Dynamics Modeling of the Educational System

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Abstract- *This work proposes a modelling process of the dynamics of the educational system as a complex system. In fact, the educational system is a system which is self-organized, and it is characterized by a non-stationary dynamics. This results in the difficulty to proceed to a rational modelling that would allow an accurate prediction of its behaviour in response to a given decision. Therefore, the modelling process of the dynamics of the educational system focuses more on how change happens within the system. In this process we consider the state of the educational system at any time* t_k *that we note* $E_S^{t_k}$ *as the overall distribution of the number of students by levels and cycles of education. The objective is to calculate the transition of the state of the system from a known state* $E_S^{t_k}$ *to the next state* $E_S^{t_{k+1}}$*; this transition of the state is conditioned by the flow parameters and the schooling parameters whose variation implies that of the dynamics of the educational system. To account for the difficulty of making accurate prediction about flow parameters, the model must allow prospecting various scenarios based on different hypotheses about these parameters. To validate our model, we would like to implement it to the case of primary education of Moroccan system about which we have enough information on the decade between 2002-2003 and 2012-2013. The validation is performed by comparing simulation / reality on this period.*

Keywords- *Modeling; Forrester approach; educational system; complex system; system dynamics*

1. INTRODUCTION

"Educational system" is an expression used with ease in common speech; everybody feels concerned about the "educational system" and everyone can build his own mental representation about the meaning of this expression that can carry. "In such a big organization as the education system, the interrelationship between the various components is also important to consider that the sum of its parts is taken individually" [1]

The educational system is multidimensional and has many points of view; it supports a variety of levels of control and regulation: pedagogical, administrative and political. It is a complex system, self-organized [2] and it is characterized by a non-stationary dynamics. This results in the difficulty to proceed to a rational modeling that would allow an accurate prediction of its behaviour in response to a given decision. Attempts to its modelling by reduction or partitioning could amplify its complexity [3] and would only lead to representations that are parcelled out and incomplete. In the modelling process of the educational system, we should take more interest in how changes occur within the system and therefore seek to understand all possible contingencies of future development of its dynamics. Considering such a system, the effects of decisions are part of the long-term ones, involving masses of people (students, parents, teaching and non-teaching staff...), and they cover a territory in the size of a country, and since its dynamic is affected by the impact of its self-organization and its sensitivity to unpredictable vagaries. Modelling dynamic systems according to Forrester approach would be well suited for this type of system. This model would not claim to predict the exact behaviour of the educational system in response to a particular decision, but just to answer questions like "What would happen if?"[5]; the model in this context allows understanding and intelligibility of the system [6].

In this article, within the framework of modelling the dynamics of the educational system, we are interested in developing a model of simulation based on the Forrester Approach (Stock-Flow) that we will apply to the case of the Moroccan education system for purposes of comparison and validation.

2. MODELING PARAMETERS

In general, the management of an educational system consists in coordinating the flow of students between different levels in different education cycles while ensuring optimal distribution of human and material resources in accordance with the educational objectives expected of the system. The distribution of the students by level and by educational cycle is the core element in the modelling process. The knowledge of this distribution can deduce the needs in teaching and non-teaching staff, in classrooms, in equipment and school textbooks. If necessary, it can be used for simulation of the overall budgetary impact of a given educational policy. The drawing (Figure 1), shows a principle of flow chart to design an education policy and strategy simulation model proposed and used by the UNESCO [7].

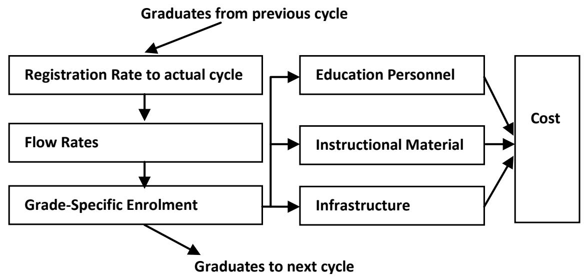

Figure 1 : Flow chart used in EPSSim (UNESCO)

In the drawing (Figure 2), a transition (t_k ⇨ t_{k+1}) corresponds to the mobility of the students' number $E_i^{t_k}$ from the instant t_k to the instant t_{k+1} as a promotion $P_{i+1}^{t_k}$ to a higher level (*i+1*), a repetition $R_{i+1}^{t_k}$ of the same level or a dropout $D_i^{t_k}$ of the school in level (*i*).

Flow parameters represent the dynamic characteristics of the system and also represent indicators of its internal performances; that is to say, its fluidity (repetition rate), its attractiveness (dropout rate) and efficiency learning (promotion rates). These flow parameters are used to calculate, from the number of newcomers in an education cycle, the distribution of students in each level. Requirements in education personal, Instructional material, and infrastructure, for an education cycle are determined from the Grade-specific enrolment which is the total of students enrolled in this cycle.

The model must allow in a first step to estimate number of newly enrolled in the specific cycle, and to calculate the student distribution. In second step, it must permit to deduce human and material requirements, and in third step, 'not including in this article', the model must permit to estimate the resulting cost for maintaining the balance between student / personal / infrastructure on various cases of system evolution.

2.1 Graphical modeling of flows

The student's mobility is symbolized by arrowed lines of flow (Figure 2) where the origin of the arrow corresponds to school year t_k, and its end to the following school year t_{k+1}. Each flow line is labelled by the type (*promotion rate* $p_i^{t_k}$, *repetition rate* $r_i^{t_k}$ *or dropout rate* $d_i^{t_k}$,) and the transfer rate that it supports during the transition (t_k ⇨ t_{k+1}). Transition (t_k ⇨ t_{k+1}) corresponds to the mobility of student population $E_i^{t_k}$ from school year t_k to school year t_{k+1}.

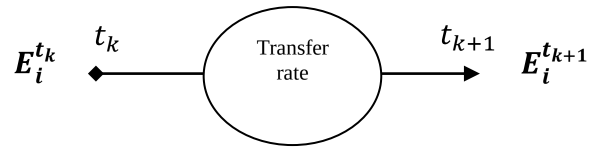

Figure 2 : A flow line (t_k ⇨ t_{k+1})

The arrow diagram in Figure 3 shows the development of enrolments $E_i^{t_k}$ in school levels during the transition (t_k ⇨ t_{k+1}) depending on flow parameters.

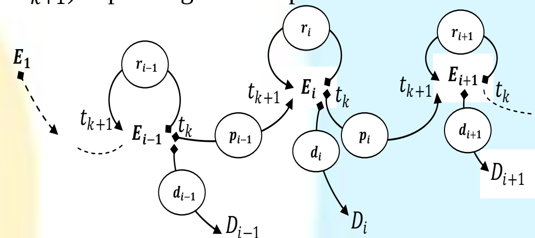

Figure 3 : evolution between school levels

The diagram in Figure 4 shows both a transition time and transition levels, to better highlight these two dimensions of the system dynamics, it is the arrow diagram of a more explicitly distinguishing changes in levels of the time in a two-dimensional representation (Levels / time).

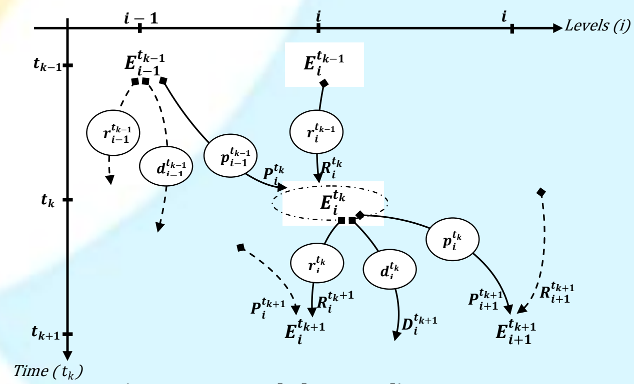

Figure 4 : extended arrow diagram

The compartment $E_i^{t_k}$ "number of pupils in the level i at the year t_k " receives two inflows lines and emits three outflows lines.

- Inflow lines are $R_i^{t_k}$ line of repeaters students in the same level *(who were at the same level last year and remain there this year)*, and line $P_i^{t_k}$ of students promoted from lower level (i-1) of the previous year (t_{k-1}).
- Outflow lines are $D_i^{t_{k+1}}$ of students in the level *i* who left school during the year t_k *(who were enrolled in (i) in year (t_k) and who do not show up the following year (t_{k+1}))*, and line $P_{i+1}^{t_{k+1}}$ of students promoted to the next level (i +1) for the next school year (t_{k+1}).

The number of students $E_i^{t_k}$ in the level (i) in the year t_k is the sum of repeaters $R_i^{t_k}$ and the students who are promoted from the lower level $P_i^{t_k}$ of the previous year: $E_i^{t_k} = R_i^{t_k} + P_i^{t_k}$. Indeed, the status of a "repeater" or a "promoted" to a year t_{k-1} does not take effect until the following year t_k. $R_i^{t_k}$ is a proportion of $E_i^{t_{k-1}}$, and $P_i^{t_k}$ is a proportion of $E_{i-1}^{t_{k-1}}$. During the transition $(t_{k-1} \Rightarrow t_k)$, the E_i compartment will cumulate the actual inflowing $E_{i-1}^{t_{k-1}} * p_{i-1}^{t_{k-1}}$, and the residual contents in place $E_i^{t_{k-1}} * r_i^{t_{k-1}}$ then it will keep the resulting $E_i^{t_k}$ content until the next transition.

$R_i^{t_k} = E_i^{t_{k-1}} * r_i^{t_{k-1}}$ *(Residual)*

$P_i^{t_k} = E_{i-1}^{t_{k-1}} * p_{i-1}^{t_{k-1}}$ *(Inflowing)*

$$E_i^{t_k} = E_{i-1}^{t_{k-1}} * p_{i-1}^{t_{k-1}} + E_i^{t_{k-1}} * r_i^{t_{k-1}} \qquad (1)$$

The distribution of students in the system S $E_S^{t_k} = \left(E_1^{t_k}, \dots, E_{i-1}^{t_k}, E_i^{t_k}, E_{i+1}^{t_k}, \dots, E_n^{t_k}\right)$ during the range of inter-transition $[t_k, t_{k+1}[$ forms the state $E_S^{t_k}$ of this system at one time t_k in which the terms $E_i^{t_k}$ represent these variables of the state of the same system [7]. Our objective is to be able, from a known state $E_S^{t_{k-1}}$ of the system S at one time t_{k-1}, to predict its future state $E_S^{t_k}$ at any time t_k :

$$E_S^{t_{k-1}} = \left(E_1^{t_{k-1}}, \dots, E_{i-1}^{t_{k-1}},\ E_i^{t_{k-1}},\ E_{i+1}^{t_{k-1}}, \dots, E_n^{t_{k-1}}\right)$$

$$\Downarrow$$

$$E_S^{t_k} = \left(E_1^{t_k}, \dots, E_{i-1}^{t_k}, E_i^{t_k}, E_{i+1}^{t_k}, \dots, E_n^{t_k}\right)$$

To calculate the individual development of all state variables, $E_i^{t_{k-1}} \Rightarrow E_i^{t_k}$ we need to know $(E_{i-1}^{t_{k-1}}, p_{i-1}^{t_{k-1}})$ *and* $(E_i^{t_{k-1}}, r_i^{t_{k-1}})$ *at* t_{k-1}. The general equation (1) is a recurrent equation in which the term $E_{i-1}^{t_{k-1}}$ is a problem for the calculation of the first year pupils in primary school $E_1^{t_k}$, because it uses $E_0^{t_{k-1}}$ while the 0 level does not exist in the system.

2.2 Enrolment in first grade of education

With regard to the first grade, the newcomers are neither promoted from a lower level nor in a transition from a lower cycle. They are new recruits in the education system about which we do not have enough information of the schooling. Promotion and transition parameters between cycles give way to the intake parameters. This data is not internal data to the school system; it must look for them in the institutions and organizations specialized in the demographic issue.

For calculating new intakes into first primary level for a year t_k, it needs to have data about a part ($P_a^{t_k}$) of children in official school intake age *(a)*. The Gross Intake Rate (GIR^{t_k}) is a total number of new entrants in the first level of primary education, regardless of age, expressed as a percentage of the population at the official school intake age ($P_a^{t_k}$).

The figure 5 is a part of Flow chart proposed by UNESCO; in the *"Education Policy & Strategy Simulation Model (EPSSim)"*.it shows how to calculate the number of new enrolled in first level of primary education.

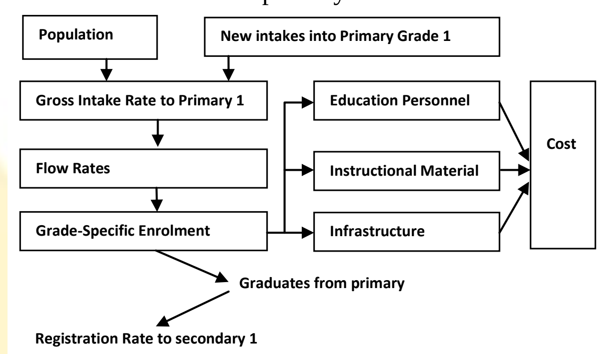

Figure 5: Enrolment in first grade of education

The knowledge of this population $P_a^{t_k}$ for a year t_k allows associating the admission parameters to estimate the likely proportion $N_{total}^{t_k}$which is calculated in relation to this population that would be at school in the first year, primary year t_k.

The gross intake rate GIR^{t_k} represents the relationship between the total number $N_{total}^{t_k}$ of new entrants in the public and private education compared to the population $P_a^{t_k}$ with an official entry age to the first year of primary school.

$GIR^{t_k} = N_{total}^{t_k} / P_a^{t_k}$ So, total intake $N_{total}^{t_k}$ is,

$$N_{total}^{t_k} = P_a^{t_k} . GIR^{t_k} \qquad (2)$$

2.3 Newly enrolled in public schooling

In this work we seek to model the education system in its public component. The private education has a different reality from a quantitative and qualitative point of view, and its management system differs from that of public education. For this reason, in the following, the modeling is restricted to public component of the system.

For a year $\boldsymbol{t_k}$, the entire school population is divided into public and private education. We agree to designate the part of the educated population in private schools compared to all of the school population by the rate $\tau_p^{t_k}$. $N_{private}^{t_k}$ is the share of students in private schools and N^{t_k} is the share of public education ($N_{total}^{t_k} = N^{t_k} + N_{private}^{t_k}$).

$$\tau_p^{t_k} = P_{a,private}^{t_k} / P_a^{t_k}$$

$$\rightarrow P_{a,private}^{t_k} = \tau_p^{t_k} * P_a^{t_k}$$

$$\rightarrow N_{private}^{t_k} = \tau_p^{t_k} * N_{total}^{t_k} \qquad (3)$$

$$\rightarrow N^{t_k} = (1 - \tau_p^{t_k}) * N_{total}^{t_k} \qquad (3')$$

Finally the number of newly enrolled in the first grade in the public schooling is:

(2) & (3) $\rightarrow N^{t_k} = \left(1 - \tau_p^{t_k}\right) * P_a^{t_k} * GIR^{t_k}$ (4)

And the overall number $E_1^{t_k}$ of students enrolled in the first grade is the sum of newly enrolled N^{t_k} and repeaters $R_1^{t_k}$:

$E_1^{t_k} = N^{t_k} + R_1^{t_k}$

$\rightarrow E_1^{t_k} = N^{t_k} + r_1^{t_{k-1}} * E_1^{t_{k-1}}$ (5)

2.4 Transition between cycles

The transition $TR_h^{t_k}$ from *(h)* cycle to *(h+1)* cycle represents the share of the student population promoted $\boldsymbol{P_{h+1,1}^{t_k}}$ to the last level (n) of the cycle (h) and admitted to the first level of higher cycle ***h+1*** in the $\boldsymbol{t_k}$ year. The last level of the last cycle is of a particular interest since the graduates at this level leave the system and have to be subtracted from the overall student headcount. Every year t_k, a number $\boldsymbol{N^{t_k}}$ of new entrants in the first year of primary level are added to the overall student headcount $E_G^{t_{k-1}}$ in the education system. On the other hand, the number of students who leave school at all levels of the system $D_S^{t_k}$ and students who have completed successfully their education in the last level of the last cycle $TR_h^{t_k}$ are subtracted from the total of students' number (figure 6).

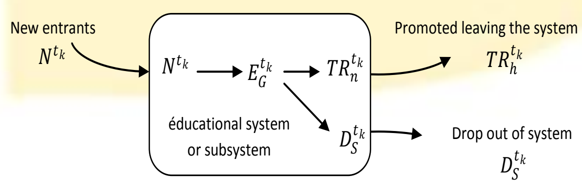

Figure 6:transition between cycles

$$E_G^{t_k} = N^{t_k} + E_G^{t_{k-1}} - D_S^{t_k} - TR_h^{t_k} \quad (6)$$

By considering the following rates,

$d_S^{t_k} = D_S^{t_k} / E_G^{t_{k-1}}$ Dropout average rates

$tr_h^{t_k} = TR_h^{t_k} / E_G^{t_{k-1}}$: Transition rate to higher cycle

The equation (6) becomes,

$$E_G^{t_k} = N^{t_k} + E_G^{t_{k-1}}(1 - d_S^{t_k} - tr_h^{t_k}) \quad \textbf{(7)}$$

The overall number of students $E_G^{t_k}$ at time t_k can also be obtained from $E_G^{t_{k-1}}$ by two methods.

1. Using cycle transition rate and dropout average rate parameters in equation (4) & (7)
2. Summing numbers of students in all cycle levels by using equations (1) & (5)

$E_G^{t_k} = E_1^{t_k} + \cdots + E_{i-1}^{t_k} + E_i^{t_k} + E_{i+1}^{t_k} + \cdots + E_n^{t_k}$

$E_G^{t_k} = \sum_{i=1}^{n} E_i^{t_k}$ *Wherein n is number of the last level*

2.5 Required teaching staff: $\boldsymbol{Tr_h^{t_k}}$

Teachers are defined as persons whose professional activity involves the transmitting of knowledge, attitudes and skills that are stipulated in a formal curriculum program to students enrolled in a formal educational institution [7]. To dispose the overall student number in a given cycle, can allows deducting required number of teachers for this cycle. There are two methods can be used for this operation: a method based on the students-teacher ratio, used most frequently for primary education and a method based on the number of students by class and hours taught by teachers, this second method is most frequently used for the levels and cycles of education other than primary education.

2.5.1 Method based on student-teacher ratio

a) Student/teacher ratio $\boldsymbol{str_h^{t_k}}$:

The ($str_h^{t_k}$)is the average number of students (pupils) per teacher in a cycle (h) at school-year (t_k), its obtained directly by dividing the total number of students enrolled in a specific cycle (h) by the number of teachers at the same cycle. When having the initial ratio $str_h^{t_0}$ relating the reference year t_0 and its annual growth rate τ_{str}, it's possible to calculate $str_h^{t_k}$ by recurrence.

Direct calculation

$$str_h^{t_k} = E_h^{t_k} / T_h^{t_k} \quad (7)$$

Recurrent calculation

$$str_h^{t_k} = str_h^{t_0} + \tau_{str} * t_k \quad (8)$$

$E_h^{t_k}$: Total number of pupils or (students) at cycle of education *h* in school-year t_k

$T_h^{t_k}$: Total number of teachers at cycle of education *h* in school-year t_k.

str_h^0= initial pupil-teacher ratio

τ_{str} = constant annual rate change of pupil-teacher ratio

b) Teacher requirements$\boldsymbol{Tr_h^{t_k}}$

$$Tr_h^{t_k} = E_h^{t_k} / str_h^{t_k} \quad (9)$$

Where

$Tr_h^{t_k}$= number of full-time equivalent teachers required

$E_h^{t_k}$= total projected number of students

$str_h^{t_k}$ Student-teacher ratio

2.5.2 Method based on class-hours per week

In this case is taken, for direct calculating, the average of students per class $c_h^{t_k}$; if $C_h^{t_k}$ is de overall number of classes in the considered cycle at time t_k :

$c_h^{t_k} = E_h^{t_k} / C_h^{t_k}$ (10)

But in projection mode, when we must calculating from initials values obtained at reference year t_0 and calculate for each t_k , the relating average number of students per class of $c_h^{t_k}$

$c_h^{t_k} = c_h^{t_0} + \tau_{sc,h} * t_k$ (11)

Where

$c_h^{t_0}$: is the number of students per class at reference year t_0

$\tau_{sc,h}$: is a constant annual rate change of average number of students per class

a) The required teaching staff: $Tr_h^{t_k}$

Total overall weekly number of hours for learning is $H_{s,h} = C_h^{t_k} * h_{s,h}$ and the overall hour number of teaching is $H_{T,h} = Tr_h^{t_k} * h_{T,h}$. logically, in normal situation the teaching duration is the same as the leaching duration then:

$$C_h^{t_k} * h_{s,h} = Tr_h^{t_k} * h_{T,h} \quad (11)$$

$$Tr_h^{t_k} = C_h^{t_k} * h_{s,h}/h_{T,h} \quad (12)$$

$$(10)\rightarrow(12):\ Tr_h^{t_k} = (E_h^{t_k} * h_{s,h})/(c_h^{t_k} * h_{T,h}) \quad (13)$$

Where:

$h_{s,h}$: *Average number of weekly hours per student*

$h_{T,h}$: *Average number of weekly hours per full-time teacher*

New teachers required at the following year t_{k+1}

$$NTr_h^{t_{k+1}} = Tr_h^{t_{k+1}} - ATr_h^{t_{k+1}} \quad (14)$$

Where:

$NTr_h^{t_{k+1}}$: *New teachers required at year* t_{k+1}

$ATr_h^{t_{k+1}}$: *Available teachers at year* t_{k+1}

New teachers required at t_{k+1} by category j

$$NTr_{h,j}^{t_{k+1}} = NTr_h^{t_{k+1}} * \delta_j^{t_{k+1}} \quad (15)$$

Where:

$NTr_{h,j}^{t_{k+1}}$: *New teachers required of category j*

$\delta_j^{t_{k+1}}$: *Rate of new teachers in the category j*

2.6 Classroom requirement $Cr_h^{t_k}$

To dispose the overall student number in a given cycle, can allows deducting required number of classrooms for this cycle. There are two methods can be used for this operation: a method based on the students-classroom standard ratio, used most frequently for primary education and a method based on the weekly learning hours and classroom-usage hours, this second method is most frequently used for the levels and cycles of education other than primary education.

2.6.1 Method based on student-classroom ratio

Standard student per classroom $sscr_h^{t_k}$: $sscr_h^{t_k}$, is the standard student per classroom ratio, it represents the maximum of student number for which a classroom is normally designed.

Total classroom required: Is the necessary classrooms number $Cr_h^{t_k}$ to receive a total $E_h^{t_k}$ of students in the cycle h at year t_k.

$$Cr_h^{t_k} = E_h^{t_k}/sscr_h^{t_k} \quad (18)$$

New classroom requirement

Two reasons for building new classrooms: The first reason is to replace olds and defected classrooms $NC_{h,replace}^{t_k}$, the number of classrooms to built is predefined with an annual replacement rate of buildings (a).

$$NC_{h,replace}^{t_k} = a * E_h^{t_{k-1}} \quad (19)$$

The second reason is to compensate the change of student number $NC_{h,comp}^{t_k}$.

$$(18)\rightarrow NC_{h,comp}^{t_k} = (E_h^{t_k} - E_h^{t_{k-1}})/sscr_h^{t_k} \quad (20)$$

The total requirement of new classrooms is obtained by summing replacement and compensation builds.

$$NC_h^{t_k} = NC_{h,replace}^{t_k} + NC_{h,comp}^{t_k} \quad (21)$$

$$NC_h^{t_k} = (E_h^{t_k} - (1-a) * E_h^{t_{k-1}})/sscr_h^{t_k} \quad (22)$$

Method based on class-hours per week.

As for the secondary and higher levels of education, classroom requirements are calculated by taking into account the number of weekly learning hours and laboratory-usage hours as well.

Standard classroom time utilization:

$sctu_h^{t_k}$, is the standard weekly time during which different category of classroom is used.

So, $scru_{h,j}^{t_k}$ is the related weekly utilization time for a specified category *(j)* of educational space.

Total classroom requirement:

Weekly time needed by each teaching category $ctul_{h,j}^{t_k}$ associated to related number of groups $NG_{h,j}^{t_k}$ in each category, it's possible to deduct the requirement in classroom by category.

$$Cr_{h,j}^{t_k} = ctul_{h,j}^{t_k} * NG_{h,j}^{t_k}/ scru_{h,j}^{t_k} \quad (23)$$

New classroom requirement

For same reasons as primary schools, calculating the new educational space $NC_{h,j}^{t_k}$ for a category (j) must take account to annual replacement rate of buildings (a_j) and the evolution of the student number:

$$NC_{h,j}^{t_k} = NC_{h,j,replace}^{t_k} + NC_{h,j,comp}^{t_k} \quad (24)$$

$$NC_{h,j}^{t_k} = (NG_{h,j}^{t_k} - (1-a_j) * NG_{h,j}^{t_{k-1}})/sscr_h^{t_k} \quad (25)$$

3. BUILDING THE SIMULATION MODEL

This section summarizes and synthesizes the main steps of building a simulation model of the evolution of the number of students in an educational system for validation we choose to compare the results to real case of the Moroccan system.

3.1 First step: reference data identification

The last year, for which there is enough school information, is considered as a reference year t_0 in the simulation process, the state $E_S^{t_0}$ at t_0 represents the initial state of the system S. Flow parameters at the initial state are also transition parameters from the previous state E_S^{t-1} to the current state $E_S^{t-1} \rightarrow E_S^{t_0}$, hence the need of knowing the state before at t_{-1}

$$.E_S^{t_0} = (E_1^{t_0}, \dots, E_{i-1}^{t_0}, E_i^{t_0}, E_{i+1}^{t_0}, \dots, E_n^{t_0})$$

$$E_S^{t-1} = (E_1^{t-1}, \dots, E_{i-1}^{t-1}, E_i^{t-1}, E_{i+1}^{t-1}, \dots, E_n^{t-1})$$

Promotion parameters of the system
$p_S^{t_0} = (p_1^{t-1}, \dots, p_{i-1}^{t-1}, p_i^{t-1}, p_{i+1}^{t-1}, \dots, p_n^{t-1})$
Repetition parameters of the system
$r_S^{t_0} = (r_1^{t-1}, \dots, r_{i-1}^{t-1}, r_i^{t-1}, r_{i+1}^{t-1}, \dots, r_n^{t-1})$
Dropout parameters of the system
$d_S^{t_0} = (d_1^{t-1}, \dots, d_{i-1}^{t-1}, d_i^{t-1}, d_{i+1}^{t-1}, \dots, d_n^{t-1})$

Case of Moroccan system

In the Strategic Plan 2005-2020, the Moroccan kingdom has agreed to a set of hypotheses and objectives by taking 2003-2004 as the base year for calculation and simulation. In this project, enrolment targets should be achieved by 2015 [8], in accordance with the recommendations of the International Forum on Education Dakar 2000 [9]. We retain amongst these objectives and hypotheses-parameters, the following,

1. **Objective 1**: Allow 90% of students enrolled in first grade in 2003-2004 to reach the end of the primary cycle until 2010-2011.
2. **Hypotheses parameters**
   - The gross enrolment in 1st year of public and private primary education rate is assumed to remain at 105%.
   - The proportion of newly enrolled in the first year of private primary education is supposed to progressively increase from 8% in 2003-2004 to 14% in 2013-2014 to 20% in 2019-2020;

For Moroccan case, these parameters for reference year 2003/2004 are identified, and recapitulated in the following table (table 1). The flows parameters are calculated from these data. The schooling data in this table are taken from the Statistical Yearbook 2005, which is edited by the High Commissary to the Plan.

Tableau 1:Initial state of Moroccan system education at 2003-2004

	1st	2nd	3th	4th	5th	6th
E_i^{2003}	740582	738031	732026	653584	562677	457738
E_i^{2004}	697434	671562	709028	664718	594004	510204
p_i^{2003}	75,30	80,90	79,70	82,00	82,60	80,71
r_i^{2003}	16,80	15,40	15,30	12,50	10,30	09,90
d_i^{2003}	07,90	03,70	05,00	05,50	07,10	09,40
Total of pupils			384950			
Number of classes			132979			
Number of classrooms			89813			
Number of teachers			135663			
Teacher per class			1			
Pupils per teacher rate			28,36			
Class per classroom rate			1,48			

* Source: Statistical Yearbook 2005

3.2. 2nd step: newly enrollment in first primary level

$(2) \rightarrow N_{total}^{t_k} = GIR^{t_k} * P_a^{t_k}$
$(3) \rightarrow N_{private}^{t_k} = \tau_p^{t_k} * N_{total}^{t_k}$
$(3') \rightarrow N^{t_k} = \left(1 - \tau_p^{t_k}\right) * N_{total}^{t_k}$

In the case of morocco, the demographic projection is given by “Centre for Demographic Studies and Research” from 2001 to 2020. The (Table 2) shows a part of this projection with calculating the relating proportion of newly enrollment N^{t_k} in public education for each projected year.

Table 2: demographic projection P_a^t and new intakes N^{t_k}

Projection CERED		*Calculated*				
t_k	P_a^t	$N_{total}^{t_k}$	$1-\tau_p^{t_k}$	$\tau_p^{t_k}$	N^{t_k}	$E_1^{t_k}$
2003	**588000**	**638410**	**0,927**	**0,073**	**587976**	**740582**
2004	**590000**	**622399**	**0,921**	0,070	**573229**	**697434**
2005	592000	621600	0,915	0,081	568702	685871
2006	594000	623700	0,908	0,092	566819	682045
2007	593000	622650	0,907	0,093	562066	676359
2008	592000	621600	0,896	0,104	557327	670756
2009	589000	618450	0,895	0,105	550730	663250
2010	585000	614250	0,884	0,116	543243	654534
2011	580000	609000	0,878	0,127	534885	644749
2012	579000	607950	0,872	0,128	530254	638505
2013	582000	611100	0,866	0,134	529274	636512
2014	**584000**	**613200**	**0,860**	**0,140**	**527352**	634286
2015	586000	615300	0,850	0,150	523005	629565
2016	588000	617400	0,840	0,160	518616	624383
2017	590000	619500	0,830	0,170	514185	619081
2018	592000	621600	0,820	0,180	509712	613718
2019	594000	623700	0,810	0,190	505197	608302
2020	**596000**	**625800**	**0,800**	**0,200**	**500640**	602835

3.3 3th Step: total enrolment in first primary level

$$(5) \rightarrow E_1^{t_k} = N^{t_k} + r_1^{t_{k-1}} * E_1^{t_{k-1}}$$

Flow parameters for transition $2003 \rightarrow 2004$ given in table 1 are considered as reference parameters to the flowing calculating. Then $r_1^{t_k} = 0{,}168$ for each t_k

$At\ \ t_k = t_0 = 2004;\ E_1^{t_{2004}} = 697434$

$At\ \ t_1 = 2005;\ E_1^{t_{2005}} = \mathrm{N}^{t_{2005}} + \mathrm{r}_1^{t_{2004}} * \mathrm{E}_1^{t_{2004}};$
$\mathrm{E}_1^{t_{2005}} = 568702 + 117169 = 685871$

$At\ \ t_2 = 2006;\ E_1^{t_{2006}} = \mathrm{N}^{t_{2005}} + \mathrm{r}_1^{t_{2004}} * \mathrm{E}_1^{t_{2004}};$
$E_1^{t_{2006}} = N^{t_{2006}} + r_1^{t_{2005}} * E_1^{t_{2005}}$
$E_1^{t_{2006}} = 566819 + 0{,}168 * 685871 = 682045$

Values of following $E_1^{t_k}$ are calculated in (Table 2)

3.4 4nd step: enrollment in all primary levels

In this step, it should be remembered that the flow parameters are assumed time-invariant according to a called baseline scenario, but in reality this assumption is not always true. To account for eventual fluctuations of these parameters, it must create alternative scenarios to describe the future evolution of the dynamic system. The baseline scenario (extrapolation): consists of a simple projection of past trends. It is about determining the consequences of the current education policy if it remains unchanged over the planned period. The alternatives scenarios allow exploring different consequences of education policies. In case of the Moroccan system, the alternative scenario allow to measuring effect of retaining 90% of students enrolled in first grade in 2003-2004 until the end of the primary cycle at 2010-2011.

3.4.1 Projection in baseline scenario

Fist level was calculated in the 2nd step, in this step we will calculate for years 2005, and 2006, the numbers of pupils in second level, *i*=2.

$p_1^{t_k} = 0{,}753;\ r_2^{t_{k-1}} = 0{,}154$ for each t_k

$(1) \rightarrow E_i^{t_k} = E_{i-1}^{t_{k-1}} * p_{i-1}^{t_{k-1}} + E_i^{t_{k-1}} * r_i^{t_{k-1}}$

$At\ \ t_1 = 2005;\ E_1^{t_{2004}} = 697434;\ E_2^{t_{2004}} = 671562$
$E_2^{2005} = E_1^{2004} * p_1^{2004} + E_2^{2004} * r_2^{2004}$
$E_2^{t_{2005}} = 697434 * 0{,}753 + 671562 * 0{,}154 = 628588$

$At\ \ t_2 = 2006;\ E_1^{t_{2005}} = 685871;\ E_2^{t_{2005}} = 628588$
$E_2^{2006} = E_1^{2005} * p_1^{2005} + E_2^{2005} * r_2^{2005}$
$E_2^{t_{2006}} = 685871 * 0{,}753 + 628588 * 0{,}154 = 613263$

On the same principle, will be calculated all values of the rest of levels for the following years. Results are recapitulated at (table 3)

Table 3: Enrollment projection until 2005-2020

year	1st	2nd	3th	4th	5th	6th
t	E_1^t	E_2^t	E_3^t	E_4^t	E_5^t	E_6^t
2003	740582	738031	732026	653584	562677	457738
2004	697434	671562	709028	664718	594004	510204
2005	685566	628588	651775	648185	606251	541158
2006	681725	613034	608250	600488	593956	554338
2007	676359	607747	589007	559836	553577	545487
2008	670756	602892	581785	539418	516084	511258
2009	663250	597925	576752	531110	495479	476900
2010	654534	591507	571964	526060	486544	456479
2011	644749	583956	566040	521613	481484	447077
2012	638505	575425	559024	516336	477315	441966
2013	636512	569410	551050	510084	472559	438017
2014	634286	566983	544963	502947	466943	433697
2015	629565	564933	542068	497204	460512	428631
2016	624383	561062	539967	494179	455140	422817
2017	619081	556564	536514	492126	452106	417804
2018	613718	551879	532347	489118	450110	414802
2019	608302	547119	527919	485420	447438	412857
2020	602835	542307	523391	481429	444131	410456

3.4.2 Staff teacher Requirement

Teacher Departure: Every year t_k, a portion of teacher $DT_h^{t_k}$ leaves the system either for retreat or for other reasons. Departure in retreat $DTR_h^{t_k}$ is given in (Table 3), and departure for reasons other than retreat $DTO_h^{t_k}$ is given by a rate $dto_h^{t_{k-1}} = DTO_h^{t_k}/T_h^{t_{k-1}}$. For Moroccan case, this rate is estimated at 0,25% [8].

$DT_h^{t_k} = DTO_h^{t_k} + DTR_h^{t_k} = dto_h^{t_{k-1}} * T_h^{t_{k-1}} + DTR_h^{t_k}$

a) **Number of available teachers $AT_h^{t_k}$ at t_k**

Data at reference year $(t_0 = 2004)$ are

$T_h^{t_0} = T_h^{2004} = 135663$ Number of teachers at t_0;

$DT_h^{t_0} = 864$ [9] Departure in retreat at t_0;

$AT_h^{t_k} = T_h^{t_{k-1}} - DT_h^{t_k} = T_h^{t_{k-1}}(1 - 0{,}25\%) - DT_h^{t_k}$

$AT_h^{t_k} = T_h^{t_{k-1}} * 0{,}9975 - DT_h^{t_k}$

The number of available teachers at 2005 can be deduced from value at previous year 2004. The number of available teachers in 2004 allows us to deduce by recurrence the number of available teachers in 2005 so, $AT_h^{2005} = 134460$, and the rest of values for the following years are calculated on the same principle (Table 4)

b) **Pupils per teacher ratio $str_h^{t_k}$:**

Data at reference year t_0

$\mathrm{E}_\mathrm{h}^{2004} = 3846950$ and

$T_h^{2004} = 135663$ [11]
$str_h^{t_0} = E_h^{2004}/T_h^{2004} = 28{,}36$

c) **Total teachers required $Tr_h^{t_k}$**

In the baseline scenario, it supposed that this ratio be maintained invariant. For each year t_k, the number of teacher required for total of pupils is $E_h^{t_k} = \sum_{j=1}^{j=6} E_j^{t_k}$
$Tr_h^{t_k} = E_h^{t_k}/28{,}36$ then for 2005, $E_h^{2005} = 3761523$
$Tr_h^{2005} = 3761523/28{,}36 = 132635$
The rest of the values for the following years are calculated on the same principle (Table 4)

Tableau 4: Teachers requirement

		teachers			
years	Pupils	Availabl	retreat	required	ratio
	$E_h^{t_k}$	$T_h^{t_k}$	$DTR_h^{t_k}$	$DTO_h^{t_k}$	$str_h^{t_k}$
2004	3846950	135663	864	135456	28,36
2005	3761523	134460	861	132448	27,98
2006	3651791	133263	953	128584	27,40
2007	3532013	131977	979	124367	26,76
2008	3422193	130668	1 056	120500	26,19
2009	3341416	129285	1 037	117655	25,85
2010	3287088	127925	1 369	115743	25,70
2011	3244919	126236	1 421	114258	25,71
2012	3208571	124499	2 148	112978	25,77
2013	3177632	122040	2 490	111888	26,04
2014	3149819	119245	3 155	110909	26,41
2015	3122913	115792	3 877	109962	26,97
2016	3097548	111625	5 209	109069	27,75
2017	3074195	106137	6 318	108246	28,96
2018	3051974	99554	7 070	107464	30,66
2019	3029055	92235	7 069	106657	32,84
2020	3004549	84935	6 635	105794	35,37

d) **New teachers required $Tr_h^{t_k}$**

$Tr_h^{t_k}$ is the difference between total teachers required and teachers available, $NTr_h^{t_k} = Tr_h^{t_k} - AT_h^{t_k}$
$str_h^{t_k}$ is less than $str_h^{t_0}$ until 2016. During this interval, the number of available teachers is higher than the total of required teachers. It is the result of the decreasing trend of the population $P_a^{t_k}$(Table 2). It would make sense to reduce the pupil-teacher ratio to take advantage of the availability of the teachers.
So, $str_h^{2005} = E_h^{2005}/AT_h^{2005} = 3761523/134460$
$str_h^{2005} = 27{,}98 \rightarrow str_h^{2005} < str_h^{t_0}$
As from 2017, $str_h^{t_k} > str_h^{t_0}$, so new teachers $NTr_h^{t_k}$ must be recruited for maintaining the pupils-teacher ratio at the predetermined value " less than 28,36." (Table 5)

Table 5:New teachers requirement

years	Pupils	teachers			rate
		available	required	recruits	
2017	3074195	106137	108246	2109	28,40
2018	3051974	99554	107464	7910	28,40
2019	3029055	92235	106657	14422	28,40
2020	3004549	84935	105794	20859	28,40

3.5 Class-room Requirement:

In primary school, the number of classes is the same as the number of teachers. At reference year t_0 the average of class per classroom $accr_h^{t_k}$is $accr_h^{2004} = Cl_h^{2004}/Cr_h^{2004}$
$Cl_h^{2004} = 132979$ *Classes at 2004* [11]
$Cr_h^{2004} = 89813$ *Class-rooms at 2004*
$accr_h^{2004} = Cl_h^{2004}/Cr_h^{2004} = 1{,}48$
Number of required classrooms is decreasing, and less than the number of available classrooms. There are no new classrooms to build in this scenario.

3.6 Alternative scenario

To Retain 90% of pupils enrolled in first primary level at 2004 in accordance with the initial objective, we should reduce the dropout rate. The average dropout rate in the reference year is 6.21%, and it must be reduced to 1.25% for whether the goal is achievable. To achieve this objective we choice a progressive mode in which the dropout rate is gradually reduced. Every year, by reducing dropout rate a part $\Delta E_{h,rec}^{t_k}$ of pupils is recovered in progressive column.
$\Delta E_{h,rec}^{t_k}$: *Part recovered in progressive scenario*
$d_{h,prog}^{t_k}$: *Dropout rate in progressive scenario*
$E_{h,baseline}^{t_k}$: *Total number of pupils in baseline mode*
$E_{h,prog}^{t_k}$: *Total number of pupils calculated in progressive scenario*

$$\Delta E_{h,rec}^{t_k} = \left(6{,}21\% - d_{h,prog}^{t_k}\right) * E_{h,baseline}^{t_k}$$
$$E_{h,prog}^{t_k} = E_{h,baseline}^{t_k} + \Delta E_{h,rec}^{t_k}$$

The actual data and results of the baseline and progressive scenarios are compiled, for comparing, in (Table 7).

Tableau 6: classroom requirement

years	classes	Class-rooms			ratio
		required	Available	New	
t	$Cl_h^{t_k}$	$Crr_h^{t_k}$	$Cra_h^{t_k}$	$NCr_h^{t_k}$	$\mathrm{str}_h^{t_k}$
2004	132979	89813	89851		28,36
2005	134460	89640			27,98
2006	133263	88842			27,40
2007	131977	87985			26,76
2008	130668	87112			26,19
2009	129285	86190			25,85
2010	127925	85283			25,70
2011	126236	84157			25,71
2012	124499	82999			25,77
2013	122040	81360			26,04
2014	119245	79497			26,41
2015	115792	77195			26,97
2016	111625	74417			27,75
2017	108246	72164			28,96
2018	107464	71643			30,66
2019	106657	71105			32,84
2020	105794	70529			35,37

Table 7: comparative table

year	rate	baseline	progressive	actual
2003	6,21%	3884638	3884638	3884638
2004	5,58%	3846950	3846950	3846950
2005	4,96%	3761523	3761523	3757932
2006	4,34%	3651790	3675112	3657404
2007	3,73%	3532013	3577584	3609303
2008	3,11%	3422192	3488735	3532061
2009	2,49%	3341416	3427936	3492312
2010	1,87%	3287089	3393355	3518753
2011	1,25%	3244918	3371151	3530458
2012	1,25%	3208572	3354880	3500755
2013	1,25%	3177632	3344034	3475190

4. COMPARING RESULTS TO REALITY

The actual data available for the period 2005-2013 in the collections of statistics, published by the Ministry of Education [11], allow us to check our simulation model by comparing actual results to the simulated results for both progressive and baseline scenarios.

4.1 Global comparison

In graph (Figure 7) there are three curves: baseline, progressive and actual. The baseline curve represents the development of the system if all parameters are invariants along the simulation period. The progressive curve shows the changes resulting by an decreasing of dropout flow parameter. The actual curve shows real values during the period 2004-2013.

In this graph we can distinguish three areas (Figure 7).

1. In the first area "2003 to 2006": the actual curve coincides with the baseline curve
2. In the second area "2006 to 2007": the actual curve brand an increase over the progressive curve.
3. In the third area "2009 to 2011"; the actual curve brands a second important increase.

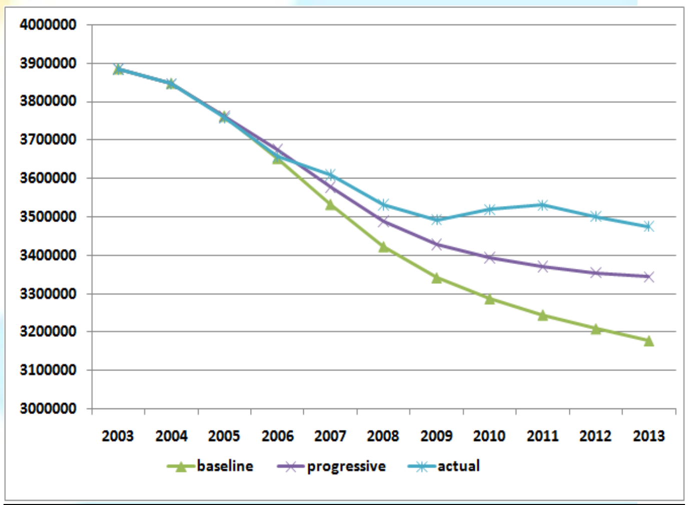

Figure 7: curves comparing

The first deviation at 2006 is a result of reducing the age of school entry from 6 to 7 years. The primary school had hosted at 2006 both age groups, 6 and 7 years. The second deviation is produced through an emergency plan during the period 2009-2012. This plan had as goal to stimulate the Moroccan system to compensate the delay in the achieving the objectives of "Education for All" before 2012.

4.2 Levels comparison 3D

In this stage we attempts to compare in 3D representation by level, year and number of pupils

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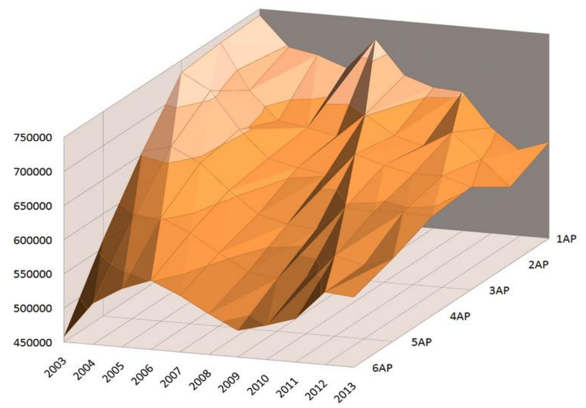

Figure 8: levels/years/pupils with real data

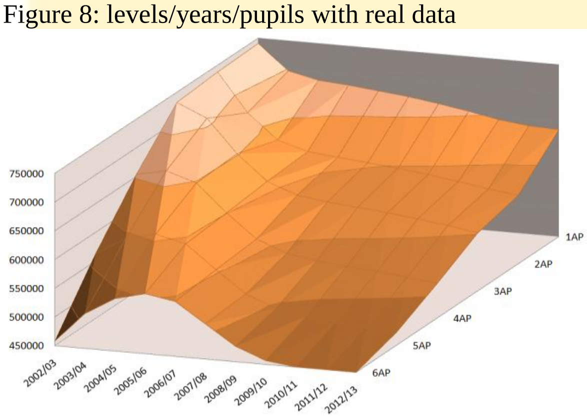

Figure 9: levels/years/pupils, with simulated data

The simulated graphic is built from baseline scenario, and it don't take account the reduction of dropout parameter. In the actual curve we can distinguish the peak at the first school year in 2006, due to the passage of school age 6 years to 7 years.

In other hand, compared to the baseline simulation, there are more pupils at the end of cycle. That shows the effect of reducing the dropout rate.

5. CONCLUSION

The education system is a complex system. There is difficult the predicate accurately its comportment in response to a particular policy decision.

Flow modeling according the Forrester approach by considering that school levels are stocks with inflows, promoted and repeaters, and any outflows to others levels (stocks). This modeling allows to propose scenarios for system development, and to negotiate likely consequences of various policy decisions.

In the next article, we projects modeling de flows by using dynamo language by using tank-valve representation for analysing different type of the system response

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