Measuring e-Government Maturity: Comparative analysis of e-Government indexes

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Abstract. In this paper the major e-government maturity indexes are compared with their strengths and shortcomings. First these proposed indexes from different authors and organizations are analyzed individually and then they are compared to each other. The purpose of this paper is not to propose a new way of measuring e-government maturity. Rather, it is an attempt to compare the existing indexes and to point out the shortcomings of the already existing indexes in order to contribute toward an improvement of these quantitative measures.

Keywords: e-Government, maturity model, digital government, ICT

1 Introduction

The purpose of developing a maturity model for e-government is to measure one's government maturity according to the model developed before and making it comparable to itself through periods of time and making it comparable to the other governments. The purposes of benchmarking include: determining what and where to make improvements, analyzing how others achieve their performance, and using this information to improve performance. Few authors have suggested models for measuring the stage of e-government development including United Nations [1], West [2], [3], and Rorissa et al. [4]. Indeed Rorissa [4] makes a review of the current benchmarking models including United Nations' model and West's models and proposes new frameworks for computing e-government maturity, which are based on the West's and United Nations' frameworks. As a result before discussing the models the advantages and disadvantages of these frameworks, it is important to state that all the frameworks are based on the West's framework.

2 Models for measuring e-government maturity

West's framework follows a two-step process. First, a value (between 0 and 100) is computed for each website sponsored by a country [4]:

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$$ei=4fi+xi \quad (1)$$

where, f_i is the number of features present on website i, and $0 \leq f_i \leq 18$; x_i is the number of online executable services on website i, and $0 \leq x_i \leq 28$.

Then the average of the individual indexes compute a single index for the country [4]:

$$E_j = \frac{\sum_{i=1}^{n} e_i}{n} \quad (2)$$

where e_i is the e-government index for website i and $0 \leq e_i \leq 100$; n is the total number of government websites for country j.

Overall, West's model for measuring e-government development index is a model with several limitations. Indeed, although this model is based on objective measuring of e-government websites and features, it still has number of limitations. First, it does not account for websites with more 18 features or more than 28 online services. Second, it gives four times more weight to features compared to services [4]. Third, it has a bias towards governments with more concentrated websites.

Examination of the above equations results that governments should have all of their websites with 18 features and 28 online services in order to have maximum points. In theory, two governments with same features and services but different websites would have different indexes according to this model. For example, if we have three governments with the features and services as follows:

Table 1. Hypothetical example of e-government features and services

	Government 1				**Government 2**			**Government 3**			
Individual Websites	w1	w2	w3	Total	w1	w2	Total	w1	w2	w3	Total
Features	10	15	18	43	18	18	36	11	12	13	36
Services	20	15	10	45	20	20	40	15	10	15	40

Then according to the model, if we calculate the e-government index according to the West's models it would result that:

$$E_1 = \frac{\sum_{i=1}^{3} e_i}{3} = \frac{4 \cdot 10 + 20 + 4 \cdot 15 + 15 + 4 \cdot 18 + 10}{3} \approx 72.3$$

$$E_2 = \frac{\sum_{i=1}^{2} e_i}{2} = \frac{4 \cdot 20 + 20 + 4 \cdot 20 + 20}{2} = 92$$

$$E_3 = \frac{\sum_{i=1}^{3} e_i}{3} = \frac{4 \cdot 11 + 15 + 4 \cdot 12 + 10 + 4 \cdot 13 + 15}{3} \approx 61.3$$

From the calculations above, it is clear that $E_2 > E_3 > E_1$. Government 2 (E_2) has far greater e-government index than the other governments from the example in Table 3. However, looking at the above example from the total number of features and ser-

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vices perspective, results that Government 1 has many more features and services than the rest of the governments, whereas Government 2 and 3 have the same amount of services. Also, if we have two governments with the same number of features and services per website but different number of websites they would result with the same e-government index although it is clear that one government has many more features and it provides many more services than the other.

As can be seen from the scenarios above, it is clear that West's model is not an objective model that would measure the e-government index properly. Indeed it has many limitations.

Next, five models that were proposed from Rorissa will be analyzed.

The first model proposed from Rorissa is named framework 2 in her paper [4]. This proposed model measures the e-government index according to e-government maturity stage calculated with the following formula:

$$E_j = \frac{\sum_{i=1}^{n} w_i e_i}{\sum_{i=1}^{n} w_i} \tag{3}$$

where, e_i is the e-government index for website i and using Equation (1) $0 \leq e_i \leq 100$; n is the total number of government websites for country j; w_i is the level of e-government service developed for website i, $1 \leq w_i \leq 4$. Although, $1 \leq w_i \leq 4$, the model allows w_i to be any positive number so it does not limit the number of stages or if desired to put more weight to some stages if we consider that some stages should have more weight. So as a result, this model is flexible in terms of number of stages or the distance between stages (weight). However, the model has its limitations as well. First, it still uses the same equation for calculating the e-government index for a single government website, which actually is one of the main limitations of the West's model, mentioned earlier. Second, this proposed model does not allow to weight individual services based on the maturity level, which in return makes it difficult to determine the level of maturity of a website, since one website can contain elements of different stages for different services or features. Third, determining the values of w_i is not straightforward because the values can be assigned in a subjective fashion.

The second model proposed by Rorissa is referred to as Framework 3 [4]. This model uses Equation (3) for calculating one country's e-government index, but removes the overweight from Equation (1) by:

$$e_i = f_i + x_i \tag{4}$$

This model values the functionality the same with services provided which might be good, however again it has the same limitations as the previous model.

The next model proposed by Rorissa referred to as Framework 4 [4]makes changes to Equation (2) by introducing the relative e-government index for site (e_{Ri}):

$$e_{Ri} = \frac{e_i - \min(e_i)}{\max(e_i) - \min(e_i)} \tag{5}$$

Then, e_{Ri} is used in Equation (3) instead of e_i, resulting with:

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$$E_{Rj} = \frac{\sum_{i=1}^{n} w_i e_{Ri}}{\sum_{i=1}^{n} w_i} \quad (6)$$

What this model does differently compared to Framework 3, as authors themselves state, is that "Because the individual website e-Government index value is calculated relative to the most robust website in the dataset, the value of e_{Ri} ranges from 0 to 1. This framework avoids the need to choose an arbitrary weighting factor and apply it to the number of features in order to rescale the values to fall between 0 and 100. By default, the computed relative e-Government index value for each country (E_{Rj}) also falls between 0 and 1, and could easily be rescaled to a value between 0 and 100, multiplying it by 100." However, since calculation of e_i and E_{Rj} did not change, some limitations are still prevalent. The main limitation in this model is that still is biased toward governments with more dense websites. Also all the limitations related to w_i stated for Framework 2 still prevail.

The next model from Rorissa, referred to as Framework 5 [4], uses a different formula for calculating e_i:

$$e_i = f_i x_i \quad (7)$$

Otherwise the model uses the Equations (5) and (6) for calculating one country's e-government index. This model uses the product of features and executable services to calculate single website's index. However, as with the other models, same limitations apply. Additionally, this model, as the authors themselves identify would produce an $e_i = 0$ if a website does not have executable services [4].

The last model, which is favored by Rorissa, is referred to as Framework 6. This model uses different calculation method for e_i. Apart from this, the model uses Equations (5) and (6). e_i calculated with this method uses combination of Framework 4 and 5 to avoid the limitation of Framework 5, where the value of e_i becomes zero if a website does not have executable services. The formula for calculating e_i in this model is as follows:

$$e_i = f_i x_i + f_i + x_i \quad (8)$$

Framework 6 is an improvement over Framework 4 and 5. However, it still does not overcome limitations of West's model and other models mentioned here. The models discussed above do not account for the overall online features and services provided by the government. Rather they look at government websites individually and find an average or weighted average. In reality, this approach would clearly favor governments who concentrate their services in few websites. All of the methods discussed above have its advantages and disadvantages. Among the advantages of these methods are ability to measure e-government development of a country and ability to benchmark e-government development of countries. Although these models have a great contribution toward quantifying e-government initiatives, yet the unbiased approach of these models should be further assessed. As discussed earlier, one of the main disadvantages of all of the models above is being biased toward concentration of features and services in fewer websites. The reason behind this is that each website is assessed individually and then the average is found for a country. As a result, these

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models do not assess the overall e-government services. It is much more important to assess the overall e-government services and features rather than the average of individual websites. In order to illustrate this an hypothetical example will be given. Indeed, spreading services and features to more websites would dramatically decrease the e-government index.

2.1 United Nations E-Government Maturity Index

Another method that is used to calculate e-government development stage is United Nations' E–Government Development Index [5]. United Nations e-Government Development Index (EGDI) is a survey that is performed by United Nations Public Administration Network every two years, starting from 2001. EGDI is a massive survey that includes all United Nations member countries performed in 2001, 2003, 2004, 2006, 2008, 2010, 2012, and 2014. It is comprised of a weighted average of three normalized scores on three sub-indexes: (1) Online Service Index, (OSI), (2) Telecommunication Infrastructure Index, (TII), and (3) Human Capital Index, (HCI) [6]. The formula used for calculating EGDI is:

$$\mathrm{EGDI} = \frac{\mathrm{OSI}_{\mathrm{normalized}} + \mathrm{TII}_{\mathrm{normalized}} + \mathrm{HCI}_{\mathrm{normalized}}}{3} \quad (9)$$

OSI measures the quality of online services and is the only sub-index that is measured collecting primary data from its survey. TII measures the telecommunication infrastructure of a country and is comprised of the number of subscriptions to (a) mobile, (b) fixed-telephone, (c) wireless broadband, (d) fixed broadband and (e) individuals using the internet in percent of the population, where the data is taken from International Telecommunication Union (ITU) [6]. HCI measures (a) adult literacy, (b) gross enrolment ratio, (c) expected years of schooling, (d) mean years of schooling [6]. However, the above stated components for calculating the sub-indexes have changed over time. Changes in these indexes are illustrated in Table 2 and Table 3.

Table 2. Human Capital Index and changes of its components (2003–2014). Source: [6]

Components of HCI prior to 2014	Components of HCI in 2014
Adult Literacy	Adult Literacy
Gross enrolment ratio	Gross enrolment ratio
	Expected years of schooling
	Mean years of schooling

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Table 3. Telecommunication Infrastructure Index and changes of its components (2003–2014). Source: [6]

Component	2002	2003	2004	2005	2008	2010	2012	2014
Internet users	☑	☑	☑	☑	☑	☑	☑	☑
Online population	☑	☑	☑	☑				
Fixed-broadband subscriptions					☑	☑	☑	☑
Personal computer (PC) users	☑	☑	☑	☑	☑	☑		
Fixed Internet subscriptions							☑	
Wireless broadband subscriptions								☑
Fixed telephone subscriptions	☑	☑	☑	☑	☑	☑	☑	☑
Mobile cellular subscriptions	☑	☑	☑	☑	☑	☑	☑	☑
Television sets	☑	☑	☑	☑				

The third sub-index which is part of the EGDI is OSI (Online Service Index). OSI measures the performance of one country's government by evaluating the national government portals as well as ministries of education, labor, social services, health, finance and environment [6], [7]. The contents and features of the websites are evaluated to assess the state of e-government in all UN member states. The evaluation of e-government state of countries goes through multiple steps of evaluation. The first step is the initial assessment by more than 90 researchers and volunteers from universities, coordinated by Data Team Coordinator. To ensure consistency, researchers were provided with training by e-government and online service delivery experts, with years of experience in conducting the assessments. The second step is to compare the evaluations by the two researchers on each country. Also, questions with discrepancies are reviewed again by the researchers [6]. On the third step, the final review by the Data Team Coordinators takes place, who analyze all the answers and reviews and verify processes before the scores are sent for approval by a senior researcher. After these three steps are performed, the statistics team produces the first draft of the OSI ranking. Finally, the individual scores of countries are normalized to range between 0 and 1 using the country with maximum score and the country with minimum score:

$$OSI_{i_{normalized}} = \frac{OSI_i - OSI_{min}}{OSI_{max} - OSI_{min}} \quad (10)$$

where, $OSI_{i_{normalized}}$ is the normalized Online Service index for country i and $0 \leq OSI_{i_{normalized}} \leq 1$, OSI_i is the initial Online Service Index prior to normalization, $\mathrm{OSI_{min}}$ is the Online Service Index prior to normalization of the country with the minimum score, and $\mathrm{OSI_{max}}$ is the Online services Index prior to normalization of the country with the highest score.

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E-government Development Index (EGDI) is a major endeavor by United Nations to measure e-government development in all of United Nations member countries. While the model for calculating Online Service Index has deficiencies and has received criticism [7]–[9], it is still the most used benchmarking tool that continues to gather data since 2001.

Two studies in particular analyze the validity of EGDI. The first study comes from Whitmore [9]. Although Whitmore credits EGDI for the major work, he recommends using factor analysis for building the e-government index. Indeed, he tests the 11 factors included in building EGDI and concludes that "Mobile subscribers per 100 inhabitants", which is part of TII, degrades reliability of EGDI and should probably be omitted. Additionally, Whitmore test the hypothesis that "The E-government Development Index can best be described by three components: the Human Capital Index, the Telecommunication Infrastructure Index, and the Online Service Index." He concludes that "…the grouping of the 11 raw data measures into three aggregate indices may not be meaningful as the indicator variables loaded more efficiently on a single factor than they did onto three separate factors. This is important because the UN reports the three aggregate indices as well as the overall E-government Development Index in its annual survey." It is important to state that Whitmore proposes a statistical analysis rather than intuition in building the EGDI.

On the other hand, a study from Stier [7] suggests to use only Online Service Index for measuring E-government development. Thus study claims that EGDI, as is calculated, is biased toward countries that have more advanced technology infrastructure and more developed human capital. As the author states "If a government in a country with an underdeveloped information infrastructure or weak human capital performs well in e-government, these good policies will be concealed in the ranking by the structural deficits" [7]. This study, pinpoints one deficiency of the EGDI which is not attributing enough credits to developing countries for their e-government efforts. Another, deficiency of EGDI is that the data is not collected every year and in regular time periods. This deficiency complicates the statistical analysis since the nature of the data is unbalanced panel data [7].

It is clear that although both of the authors, [9] and [7], give a credit to the extraordinary effort by United Nations for the survey and calculating the EGDI. However, both studies also identify some deficiencies in EGDI. According to these studies the deficiencies can be summarized as: (1) Mobile subscribers per 100 inhabitants should be dropped from EGDI, (2) EGDI is biased toward developed countries that have better telecommunication infrastructure and more developed human capital, and (3) EGDI is unbalanced panel data which complicates statistical analysis.

2.2 Other e-government indexes

Apart from EGDI, there have been other efforts to measure the e-government development such as: European Commission's e-government Benchmark performed by Capgemini [10], The Economist Intelligence Unit Digital Government Rankings [11], Brown University – Brookings Institution e-government data [12], and Waseda-IAC

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International E-Government Ranking [13]. However, none of these methodologies have the consistency and longevity of UN EGDI.

European Commission's e-government Benchmark is an index developed by CapGemini for the purposes of European Commission [10]. The study is performed in 32 countries surveying 28,000 internet-using citizens. According to the report, it provides 95% relevancy in terms of robustness. The report provides insight in three broad areas: (1) A demand-side citizen view of public services, (2) three life-event assessments that are core to a healthy economy (starting and early trading of a business, losing and finding a job, and studying) and, (3) Assessment of five key technology enablers (eIdentity, eDocuments, Authentic Sources, eSafe, and Single Sign On). The limitation of this benchmark is as follows: the number of years this benchmarking tool has been performed, the benchmark includes only 32 countries, and the survey looks at the e-government only from the citizens' perspective.

The Economist also has created an e-government ranking but barely for two years (2009 and 2010). This benchmark forms the e-government index based on six categories with different weights: (1) Connectivity and technology infrastructure - 20%, (2) Business environment - 15%, (3) Social and cultural environment - 15%, (4) Legal environment - 10%, (5) Government policy and vision - 15%, and Consumer and business adoption - 25%. The limitations of this index are that it was measured only for two years and the methodology of creating the index is shallow.

Brown University – Brookings Institution e-government data is a large e-government dataset available for: (1) 70 largest American cities for 2001, 2002, 2003, and 2004, (2) 50 American states for 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, and 2008, (3) 60 United States federal agencies for 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, and 2008, and (4) 198 nations around the world for 2001, 2002, 2003, 2004, 2005, 2006, 2007, and 2008. It is of crucial interest of this thesis the data gathered for nations around the world gathered in the period 2001-2008. The study is very comprehensive and detailed gathering data about 198 countries in areas such as: Online Services, Publications, Databases, Privacy Policy, Security Policy, W3C Disability, and Accessibility [12]. However, although very good, the data gathering has stopped in 2008, and it seems the project has been discontinued. This research will not be taken into consideration for two reasons. First, the study is no longer being conducted. Second, the data is not freely available and it is costly. Due to lack of resources, the data from this study is not available to the author.

Waseda-IAC International E-Government Ranking is the last e-government ranking that will be analyzed in this research. This e-government ranking is performed from Waseda University in cooperation with International Academy of CIO (IAC). This survey is based on 9 major indicators and 33 sub-indicators in the public sector, as well as the relationship between governments and their stakeholders. They include: (1) Network Preparedness; (2) Management Optimization; (3) Online Service; (4) National Portal/Homepage; (5) Government Chief Information Officer; (6) E-Government Promotion; (7) E-Participation/ Digital Inclusion; (8) Open Government/Data and (9) Cyber Security [13]. The 2014 survey includes 62 countries. This survey is another major effort to measure the e-government maturity or rank

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countries based on the aforementioned criteria. The limitation of this survey is the number of countries ranked by this survey compared to UN EGDI.

3 Comparative analysis of the most popular e-government ranking systems

Previously, the most important indexes that measure e-government maturity were described. Now, the comparison of these indexes will be performed, by analyzing the main characteristics of these indexes such as number of countries analyzed, number of years for which the data is available, frequency of calculation, how many indicators are used in calculation, as well as is the calculation of the index ongoing or discontinued. Comparing these five indexes it is clear that only two indexes are more suitable for statistical analysis: UN EGDI and Waseda-IAC, whereas the other indexes suffer from the biggest limitation which is they are discontinued and there is not fresh data available for them. For this reason, the latter indexes will not be analyzed furthermore. The summary of the comparative analysis is given in Table 4.

Table 4. Comparison of e-government Indexes

E-government Index	Countries	Years	Frequency	Indicators	Ongoing
UN EGDI	193	8	Bi-yearly	10	Yes
European Commission	32	1	N/A	3	No
The Economist	70	2	Annual	6	No
Brown University – Brookings	198	8	Annual	7	No
Waseda-IAC	62	10	Annual	9	Yes

4 Conclusions

The contribution of this study lies in two areas. First, it analyzed how different models measure the maturity of e-government, i.e. how these models are built. Second, this study makes a synthesis of actual measurements by different organizations and how applicable they are in making quantitative analysis. Based on the analysis, the results show that United Nations E-government Development Index (EGDI) is the most appropriate for use in quantitative analysis for because it measures the index for 193 countries, it uses 10 indicators, and it has a consistency of measuring the index every two years. However, even EGDI has its weaknesses. One of the weaknesses which applies to all of the indices analyzed in this study is that the calculation of the index has changed over time and the statistical analysis using time series is not very suitable.

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