Dynamic Systems State Model for E-Readiness Estimation

An evaluation of the e-readiness layered model

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***Abstract*—The E-readiness Layered Model (ELM) tends to cover the lack of indicators measures for the e-readines index calculation. This paper's aim is to test the effectiveness of this model through the comparison of an ELM estimted index and a calculated index. Indeed, European I2010 indicators' measurements database is used in this test and the comparison of data series shows a high correlation between the two indexes (Pearson and Spearman coefficients are above 0.95). Also, the two main differences between the data series are analysed in the light of two other international e-readiness initiatives (the Economist Intelligence initiative Unit one and the International Telecommunication Union one). This test shows that ELM could lead to estimate the e-readiness index using 6 indicators instead of 20 (70% less).**

Keywords-e-readiness; dynamic system modeling; state model; e-readiness layered model; Spearman coefficient.

I. INTRODUCTION

The world discovered in 2011 the importance of composed indexes through the powerful financial rating agencies, such as Standard & Poors and Moody's. Indeed, the famous "AAA" rating for countries and financial institutions solvency can influence their economic stability. Similarly, the Shanghai ranking participates in guiding students towards the highest-ranked universities; the backwardness of the French universities in this index led to the creation of a parliamentary commission for the development of education in France.

In this international context, the e-readiness indexes are an important approach for measuring and developing the integration of new technologies in countries and regions. These indexes are important as they contribute to the governments' e-Strategy assessment and the orientation of Foreign Direct Investment (FDI) to different countries (investment in offshore software development, in call centers, etc.). However, the availability of Information and Communication Technologies (ICT) indicators' measures is one of the main issues for the development and spread of this concept.

To address this issue, Belkhayat et al. [1] proposed an E-readiness Layered Model (ELM) to reduce the measurements' need in the e-readiness estimation process. Belkhayat et al. [11] proved the convergence of the ELM and tested its pediction accuracy for one indicator. This paper evaluates the ELM capacity to reduce the indicators measurements' need for the e-readiness index estimation.

Indeed, Section 2 of this paper introduces the main issues related to the excessive measures need to calculate e-readiness indexes. Section 3 gives a brief presentation of the layered approach proposed in the literature to overcome this problem. In Section 4, we precise the testing approach adopted and the results observed.

II. EXCESSIVE NEED OF INDICATORS MEASURES: MAIN OBSTACLE TO THE E-READINESS CONCEPT DEVELOPMENT

The e-readiness tends to measure and analyze the level of integration of ICT in countries' development. The measurement of e-readiness is a global index based on the compilation of a set of indicators correlated to ICTs. This concept of e-readiness has gained importance globally within last decade. Indeed, the action plans of the two World Summits on the Information Society (Geneva 2003 and Tunis 2005) called for the periodic evaluation and comparison of international performance in the field through a composite index comprising comparable statistical indicators [2]. To this end, several organizations, such as International Telecommunication Union (ITU), World Economic Forum (WEF), the Economist Intelligence Unit (EIU), have focused on this concept and have developed specific approaches for the e-readiness measurement and its exploitation in guiding the development of new technologies in different countries and regions. Two main objectives are reported for these approaches: ICT integration evaluation and different countries ranking according to a composite index [3].

Thus, each of these e-readiness approaches relies on a set of indicators that reflect a vision of the ICTs role in countries' development. These indicators can be related to the digital infrastructure, ICTs human resources, and also other areas that may be impacted by new technologies such as governance or economics. At this stage, the number of indicators considered by each approach may range from a dozen (11 approach ITU) to more than a hundred ("e-readiness ranking" developed by IBM and EIU [4][5][6][7].

Thus, the calculation of an e-readiness index requires thousands of indicators measurements (the number of indicators multiplied by the number of countries in the panel). Also, to get an accurate picture, these measures should be carried out synchronously and in a relatively

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small window of time. The UN report [7] presents the latter as a challenge: a window of 30 days was set in the approach used to measure the e-Government index, but the realization could not be done in less than 75 days due to the complexity of collecting and processing indicators measurements.

Faced with the lack of measures, regular e-readiness evaluation initiatives resort to reducing the indicators framework or forcing the measurements database completeness using measurements from previous years or estimating the missing measurement mainly by the hot deck method (expert comparison to other similar countries) [8]. However, the reduction of the indicators framework impacts the relevance of the index while the missing data estimation is difficult in the ICT field due to the unavailability of large historical databases and the frequent change of the indicators definition (necessary changes to take account of technological developments and societal phenomena related to ICT (4G-3G - DSL, social networks, e-learning, etc.) [9].

On the other hand, measurement quality differs from one country to another depending on the data source, the survey methodology or even the perception of people who respond to these inquiries.

Davidrajuh produced an attempt to address the first issue through fuzzy logic [10]. To cope with the problem related to the exponential number of inference rules needed, this attempt was based on the aggregation of e-readiness indicators in a smaller set of "key indicators". However, the author does not specify the validation process and the results of this approach tests. We have not found any other related work.

III. Layered Approach and State Model for Predicting the E-Readiness Indicators Measures

We proposed an approach for modeling the e-readiness indicators evolution considering them as measurable characteristics identifying a “virtual" dynamic system [1]. This paper focused on a layered modeling approach and cross indicators impactability concept leading to a dynamic system state model. Indeed, the indicators are classified into three layers (basic layer, intermediate layer and target layer) according to the importance they represent to the e-Strategy process owner which is the highest authority of the state or country:

Basic Layer: featuring the basic indicators that can be of two types: basic indicators on which it is possible to act by decision (example: Cellular phone network coverage or the rate of research and development (R&D) budget to Gross Domestic Product (GDP) can be directly impacted by government decision) or general prerequisite indicator part of a wider area than that studied (example: illiteracy rates).

Target layer: featuring indicators that represent a development goal, e.g., rate of e-business GDP to GDP.

Intermediate layer: having intermediate indicators that are neither basic indicators nor target ones. These indicators generally represent milestones that help ensure the smooth progress of projects but are not final goals in themselves, e.g., percentage of the population using the Internet.

Thus, this classification is based on an assimilation of e-readiness to a dynamic system whose state is characterized by the chosen indicators framework and where the basic indicators represent the system control levers. This design leads to a state model linking indicators variations over time:

$$EV_{k+1} = (RIM_k)^T * EV_k + C_k \tag{1}$$

where EV_k is the indicators measures evolution vector for the period k (period between T_{k-1} and T_k); C_k is a constant vector corresponding to the basic indicators evolutions planned by the e-Strategy stakeholders for the next period and $(RIM_k)^T$ is the transition matrix calculated on the basis of previous measures and an indicators’ impactability matrix [11].

Belkhayat et al. used Kalman filtering for testing the ELM convergence and the indicators prediction accuracy [11].

Thus, the ELM state model suggests that the knowledge of current measures and the planed variations in basic indicators (C_k commands) allows us to predict the other indicators variations and then the reconstitution of the next system state vector.

ELM is a new indicators’ measurements prediction approach used in the e-readiness field where the unavailability of large historical databases and the frequent change of the indicators definition are limiting the use of other known prediction methods used in the conventional sectors [9]. We could estabilish the convergence of the state model and the evaluation of the accuracy of the indicators’ estimations in comparison with measured values [11]. In this paper, we evaluate the accuracy of the e-readiness index based on the prediction model in comparison with the other e-readiness indexes measured and estimated by other institutions. The methodology and results of this evaluation are the subject of the next section.

IV. ELM Evaluation: Layered Model Applied to the I2010 Initiative

A. Materials and methods

We used the I2010 database [12] to test the efficiency of ELM through the evaluation of its potential reduction of measures need to calculate e-readiness using the predictive model. This database fits to our test needs because it is containing regular yearly measurements for a significant number of countries and indicators (29 countries and 52 indicators).

The testing approach relies on the comparison of two e-readiness indexes: the one calculated on the basis of all 2010 measures and the one calculated on the basis of 2010 basic indicators measures and the ELM state model. Indeed, the use of 2008 and 2009 measures, as well as the 2010 basic indicators measures, leads to the prediction of the other indicators variations; then, one can calculate the 2010 index based on the predictive model.

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To execute this approach, we began by reducing the database to keep only the indicators and the countries for which we have all 2008-2009-2010 measures. The reduced database included 20 countries and 20 indicators.

The aim of the second step was to classify indicators according to the ELM three layers. The third step provided the necessary inputs to calculate the transition matrix of the state model (impactability matrix and calculation of indicators optimal values). Appendix 1 contains these elements that are the same used in [11] for the model convergence validation tests.

The last step concerned the estimation of the indicators variations and the calculation of the two indexes to compare. In the following, we note « I2010-P » the index calculated on the basis of predictions and « I2010-M » the index calculated on the basis of all 2010 measures.

B. *Results and discussion*

Figure 1 shows the two indexes for the 20 countries of the panel. We based the correlation analysis of these two data series on the Pearson correlation coefficient which “is a measure of the linear association between two variables using quantitative data”, and the Spearman correlation coefficient which is a “correlation measure of association between two variables when ordinal or rankordered data are available” [13]. The two data series correlation analysis gives us 97.5% for the Pearson correlation coefficient and 95.3% for the Spearman correlation coefficient (countries ranking correlation). These correlation coefficients values (close to 100%) denote that the two data series are highly correlated.

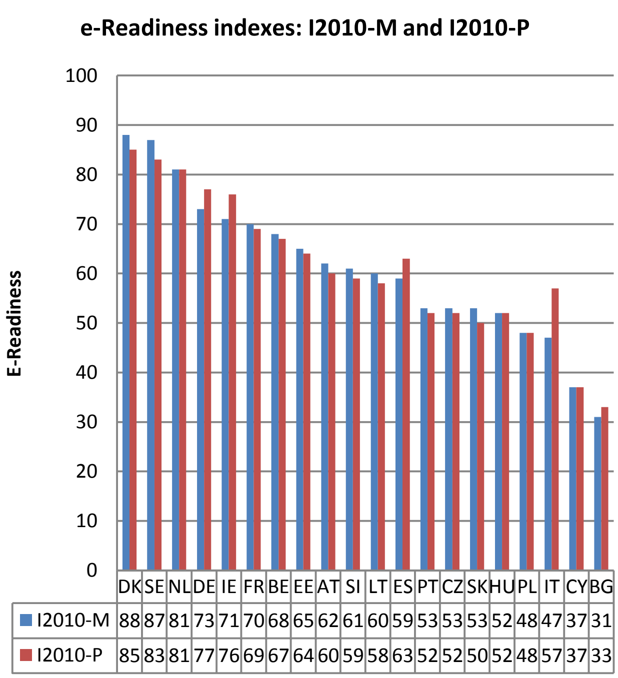

Figure 1: E-readiness 2010 – Measures # Predictions.

Also, the graphic analysis shows two main issues: the first is related to the measures and ranking deviations of Spain and Italy and the second is related to the tighter spreads between the five countries of the leading group: Denmark, Sweden, Netherlands, Germany and Ireland. To figure out these issues, we made comparisons of our two indexes among the other main e-readiness indexes measured in 2010: « e-readiness Ranking 2010» published by the EIU and IBM and IDI (ICT Development Index) published by the ITU (International Telecommunication Union).

1) First issue: Italy and Spain indexes and ranking differences

Italy and Spain indexes have significant differences that affect the ranking. Indeed, if Italy and Spain are removed from the data series, Figure 2 includes the two indexes ranking differences of the other 18 countries (Denmark being the leader).

Figure 2 shows that the countries ranking does not change except for Slovakia and Hungary, which had a small gap of about 1% and exchanged their position by passing Slovakia behind Hungary.

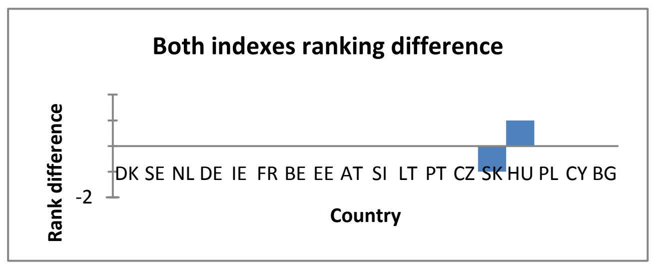

Figure 2: Countries ranking difference between I2010-P and I2010-M.

To understand this difference, we gathered the ranking of the two countries in the two other e-readiness indexes mentioned above. Hungary exceeds Slovakia of about 3% in the "e-readiness Ranking 2010 report”. In IDI, Hungary exceeds Slovakia of about 2%. These findings confirm that the index « I2010-P » complies with the two countries ranking in the other indexes measured in 2010.

Regarding Italy and Spain rankings, we find that Spain moves from the 12th position to the 9th position winning three ranks and Italy goes from the 18th to the 13th position winning five ranks. Also, we gathered their respective rankings (in the panel of studied countries) in the other published indexes. Table I shows the ranking of the two countries following the four indexes under comparison:

TABLE I. ITALY AND SPAIN RANKING IN THE FOUR INDEXES

	I2010-M	I2010-P	EIU-IBM	IDI (ITU)
Spain	12	9	9	10
Italy	18	13	11	12

Table I confirms that the index « I2010-P » complies with the two countries ranking in the other indexes measured in 2010. This allows us to estimate that the

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ranking of Spain and Italy according to I2010-P is more accurate than their ranking in I2010-M.

2) Second issue: The tighter spreads between the leading group countries

The distance between the first and the fifth of the ranking frontrunners is tighter in I2010-P. Indeed, the gap decreases from 18 points in I2010-M (more than 20% of the leader index) to 9.5 points in I2010-P (~ 12% of the leader index). In comparison with the other indexes, this difference is about 8% in the "e-readiness Ranking 2010" and 15% in IDI. This allows us to confirm that I2010-P is more accurate than in I2010-M regarding this issue.

The accuracy of I2010-P is clearer if we consider only Denmark, Sweden, Netherlands and Germany. Indeed, the amplitudes of the indexes for these four countries are in Table II as follows:

TABLE II. THE AMPLITUDE OF THE DISTANCE BETWEEN THE FOUR FRONTRUNNERS (BY INDEX)

	I2010-M	I2010-P	EIU-IBM	IDI (ITU)
amplitude	16,8%	9%	8,1%	11,6%

This table shows that the amplitude of I2010-P is within the same range than those of EIU and IDI while the amplitude of I2010-M is more than two times the EIU one.

V. CONCLUSION

The lack of ICT indicators measures is hindering the e-readiness (e-strategy) concept development (e-readiness is the first phase of the e-strategy process). ELM approach attempts to overcome this problem through a predictive system based on dynamic systems state models. This paper has attempted to assess the contribution of this approach by comparing an index calculated on the basis of 20 indicators measures and an index calculated on the basis of six basic indicators measures and the predictive model (used input tables for the ELM model are presented in the appendix 1).

The Pearson and Spearman correlation coefficients of the results exceed 95%. This ensures that the two indexes are highly correlated. On the other hand, the graphics exploratory analysis revealed two main differences between the two compared indexes. The results comparison with other e-readiness indexes measured in 2010 showed a greater consistency for the index based on the predictive model. Thus, this test assumes the robustness of the predictive model based on the ELM while allowing a significant advantage through the reduction of indicators' measures need of 70% (from 20 to 6 indicators).

However, it should be remembered that the predictive model requires the availability of the two previous periods' measurements. This leads us to conclude that the ELM approach can be very useful for initiatives that plan to last over time (annual rankings). Indeed, these initiatives can invest in exhaustive measures of the first two years and then use the ELM approach to decrease the need of indicators measurements. Also, the ELM can be used as a simulator to assist in the e-strategy fomulation (based on e-readiness diagnostic) through the prediction of the impact of planed actions on basic indicators. Indeed, the stakeholders can estimate the impact of their action plan before its validation.

Finally, we find that the ELM approach is not specific to e-readiness and can be exploited in other sectors like human development where indicators definitions can change over time.

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APPENDIX 1

The optimal values in Table III are estimated on the basis of the measured maximum value and a potential evolution margin [11].

TABLE III. SELECTED SET OF INDICATORS, THEIR CLASSIFICATION AND OPTIMAL VALUES

N°	Indicator	Layer*	Opt V
1	% of population doing an online course (in any subject)	T	9
2	% of population interacting online with public authorities	T	75
3	% of enterprises interacting online with public authorities	T	100
4	Total electronic sales by enterprises, as a % of their total turnover	T	24
5	% of enterprises using any computer network for sales (at least 1%)	I	30
6	% of population who are regular internet users (at least once a week)	I	95
7	% of population looking for information about goods and services online	I	90
8	% of population looking online for a job or sending a job application	I	28
9	% of population looking online for information about education, training or course offers	I	40
10	% of enterprises submitting a proposal in a public e-tender (e-procurement)	I	23
11	% of population ordering goods or services online	I	74
12	% of population selling goods or services online (e.g. via auctions)	I	23
13	% of enterprises using any computer network for purchases (at least 1%)	I	57
14	Fixed broadband penetration	B	50
15	% of households having a broadband connection	B	100
16	% of enterprises having a fixed broadband connection	B	100
17	% of households with access to the Internet at home	B	100
18	% of population using online banking	B	100
19	% of basic public services for citizens, which are fully available online	B	100
20	% of basic public services for enterprises, which are fully available online	B	100

* T: Target; I: Intermediate; B: Basic

Table IV bellow contains the indicators Impact Matrix proposed in [11]. The firt line of this matrix assumes that the target indicator N°1 is impacted by the indicators N° 9, 11, 15 and 18. The value in a cell corresponds to the relative importance of the corresponding impact: the indicators N° 9 and 15 have a greater impact on the indicator N° 1 than the indicators N° 11 and 18.

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TABLE IV. SELECTED INDICATORS IMPACT MATRIX WITH RELATIVE WEIGHTS

N°	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
1	0	0	0	0	0	0	0	0	5	0	3	0	0	0	5	0	0	2	0	0
2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	5	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	5
4	0	0	0	0	5	0	0	0	0	0	5	0	0	0	0	0	0	5	0	0
5	0	0	0	0	0	5	0	0	0	1	3	0	5	0	0	0	0	3	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	5	0	1	0
7	0	0	0	0	3	5	0	0	0	0	0	0	0	0	0	0	0	0	1	0
8	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	4	0	1	0
9	0	0	0	0	0	0	0	5	0	0	1	0	0	0	0	0	5	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	3	0	1
11	0	0	0	0	5	0	3	0	0	0	0	1	0	0	0	0	0	5	0	0
12	0	0	0	0	0	0	0	0	0	0	5	0	3	0	0	0	0	3	0	0
13	0	0	0	0	5	0	0	0	0	0	0	1	0	0	0	2	0	3	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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