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E-READINESS: A NOVEL APPROACH FOR INDICATORS MEASUREMENTS ESTIMATION AND PREDICTION

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ABSTRACT

E-Readiness is an assessment process for the ICT (Information and Communication Technologies) availability and use in a country. It consists in the calculation of a composite indicator based on a conceptual framework related to ICT aspects. The assessment report is used in E-Strategy to formulate action plans for e-Readiness index development. Several approaches are used for e-Readiness since the end of nineties; these approaches lack flexibility and require frequent and precise measurements. Thus, two issues are addressed in this paper: the missing measurements estimation problem and the lack of e-Strategy formulation assistance and simulation tools and approaches. Indeed, we propose in this paper an approach to define the transition matrix of the e-Readiness state equation based on a layered model. This construction leads to a state model related to the e-Readiness dynamic system and then is used with KALMAN Filter to cover the two addressed issues. Indeed, the commands variables are indicators that can be manipulated by e-Strategy stakeholder and the KALMAN filter estimation and prediction functions are used as a simulator. For validation, we constructed a model based on the I2010 e-Readiness initiative and we tested the convergence of the model and its prediction function. Results are encouraging since the tested model prediction function converges in 24 cases out of 27 (89%).

Keywords: *E-Readiness - E-Strategy, Index, Missing Data, Dynamic Systems, Kalman Filter*

I. INTRODUCTION

Since the end of last century, developed countries have realized that "The digital revolution" had to be harnessed and exploited to consolidate the countries' economic power and human development. Thus, these countries have adopted an "e-Strategy" integration process based on three phases [1]:

- The "e-Readiness" assessment which is endeavoring to diagnose the situation of ICT and their impact on countries development.
- The e-strategy formulation: fixing strategic priorities in the light of the "e-Readiness" analysis; Deliveries of this phase are an integrated strategy and action plan for the ICT development and use in the country.
- Implementation: This phase concerns the implementation of the approved strategy and action plans.

The e-Readiness concept has gained importance since the new millennium first years. Indeed, the two World Summits on the Information Society insisted in their recommendations on the need to develop an index of ICT. The Geneva and Tunis Plans (in 2003 and 2005) have called for the periodic evaluation and comparison of international performance in the field through a composite index based on comparable statistical indicators [2].

This article addresses two issues related to this process: the need of excessive relevant indicators measures and the lack of conceptual simulation tools to support the e-Strategy formulation phase. These two issues will be detailed in the state of the art. The second chapter presents the proposed approach for the e-Readiness state model transition matrix definition and the process proposed for the use of Kalman filter, and the last chapter presents the results of the prediction function made on the basis of data from the European Union i2010 initiative.

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II. STATE OF THE ART

In this chapter, first we present the state of the art of e-Strategy process and the corresponding international approaches and initiatives. Then, we give a brief presentation of the ELM[1] model proposed in [3].

II.1. E-Strategy Process

Since the late 1990s, several organizations were interested in the concept of e-Strategy and have developed specific approaches to the measurement of e-Readiness and its use in guiding the ICT development and integration in different countries and regions of the world. These approaches had two main aims: 1) diagnostic of ICT integration level and 2) ranking different countries or states according to a composite index [2].

These e-Readiness approaches have been developed in different contexts: we can find those developed in an academic context such as the Harvard University approach CID, those developed in the framework of international organizations such as the approach adopted by the ITU (International Telecommunication Union) to produce the IDI (ICT Development Index), those developed by some countries for their own use such the approach adopted by India for the e-Readiness analysis of its various federal states, and other approaches developed by large strategy consulting firms such as aT Kearney and McConnel. Thus, many definitions of e-Readiness emerged since the late 90s. All these definitions tend to consider the measure of "Availability" and "Use" aspects of ICT [1].

In this concept, [4] and [5] contain a summary and illustrated process of e-Readiness calculation which corresponds to the application of a model (set of mathematical functions defined) on the measures of a set of indicators. Each indicator represents a quantitative or qualitative aspect related to the ICT integration (Availability and Use) in the country. The e-Readiness index analysis report is the deliverable of this phase. The figure 1 summarizes the steps of this process ([6] [7] [8] [5] [9] [4]).

Each of these approaches is based on a set of indicators that reflect a vision of the role of ICT in developing countries. Some approaches focus on digital infrastructure (DSL penetration, rate of GSM coverage in rural areas, etc.), while other approaches include the economic and social dimension in their lists of indicators (rate of population attending an online course, e-Commerce share in the overall companies' turnover ...). To this end, the number of indicators considered by each approach can grow from a dozen (11 for the ITU approach) to more than one hundred ("e-Readiness ranking" developed by IBM and EIU).

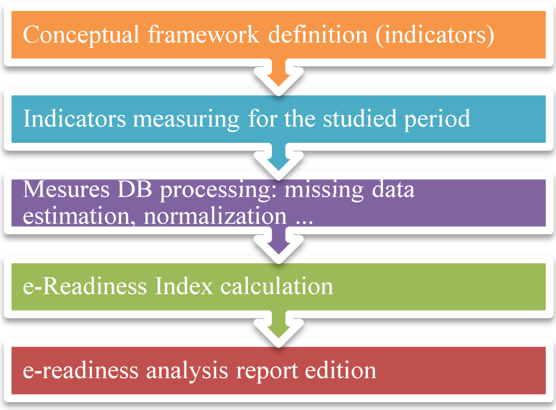

Figure 1: E-Readiness Assessment Process

Thus, some organizations have developed initiatives for the regular e-Readiness calculation and analysis of a panel of countries. Among these initiatives, "I2010" was a part of the European Union e-Strategy for the 2005-2010 period; NRI is developed jointly by the World Economic Forum and INSEAD to cover the e-Readiness analysis of about 140 countries, and the "e-Readiness ranking" initiative conducted by the Economist Intelligent Unit (EIU) and IBM addresses about 70 countries. The four main initiatives for calculating the e-Readiness of a set of countries are published by the World Economic Forum, the EIU-IBM, the United Nation and the International Telecommunication Union. All these initiatives follow this process to build their index ([10] [11] [12], [13] [14] [15]).

To produce their annual rankings, these initiatives must have thousands of measurements (the number of indicators multiplied by the number of covered countries). Also, to have an accurate picture, these measurements must be carried out synchronously and in a relatively small window of time. The UN report [13] presents the latter as a real 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

[1] E-Readiness Layered Model

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due to the complexity of the collection and processing of the indicators measures [13].

Faced with the lack of measures, these various initiatives resort to reduce the indicators conceptual framework [2], or estimate missing measurements. Also, the quality of measurements differ from one country to another depending on the data source, the survey methodology or even the perception of people who respond to these inquiries. Some initiatives such as i2010 consider in their analysis as aberrant the more distant measures to the average of the whole set of countries measures [16].

The table 3 in annex 1 presents a comparison of different initiatives regarding the measures availability and missing data estimation method: (used sources are the publications of the various initiatives [10] [11] [12] [15] [16] [17] and associated websites). We can find that for these initiatives, the treatment of missing measurements is based on two approaches: the use of the latest available measure (previous years) or the missing measurements estimation by comparison with similar countries (hot deck method). We notice that the HDI[2] (Human Development Index), which is a widely adopted index, uses the hot deck method for handling the missing data.

Also, as we noticed previously, the missing measurements problem is accentuated in the ICT domain due to the frequent changes in the indicators set and definition due to the rapid development of new technologies [10] and their socio-economic impact. Indeed, as an example, I2010 have changed several indicators definitions in 2008. The indicators measurement process has encountered several difficulties even with the assistance of EUROSTAT: 1) in 2008, about 20% of measures were missing; 2) only 50% of the indicators were regularly measured for the three years 2006-2008.

Regarding these facts, we can conclude that the current e-Readiness approaches have two main limits regarding indicators measurements:

- Weakness in taking charge of processing the collected data: missing measures and inconsistent measures.
- The e-Readiness indicators framework can be truncated because of calculating the e-Readiness regularly is limited by:
    - The cost of the measurement process,
    - The technical feasibility of simultaneous measurement of an important set of indicators is not evident especially in developing countries.

Thus, the first issue considered in the state of the art is that the processing of the indicators measures availability and quality represents a major limit to the development and the dissemination of the current e-Readiness approaches.

The second issue identified in the e-Strategy process is the lack of simulation tools to support the e-Strategy formulation phase in the light of e-Readiness measures.

Indeed, the e-Strategy formulation phase is based on the e-Readiness report to produce the main deliverable which is the action plan proposed to improve the integration of ICT through an e-Readiness target [18] [19] [20]. However, we note the lack of tools and approaches to support this e-Strategy formulation phase: the comparative reference in the literature [1] has identified only six approaches delivering a report outlining proscriptions for e-Strategy development among the twenty five approaches compared. All these six approaches have been used in case studies and their promoters do not publish formal methodologies for this purpose. We have not found in the literature any evolution of this statement.

II.2. Approaches Proposed To Address The Identified Issues

[21] produces an attempt to address the first issue through fuzzy logic. To cope with the problem related to the exponential number of inference rules needed, this attempt is 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.

[3] proposed an approach for modeling the e-Readiness indicators evolution considering them as measurable characteristics identifying a “virtual" dynamic system. This article focused on a layered modeling approach and cross indicators impactability concept leading to a dynamic system

[2] Since 1990.

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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: GSM coverage or the rate of R&D budget to 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. Example: 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 (Example: percentage of the population using the Internet).

Thereafter, the Relative Impact (RI) concept is introduced as follows: The RI of the indicator I_l on the indicator $I_{l'}$ is the $I_{l'}$ measure variation due to a unit variation of I_l:

$$RI(I_l/I_{l'}) = I_{l'}|(I_l + 1) - I_{l'}|(I_l) \; ; RI(I_l/I_l) = 0$$

The new indicators classification and the RI definition could lead to the state equation (1) bellow where EV_k is the indicators measures evolution vector for the period k (period between T_{k-1} and T_k); RIM is the RI matrix and C_k is a constant vector corresponding to the basic indicators evolutions planned by the e-Strategy stakeholders for the next period. Indeed, the new classification could separate the basic indicators that can be directly impacted by stakeholders' decisions from the other indicators for which the evolution can be predicted following the RI matrix.

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

Even so, the article doesn't precise how to calculate the RIM matrix and a fortiori doesn't comport numerical applications for this approach.

Furthermore, the fields of dynamical systems study use filtering tools to estimate and predict the observed systems trajectories: "Filtering consists in estimating the state of a dynamic system [...] from partial observations generally noisy." [22]. The Kalman filter is the optimal filter for estimating the state of a dynamic system where the noises associated to the measuring process and the state model are white noises, centered and independent [23]. Thus, we propose in this article an approach for the use of the Kalman filter on ELM models to produce the estimation and prediction of the indicators evolution exploiting available measurements.

III. E-READINESS STATE EQUATION: TRANSITION MATRIX AND FILTERING PROCESS

To use the e-Readiness dynamic system state model proposed in [3], we first propose an approach for the calculation of the transition matrix of the state equation and then we propose an algorithm for the use of Kalman filtering for indicators' measurements prediction.

III.1. State Model Transition Matrix

As noticed in the state equation (1), the transition matrix of the state model is: $A = (RIM)^T$ and C_k is the vector containing basic indicators changes planned for next period. Thus, the changes agreed in C_k are effective in T_{k+1} and will impact M_{k+1} and EV_{k+1}.The impact of C_k will be spread in T_{k+2} through RIM_{k+1} and EV_{k+1} used to calculate EV_{k+2} in the state equation (1) and so on.

However, the matrices RIM_k must be set to be injected into the equation. Thus, we propose bellow a process for the definition of the RIM matrix. Indeed, for the definition of the relative impact matrix, we consider the following two principles:

- The I_l indicator evolves to its maximum extent when all its predecessors indicators (indicators impacting I_l) reach their maximum extent. This maximum is a local optimum that can change over time. As an example, the target indicator "Share of ICT sector in total employment" would reach its maximum if the intermediate indicators that are impacting it are at their maximum: "% of enterprises using eGovernment services", "% of firms using ERP "... The strength of this principle depends on the relevance of the set of indicators and maximum definition adopted by experts.
- The relative impact of an indicator $I_{l'}$ on I_l decreases when I_l is approaching its maximum value.

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If we denote $PRED(I_j)$ the set of all indicators impacting I_j and N_b the indicators set cardinal, M_k the k[th] measurements vector and $Max(I_j)$ the maximum value for the indicator number j, the above two principles can be materialized by the following equation:

$$\left(\mathrm{Max}(I_j) - M_{kj}\right) = \sum_{i=1}^{Nb} \left(\mathrm{Max}(I_i) - M_{k-1_i}\right) * \mathrm{RI}\left(I_i|I_j\right)_k \quad ,1 \le j \le \mathrm{Nb} \text{ and } \mathrm{PRED}\left(I_j\right) \neq \emptyset$$

As $RI\left(I_i/I_j\right) = 0 \; if \; PRED\left(I_j\right) = \emptyset$, we focus on solutions where $\mathrm{PRED}\left(I_j\right) \neq \emptyset$. One solution is as follows:

If $\left(Max(I_i) - M_{k-1_i}\right) > 0$ then,

$$RI\left(I_i|I_j\right)_k = \alpha_{ij} \frac{Max\left(I_j\right) - M_{k_j}}{Max(I_i) - M_{(k-1)_i}},$$

$$\left(\alpha_{ij} = 0 \; if \; I_i \notin PRED\left(I_j\right)\right); \quad \sum_{I_i \in PRED(I_j)} \alpha_{ij} = 1$$

Else: we have $\left(Max(I_i) - M_{k-1_i}\right) = 0$ which means that I_i is at its maximum at the period k-1, then:

If $(EV_k)_i=0$ which means that there was no evolution and then no impact, then, we can set $RI\left(I_i|I_j\right)_k = 0$,

else, we consider that the impact of $-(EV_k)_i$ is equivalent to –(the impact of $(EV_k)_i$) which means that the relative impact is independent of the sign of the indicator measure evolution. Thus, we have:

$$RI\left(I_i|\, I_j\right)_k = \alpha_{ij} \frac{Max\left(I_j\right) - M_{k_j}}{Max(I_i) - M_{(k)_i}}$$

We can notice that $RI\left(I_i/I_j\right)_k = 0$ if I_j is at its maximum; This is because of the fact that an indicator (I_j) can be at its maximum value even if one or more elements of $PRED(I_j)$ are not at their maximum. As example, experts can propose in the impact graph that the target indicator "ICT sector share of total GDP" impacts the basic indicator "DSL coverage"; this basic indicator can be at its maximum of 100% even if the target indicator impacting it is not at its maximum. This case should not be frequent and can occur mainly for basic indicators that can be pushed to its maximum by decision. For the model, if this case occurs, the maximum of (I_j) should be changed or the indicator should be measured frequently to validate or correct it's state; this would reset the impact of the inertia of the system on I_j when $RI\left(I_i/I_j\right)_k$ will be recalculated.

α_{ij} represents the weight of the indicator I_i in the set of all indicators impacting I_j. To calculate these weights, the experts assign to each indicator impacting I_j a rating from 1 to N (configurable scale) depending on the importance of the corresponding impact. The weight of this impact is the rate divided by the sum of the rates of the edges impacting I_j.

$$\alpha_{ij} = \mathrm{Rate}(I_i I_j) / \sum_{I_k \text{ in } \mathrm{PRED}(I_j)} \mathrm{Rate}(I_k I_j)$$

Thus, the construction of the RIM needs to define the impact matrix (α_{ij}) and the maximum values vector.

III.2. Kalman Filtering Process

The indicators estimation process goes through three major steps:

- The first step concerns the treatment of the indicators measurements database: interpolation, standardization and indicators evolutions calculation
- The second step concerns the inputs of the state equation: Transition matrices and constant vectors.
  - The classification of indicators within the three layers. The constant vectors (C_k) concerning the basic indicators.
  - The definition of indicators optimal values and impact graph (matrix) for the calculation of transition matrices as described above.
- The third step concerns the use of the state model with Kalman filtering and prediction functions
  - The definition of noise covariance matrix
  - The use of Kalman filtering and smoothing functions with a first period measures evolution to reach the model convergence

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- The use of Kalman prediction functions for the estimation of the indictors measures evolution for the next period
- Reconstruction of the indicators measures estimation using the predicted evolutions and the last available measures

The Kalman functions are used with a step equal to one which means that the calculation of the next value uses the transition matrix RIM recalculated on the basis of the last estimated indicators' vector values. Thus, the third step is used within a loop to cover all the prediction periods needed ("n" years).

III.3. Materials And Convergence Tests

In June 2011, the European Commission in charge of the i2010 initiative released the database measurements of selected indicators at the end of this initiative. This database includes the definition and classification of indicators and measures for 29 countries covered by I2010. These range from 2003 to 2010, but its completeness varies from one country to another and from one year to another. The DB includes the changes that were made to the list of indicators and their definitions. Thus, for the validation of our approach, we started by the convergence of the generated state model:

Framework and database processing and reduction

In order to make the convergence tests of our model, we started by holding a sub-database of a maximum set of countries and indicators having a minimum of missing measurements. In this order, we selected a list of indicators according to the non-exclusive rules:

- Measures availability: we have identified the indicators that have a maximum of measures between 2005 and 2010, for a minimum of 20 countries.
- No indicators redundancy: for the same ICT aspect, we kept only indicators normalized to the total population (instead of those covering the same aspect and normalized to the internet users for instance). We also eliminated the indicators that detail the type of Internet use (to read newspapers, listen to the radio or to download the games).
- Coverage of the set of indicators: selected list should include indicators of the different layers of the "e-strategy" in order to build a representative impact graph.

Thus, we selected a list composed of 20 indicators. The average number of measurements per indicator for all countries is beyond five measures for a period of six years.

Finally, we could use 21 countries to validate the convergence of the state model and 27 countries to measure the contribution of the predictive function of the model to attend the aims of estimating the missing measurements and system evolution simulation for assistance to the "e-strategy" formulation.

Inputs of the state equation

The state model we proposed has a transition matrix RIM which needs the impact matrix (α_{ij}) and the indicators local maximum values vector to be set. Table 1 bellow indicates the set of selected indicators, their classification into the different layers and their "maximum" values (based on 2010 measures):

Table 1: Selected Set Of Indicators, Their Classification And Maximum Values

N°	Indicator	Layer	Max
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	I	57

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	computer network for purchases (at least 1%)		
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 Layer, I: Intermediate Layer, B: Basic Layer

To define the maximum value (local maximum for the study period) for intermediate and target indicators, we consider that an indicator can grow to the actual local maximum value plus a potential growing range of around 10% per annum if the values are high (near 100%) or about 5 points per year if values are low. Then, the maximum value used to calculate the RIM is the minimum of:

- 100%,
- actual maximum value multiplied by 1.1 and rounded up (per year),
- actual maximum value plus (1 * 5) and rounded up to "number 5" multiples (per year).

Also, we notice that the actual maximum value is set after eliminating the last quintile of countries measures to remove aberrant and extreme values. If we take as an example the first indicator, the top ranked country is at "32.2" and the second country is at "9.1", while the European average is less than 5. This technique could eliminate the outlier of 32.2 which is clearly an imprecise data since this indicator of the concerned country is close to the value "3" from 2007 to 2009.

Table 4 (annex 2) concerns the relative weights of the indicators impacts. The Impact Matrix is obtained by transforming this matrix into a stochastic matrix dividing each cell by the sum of its corresponding line.

Like the indices conceptual framework construction, this impact matrix is an expert work reflecting a certain understanding of the relationship between indicators related to new technologies. This expert work is needed in this area since the lack of long series of measurements makes machine learning techniques difficult to exploit. Also, it should be remembered this matrix is not a purpose in itself. Its purpose is to be an input into the model to assess its capacity to cover the need of measures estimation and prediction. The results, presented bellow, seem to be promising and encouraging to go further in this way.

State Model Convergence

To perform the validation of our model convergence using the Kalman filter, we have developed the algorithm below:

- Importing model inputs
- Measures Treatment: interpolation, standardization, injection of white noise,
- Kalman filter inputs construction:
  - Initialization matrix: To test the model robustness to the initialization values, we initialized the system by outlier values: "5" for the evolution measure and 1 for the error covariance (P0).
  - Transition matrix calculation,
  - Constants matrices calculation on the basis of the measured basic indicators evolutions,
  - Model and measurement process noise covariance matrices:

  For these matrices, we adopted a strategy where measurement process noise "r" is equal to 0.9 giving more importance to the model to confirm the convergence of the filtering function.

- A loop for the Kalman Filter and smoothing functions execution and transition matrices recalculation on the basis of the last estimated values,
- For each indicator, plotting the curves of the input measures and the ones reconstructed from the filtered measures evolutions.

Figures 2 and 3 below are examples of the outputs. We specify in the title of each figure: the concerned country (ies) and/or the relevant indicators, and the filter initialization values. The blue curve represents the actual noisy measurements evolutions and the red curve represents the output of Kalman filtering based on our state model. These figures show a rapid convergence of the model based on measurements evolutions.

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To evaluate the model convergence, we compare the indicators measures reconstructed from the filtered measures evolutions and the indicators measures observed. Overall, the error distribution at the last observation for 420 cases (20 indicators and 21 countries) is as follows: for 384 (92%) cases the error is less than 1%, for 17 cases (4%) the error is slightly greater than 1% and 17 cases (4%) where the error is greater than 1.5%. A maximum of 7% is reached for the indicator N° 4 and the CY (Cyprus) country. For this case, we find that the extent of the indicator, even after normalization, is between 6 and 7 when all other countries range from 30 to 100. This makes the measurement of the indicator low and the error of about 0.4 (7%) is equivalent to the injected noise values range.

Thus, we consider that the convergence of the model is established for more than 96% of the 420 case of the panel. Also, we notice that the convergence occurs between the third and sixth filter iteration.

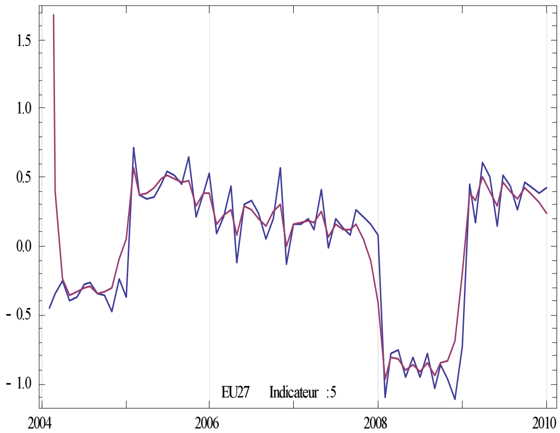

Figure 2: Evolutions Filtering Convergence: EU-Ind: 5 - Init-EV$_0$5-P$_0$1-R0.9

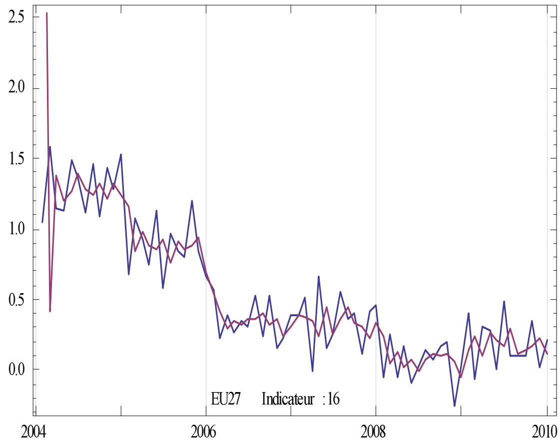

Figure3: Evolutions Filtering Convergence: EU-Ind:16 - Init-EV$_0$5-P$_0$1-R0.9

IV. PREDICTION FUNCTION FOR ASSISTANCE IN THE E-STRATEGY FORMULATION AND MISSING MEASURES ESTIMATION

To assess the contribution of the model's predictive function, we have proposed to make measurements prediction on a period of three years (minimum strategy cycle) and compare the obtained prediction with the observed measurements of the year 2010. For this purpose, we have identified an indicator for which no one of its impacting indicators have been changed (indicators definition or measurement method). The indicator 6: "Regular Users of the Internet" reported to the population is the only one to fulfill this requirement. Thus, we proceed in two steps:

- Period from 2004 to 2007: we use filtered measures,
- Period from 2008 to 2010: we use the measures of basic indicators that impact indicator No. 6 to predict its measures. The evolutions of these basic indicators represent the commands previewed to be injected in the system as simulation scenario.

To calculate the transition matrices, we proceed by iterations where each prediction is injected in the inputs data for the next iteration (Kalman prediction with step equal to 1). Also, would be remembered that the optimal values chosen for this test are based solely on measurements from 2004 to 2007. This process is applied to a panel of 27 countries for which measures are available. The curves for the

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prediction of the indicator N ° 6 for these 27 countries are presented in Annex 3.

The analysis of the deviations between the indicator measure and prediction of 2010 can distinguish four groups of countries:

1. Countries where the absolute value of the error is less than 5%: This group includes 17 countries (63% of cases), 12 of which are at less than 3%.

2. Countries for which the predicted measures converge to less than 5% compared to the same indicator measures issued by IWS (Internet World Stats). These countries are France and Poland. The last column of Table2 contains the difference between predicted values and IWS values. Regarding the low differences observed, we believe that the i2010 measurements are corrected by the prediction.

Table 2: Gaps Compared With IWS Measures (FR And PL)

Country	I2010	Prediction	Internet WorldStats	Gap/IWS
France	76	70,3	69,5	1,15%
Poland	54,15	58,9	58,4	0,09%

3. Countries for which the prediction converges when it starts before 2007. For these countries, we believe that the starting measure of the prediction period (2007) is not accurate: the convergence to less than 5% is established with a prediction of 4 years starting from 2006. The most obvious case is that of Sweden where the convergence of the prediction starting from 2006 is less than 1% (figure 4).

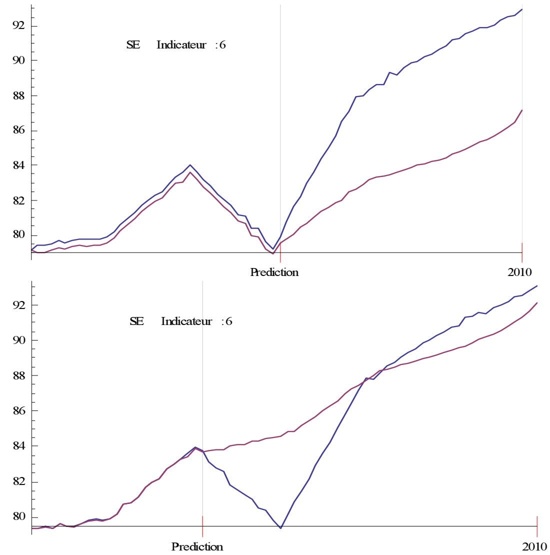

Figure 4: Measures And Predictions Curves: SE – Ind: 6- Starting 2007 (Resp 2006)

This group includes, in addition to Sweden, Belgium, Lithuania and Hungary. Ireland joins the group converging to less than 1% with prediction starting from 2005 over a period of 5 years where the values have almost doubled over a range exceeding 30 units.

4. The last group includes the remaining countries: Italy, Slovakia and the United Kingdom (UK). For Italy, we can see on the graph in the figure below that convergence is established in 2008 and 2009 but the prediction curve "runaway" in the last year. This is due to the fact that indicator No. 19 "Availability of Internet public services for citizens", which impacts the indicator No. 6, evolves from 50 in 2009 to 100 in 2010. This fact can be seen as a weakness of the model that does not handle the evolutions propagation delay and especially those having significant amplitude. For Slovakia and the UK, we did not detect any abnormality in the measurements.

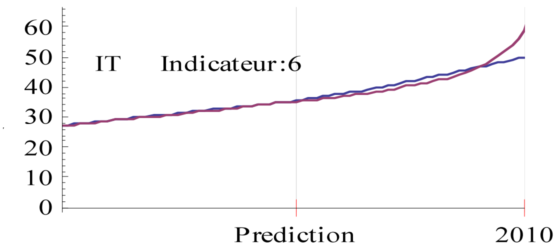

Figure 5: Measures And Predictions Curves: IT – Ind: 6

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Thus, the first three groups of countries for which the prediction model shows encouraging results include 24 countries or 89% of the 27 countries studied. We believe that this prediction approach can have an added value to the two aims of this work: 1) provide a simulation tool to assist decision makers who formulate their e-Strategy, 2) provide a new approach for missing measures estimation of intermediate and target indicators.

V. CONCLUSION

The e-strategy process is based on two major steps: measuring the ICT index (e-Readiness) and the e-Strategy formulation. In this work we set two main aims: 1) to propose an approach for the e-strategy formulation assistance based on e-Readiness measurements, 2) to propose a new approach for missing measures estimation adapted to the e-Strategy context.

Based on the state equation proposed in [3], the measurable indicators are assimilated to dynamic system characteristics. Then a layered classification associated with the relative impact concept could lead to the construction of a state model linking the evolutions of these indicators. Thus, the problem of estimation and prediction of indicators measures is moved to estimation and prediction of indicators measures evolutions (system speed). In this paper, we proposed an approach for the state model transition matrix definition and the process to use the Kalman filter estimation and prediction functions to build an e-Readiness evolution simulator.

For the validation of our approach, we used data from the European Union I2010 initiative that remains the only available database of e-Readiness indicators measures. We first proposed a state model (indicators classification and impact matrix definition) and established its convergence. Then, the predictive function of the model was tested on an intermediate indicator whose impacting indicators set remained stable over the period of measurements availability. This estimation and prediction approach shows encouraging results where 24 countries (89% of the 27 countries of the panel) show convergence within 5% of indicator 2010 measurement value. However, our approach does not take into consideration acceleration or saturation phenomena that can absorb the effects of a rapid or sudden evolution in the indicators measurements. This weakness represents a track to improve our approach.

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VI. ANNEXES

VI.1. Annex 1: Main E-Readiness Calculation Initiatives Measurement Database Comparison

Table 3: Main E-Readiness Calculation Initiatives Measurement Database Comparison

Approach / Organism	States / Indicators	Measures availability and missing data handling
e-Readiness rankings EIU-IBM	S :70 / I : >100	Only the values of the six areas of analysis are published in the annual report. The data sources are published and are mainly the same that those used by the other approaches (UN, IMF, ITU …)
IDI ITU : International Telecom Union	S :157 / I :11	Annual measures are available in the reports. Missing values are estimated by comparison with similar countries (HotDeck). The portion of measurements estimation of certain indicators or countries are estimated is about 80%. The 2010 report includes data for 2008. A more global set of indicators measures database is available for sale.
ISI / IDC	S :53 / I :15	Annual measures are proposed in the for sale report. No DB measures since launch. A consultation tool is available online but includes 2004 data
I2010, EU: European Union	S :29 / I :52	The complete DB is published as ready to use DB format. Data sources and surveys are provided. Scope and definition changes that may affect the analysis of the measures time series are explicit. Some measures are missing but no method is cited for their handling.
NRI WEF & INSEAD	S :144 I :54	The measures are published in the annual report. The last available measure is used for missing data. These measures can date since 2009. There is no DB dedicated for measurements since launch.
UN e-Gov Development Index United Nation	S :193 I :10	The measures are published in the annual report. An interactive tool is available online to view the results by region, country or the analysis axis chosen for a selected year. The results can be exported to Excel which would be a DB. No missing data (the set of indicators and the measurement process are adapted not to have missing data). (One indicator is a sub-index measured through large surveys)

VI.2. Annex 2: Selected Indicators Impact Matrix With Relative Weights

Table 3: 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
…																				
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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VI.3. Annex 3: Indicator N° 6 Prediction Curves

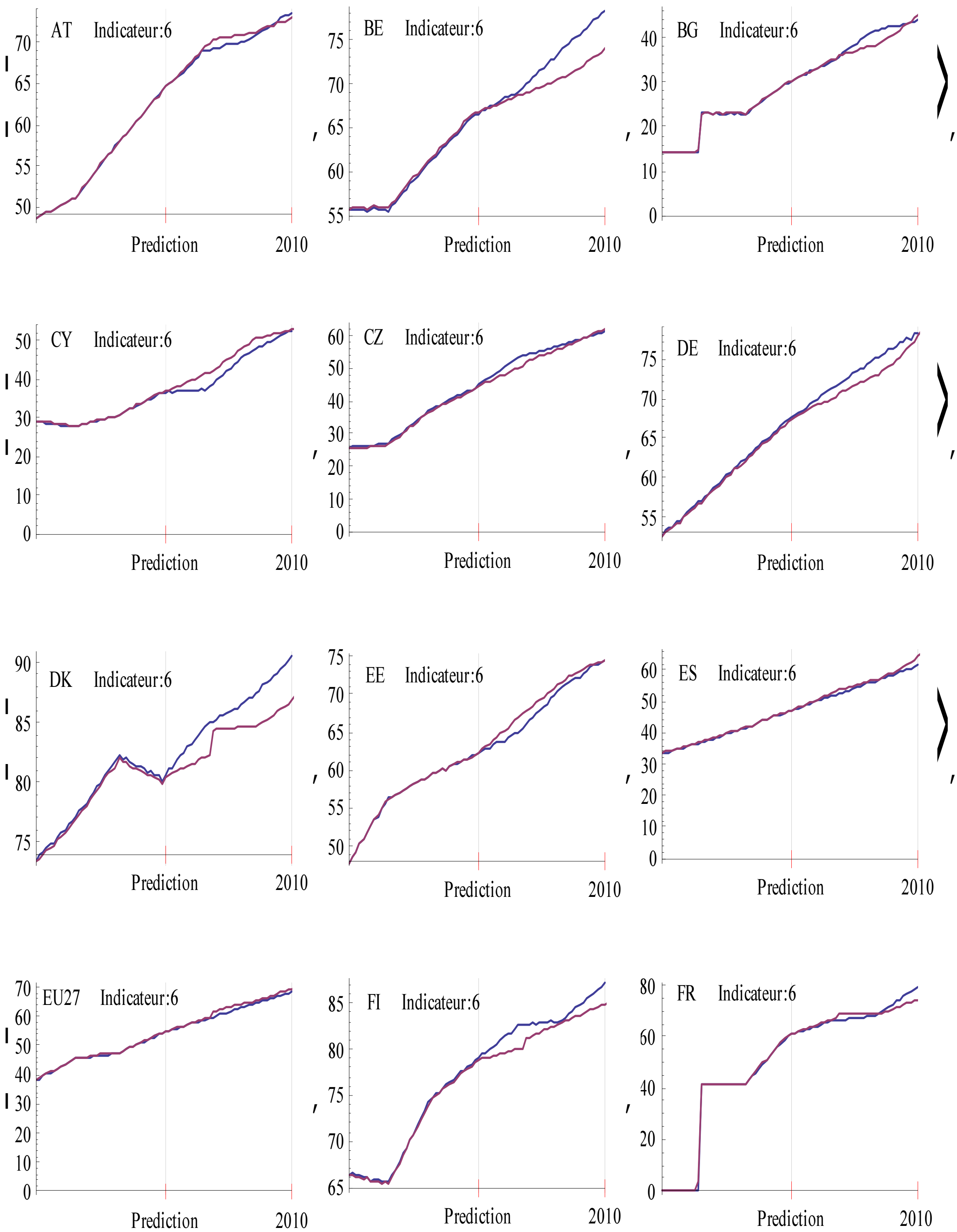

Figure 6: Prediction Curves: Countries: All – Ind : 6 - (1)

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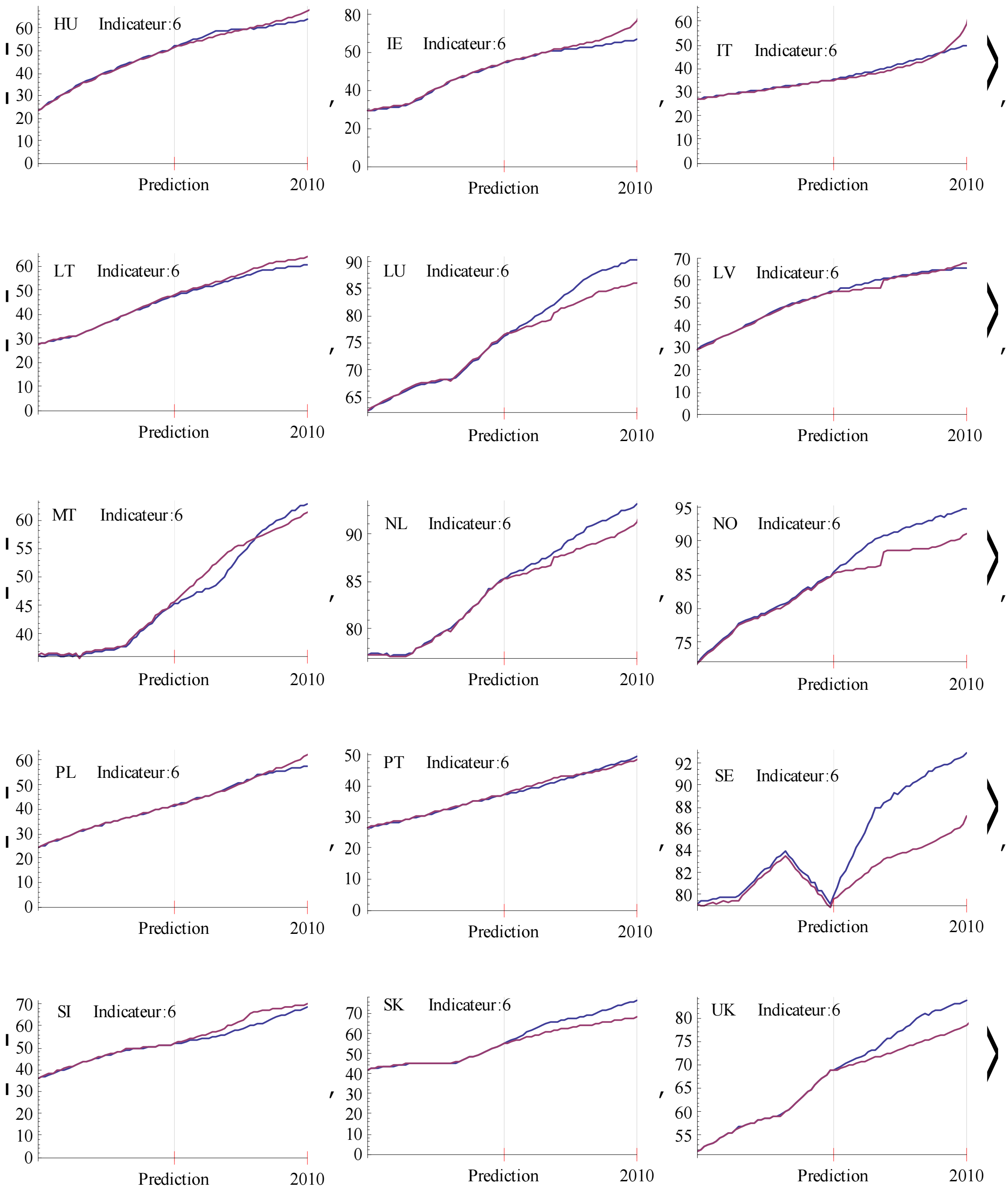

Figure 7: Prediction curves: Countries: All – Ind : 6 - (2)