency measurement of e-government performance as a whole system.

To compensate for the gaps in assessing effectiveness and efficiency of e-government around the globe, a purpose of the current study is to evaluate e-governmental services by measuring united nation ranking index according to their performances. Relating the efficiency measurement of e-government performance, DEA technique can become a reference methodology for practical assessment of e-governmental development system.

II. E-government system

The use of ICT to govern has increasingly been the focus of several nations, analogically with e-business; ICTs offer governments an effective resource to serve citizens and other stakeholders through e-government. The objective of the first phase of the world summit on information society (WSIS) that has been held in Geneva was to develop and foster a clear statement of principles and plan of action that take concrete steps to establish the foundations for an information society for all [10], since then, many countries especially developing countries have engaged to build e-government strategies and plans.

Regarding the Layne and Lee's (2001) four development stages [11], most of emerging countries fall to overpass interactive stage, while some developed countries have reached connected stage. However, the implementation of e-government strategies have met a great challenges in developed countries as well as emergent countries, each country faces a different set of factors that can help or hinder its overall progress towards e-government development, with low levels of infrastructure and human capital, a lack of access to both ICT and education infrastructure in emerging countries remain at lower levels of e-government development with serious of digital divide. In contrast with an advanced nation where technical side remains advantage points, the engagement of information society becomes a matter of choice. Therefore, analyzing e-government development progress or performance

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may need a deep investigation on those factors, and look into the interaction between them.

To track the progress of e-government development of countries globally over time, UN has designed an assessment survey base on three most important dimensions, scope and quality of online services, development status of telecommunication, and inherent human capital. In our approach, we will consider those factors as main variables of technical measurement. More detail will be explained in Section III.

III. Data Envelopment Analysis

Data envelopment analysis (DEA) is originally designed to measure the relative efficiency of peer decision making unites, and it has been widely used to evaluate the comparative efficiencies of system processes [12], [13]. Most of the DEA applications assume that system processes consist of one stage. However, in e-government system circumstances, the implementation has more than one stage. Therefore we will consider two-stage processes to evaluate the efficiency measurement. In this paper, we adapt two-stage DEA models by considering input and output slacks.

A. Efficiency Measurement Concept

We define the efficiency measurment as:

$$\text{efficiency} = \frac{output}{input}$$

With multiple inputs and outputs, the difficulty of comparing the efficiency of target unit becomes apparent. Therefore, the measurement of relative efficiency where there are multiple possibly incommensurate inputs and outputs was addressed and developed by Farrell and Fieldhouse [14].

$$\text{Efficiency} = \frac{weighted\ sum\ of\ outputs}{weighted\ sum\ of\ inputs}$$

For an unit j can be written as:

$$\text{Efficiency of unit j} = \frac{u_1 y_{1j} + u_2 y_{2j} + \cdots.}{v_1 x_{1j} + v_2 x_{2j} + \cdots.}$$

where $u_1 = the\ weight\ given\ to\ output\ i$, $y_{1j} = amount\ of\ output\ 1\ from\ unit\ j, v_1 = weight\ given\ to\ input\ 1, x_{1j} = amount\ of\ input\ 1\ to\ unit\ j$. (Note efficiency is usually constrained to the range [0, 1]). Charnes, Cooper and Rhodes [15] recognized the difficulty in seeking a common set of weights to determine relative efficiency

One key assumption of classical DEA model (or radial) is a system's relative efficiency depends on how much it can proportionally expand all of its inputs given its input or vise-versa (reducing all of its inputs given its output). However, the classical "radial" DEA model has been known for having two primary limitations. First, some decision-making units (DMUs) may be measured against a weakly efficient input-output point in the possibility set, which also serves as the reference points for their corresponding DMUs, have positive input or output slacks with respect to strongly pareto-efficient points. Second, a high proportion of DMUs can turn out to be efficient due to a small sample size relative to the number of inputs and outputs [16], [17].

Regarding the issue of referencing non-pareto-efficient targets, and as a non-radial approach [18], [19], based on SBM, and proposed another model to rank efficient DMUs. Tone 'approach has two stage, first one is by running standard SBM to classify efficient and inefficient DMUs, and the second stage will use super SBM for only efficient DMUs.

B. Mathematical Formulation

In this paper, we highlight the slacks-based measure for technical efficiency in DEA model. Suppose there are n DMUs, $\{ DMU_K$ (K=1,2,..n)$\}$, LET $x_k = (x_{1k},..,x_{mk})$ and $y_k = (y_{1k},..,y_{sk})$ denoted the input and output vectors of kth DMU.The ith input of kth DMU is denoted as x_{ik} and the rth output of the kth DMU is denote as y_{rk}, respectively. The slacks-based measure SBM is defined to be an optimal value of the following problem:

$$\min \rho_k = \left(\frac{1-\frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{ki}}{1+\frac{1}{s}\sum_{r=1}^{s} s_r^+ / y_{kr}}\right) \quad (1)$$

$$\text{Subject to } \sum_{j=1}^{n} \delta_j x_{ji} = x_{ki} - s_i^- \quad \text{for i= 1,..,m}$$
$$\sum_{j=1}^{n} \delta_j y_{jr} = y_{kr} - s_i^+ \quad \text{for r = 1,..,s}$$

$$\delta_j \geq 0 \text{ for j = 1,.....,n}$$
$$s_i^- \geq 0 \text{ for I = 1……, m}$$
$$s_r^+ \geq 0 \text{ for r = 1… s}$$

The variable δ_j indicates the intensity under which DMU j takes part in forming the efficient frontier. s_i^-, s_r^+, are two vectors indicating the input excess and output shortfall, respectively. The problem (1) given above is a nonlinear programing problem, it can be transformed into a linear programing problem by using Tone and Charnes transformation, which can be solved by efficient algorithms:

$$\min \ \rho_k = t - \frac{\frac{1}{m}\sum_{i=1}^{m} s_i^-}{x_{ki}} \quad (2)$$

$$\text{subject to} \quad t + \frac{\frac{1}{s}\sum_{r=1}^{s} s_i^+}{y_{kr}} = 1$$

$$\sum_{j=1}^{n} \delta_j x_{ji} = t x_{ki} - s_i^- \ for\ i = 1, \ldots, m$$

$$\sum_{j=1}^{n} \delta_j y_{jr} = t y_{kr} + s_i^+ \ for\ r = 1, \ldots, s$$

IV. Data Source and Methodology

As mentioned early, in our approach we consider the ranking performance of countries on a relative scale that has been adapted by united nation department division for public administration and development management (DPADM). The annual UN ranking index provides relevant information to

support government's policy makers in shaping their e-government programs for development.

A. Data Source

In order to measure an e-government development index (EGDI), The United Nations has design three most important dimensions of e-government, Online service index (OSI), Telecommunication Infrastructure index (TII), and human capital index (HCI).

To measure the three indicators, UN has based on an expert assessment survey of the presence state for the three indicators' composites of all United Nations members, which assesses national development and provides insights of common themes in development patterns of e-government policies and implementation strategies. We highlight the three indicators components in the following Table I.

TABLE I
DESCRIPTION OF INDICATORS

Indicator	Components/composites
Online service	Whole of e-government. Multichannel service delivery. Bridging the digital divide Increasing usage. Open government
Telecommunication infrastructure	Internet user Telephone lines Mobile subscription Wireless broadband subscriptions Fixed broadband
Human capacity	Adult literacy rate. Gross enrolment ration. Expected years of schooling Mean years of schooling
E-government development	Online service Telecommunication infrastructure Human capacity

Statically speaking, to avoid the dispersion of any average of normalizing variables, Z-score standardization treatment must be applied to each variable, and EGDI is a weighted average of three normalize score index, OSI, TII, and HCI. Therefore, each of these indicators was standardized via the Z-score procedure to drive score for each component indicator, where a standard Z-score calculation is:

$$x = \frac{\varepsilon - \mu}{\sigma}$$

where **ε** is a raw score to be standardized, **μ** is the mean of the population, and **σ** is the standard deviation of the population. Mathematically, UN experts present EGDI's weighted average in the following form:

$$EGDI = \frac{1}{3}\left(OSI_{Normalized} + TII_{Normalized} + HCI_{Normalized}\right)$$

As indicated, the EGDI is used as a benchmark to provide a numerical ranking of e-government development across united nation member states.

B. E-Participation Index

Examine the e-government performance won't be efficiency if we only consider the three indicators. Building websites, infrastructures, and providing online services can be only a matter of how the governments is ready to exploit those facilities. In fact, add to those indicators, the performance of e-government system can be analyzed and measured by looking into how far the citizens are using and responding to this modernized activity.

Analogically with the previous indicators, United Nation experts have designed a supplementary indicator that reflects the interaction between government and their citizens by having an administration process and public information without or upon demand.

E-participation index (EPI) is considered to be one of online service index's composite, its main goal was to offer insight into how different countries are using online tools to promote citizens participation.

C. Evaluation

In our approach, we choose four indexes to evaluate e-government performance by using DEA model. We consider participation index is the output for governments 'effort to bring the e-government system to stage full connected. The more citizens are participating and reacting with the system the more success can be achieved.

In order to make e-government system work properly, the governments are investing on three indexes, which are telecommunication infrastructures (TII), human capital (HCI), and providing many services to be online (OSI). We consider those indexes to be the input for our evaluation technique. Noting that determining variables for inputs and outputs is critical for producing reliable results, Therefore, the numbers of variables for inputs and outputs variables should be meet the analysis requirements.

TABLE II
INPUT-OUTPUT VARIABLES

Index	Description	Index attribute
OSI	Online service index	Input
HCI	Human Capital Index	Input
TII	Telecommunication Index	Input
EPI	E-participation Index	Output

D. Methodology

To analyses the feasibility of DEA technique for our approach, a given government's overall operational performance for providing efficient e-government services is an approximation from a comprehensive index, which objectively assigns three inputs and one output to the DEA efficiency function.

We randomly choose eight countries from UN survey assessment (Table III). Developed and developing countries have been tested, two-stage DEA approach is employed to assess technical and scale efficiency.

After we run the data envelopment analysis computer program, we generate two-stage approach, in the term of

efficiency scale, we got the same result as a one-stage approach (Tone's model).

The astonishing finding here is the rate of efficiency scale itself, comparing to The UN e-government development index, the ranking according to efficiency scores has different result, Table IV.

Running DEA technique for e-government four variables (3 inputs and one output) shows that the last country ranked for EGDI is the first one in view of efficiency measurement score rank. What we can notice here is the evaluation performance of e-government system can be size by how much the government is engaging and enabling citizen to participate in public policies matters and decision-making process. In contrast with UN e-government ranking index, we believe that the E-participation index (EPI) can be the main index to size the output of e-government system performance and gives a result of how much the e-government systems is efficient and provide insight of different strategies in development patterns among united nation members.

TABLE III
UNITED NATION EGDI INDEX

	Input			Output
DMUs	OSI index	TII index	HCI index	EPI index
Australia	0.9291	0.8041	0.9978	0.9412
China	0.6063	0.3554	0.6734	0.6471
India	0.5433	0.1372	0.4698	0.6275
France	1	0.8003	0.8812	0.9608
Morocco	0.6929	0.3350	0.4901	0.8039
South Africa	0.3858	0.3466	0.7282	0.3333
Turkey	0.5591	0.3605	0.7133	0.4902
Swaziland	0.1339	0.1629	0.8562	0.3725

TABLE IV
RESULTS OF DEA TECHNIQUE

Country	Australia	China	India	France	Morocco	South Africa	Turkey	Switzerland
EGDI (rank)	0.91 (1)	0.545 (4)	0.383 (8)	0.89 (2)	0.50 (6)	0.486 (7)	0.544 (5)	0.726 (3)
Efficiency score (rank)	0.63 (5)	0.725 (3)	1 (1)	0.65 (4)	0.97 (2)	0.418 (7)	0.55 (6)	0.313 (8)

V. CONCLUSION

E-government system should be evaluated base on it productivity and change that bring to societies. In contrast with a comparative assessment, our paper consider ranking the performance of e-government system can be achieved in efficiency manner, we apply DEA on eight united nation members to examine their e-government performance, and we rely on the most important e-government development indexes, namely: OSI, TII, HCI and EPI as a set of variable to assess efficiency measurement for the chosen members. The result shows that how the citizen interaction with government factor (EPI) can be the main key to evaluating the e-government performance.

Considering the data envelopment analysis technique and general e-government development indexes won't result an efficiency measurement of e-government. However, we would like to highlight that our approach can be extended by looking into EGDI's composites and evaluate the score of each index, which will result to have efficiency EGDI score that will be used for ranking assessment, as well as evaluating e-government development performance.

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