Application of Computer Simulation in Education Development Planning

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Abstract

**Keywords:** Education Policy Simulation, Education Policies and Strategies, Policy Analysis, Education Development Plan.

In the context of strategic planning, computer-based policy simulation is widely used when preparing education sector development plans or programmes, as a tool for scenario planning and resource projections. Since there are too many actors, interests and the interrelations between these in the education sector, it is necessary to have not only a reliable information system, but also an objective forecasting tool to facilitate policy consultations regarding financial constraints and their consequences on education and national development.

Policy simulation makes use of computer modelling techniques to anticipate and assess the consequences of education policies. Since early 1980s, UNESCO’s upstream support has given priority to policy analysis through computer simulation in response to countries’ increasing financial constraints, and to shifting international cooperation approaches and patterns from project to sector-wide policy support.

UNESCO’s field experience shows that education policy simulation allows a holistic vision of the sector and helps match enrolments with resources, provides timely information to decision-makers, and facilitates policy dialogue. External funding agencies, e.g. the World Bank, tend to consider that “credible plans” should be based on computer simulation. UNESCO has focused on reinforcing national capacities in this field in order to support countries’ leadership and equal partnership with the donor community.

UNESCO designed in 2001 *EPSSim*, a generic education policy simulation model, with a view to supporting national education administrations in the design of medium and long-term education policy and strategies. This model was conceived in such a way as to provide methodological support to education planners and specialists in their efforts for the formulation of credible education development plans and programmes, in particular within the framework of the Education for All (EFA) movement. This "generic" model can be used primarily as a demonstration tool. With minimum adaptation, it can also be used for testing the feasibility of the overall education policy of a given country. However, this model needs careful
restructuring and necessary adaptation if one wishes to use it as a tool for designing a detailed education policy or an action plan for medium and long term educational development.

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I. Introduction

Before the 1980s, the work of education planners in many countries mainly consisted in forecasting and managing the quantitative growth of school enrolments. This meant that the social demand for education would be met to the extent that the financial capacity of the State allowed it to ensure the expansion of education at all levels. However, since the 1980s, many countries have encountered economic and financial difficulties, making the implementation of development plans more and more subject to economic and budgetary hazards and uncertainties. As a consequence, many developing countries gave up long-term planning in favour of short-term programming in the form of projects. In the face of the mitigated impact of a large number of these projects, these countries, often spurred on by their multilateral and bilateral partner agencies, have opted for a programme approach with the view of ensuring sector-wide coherence and a better effectiveness in their investments.

The search for coherence, transparency and rational use of resources in educational planning and management has led the recipient countries and the donor community to adopt a systemic approach to educational development. It is in this context that some developing countries have designed simulation models as supporting tools for the preparation of coherent education sector development plans. This endeavour was facilitated by the development of information technologies.

Before the use of computer simulation, it was difficult to test a sufficient number of simulation operations so as to measure the impact of numerous decisions on the development of an education system, and in particular their financial consequences. Computerised simulation has contributed a great deal to the preparation of coherent national educational policies and strategies and to the technical quality of education development plans. With this tool, the planners have been able to raise to a higher degree the conceptual coherence of these plans and the appraisal of their feasibility.

The simulation models have become an indispensable tool in ensuring coherence in the development of the education sector, and a better understanding of the implications of its objectives, by facilitating the identification of required pedagogical and institutional inputs, as well as the financial resources which these involve. The usefulness of a simulation model culminates in the construction of education development scenarios, in the
sense that it allows to appraise the feasibility of chosen options and the measurement of their consequences, in real time, before their final adoption.
II. Use of computer simulation in education development planning

Computer simulation is a tool *par excellence* for scenario planning. It is used to test the viability of an education development strategy and to propose alternatives that can help cope with dynamic and changing environments. Scenario planning in education is a non-predictive means of examining a variety of possible futures for the development of the whole education system or the specific issues that one is interested in.

The simulation method is widely used as a strategic planning and management tool allowing for policy-making, informed policy dialogue and resource negotiation for education development. The scenarios, produced through simulation as results of a long process of trial and error by taking into consideration the policy options and the technical feasibilities as well as the financial constraints, can feed into constructive policy and social consultations about the perspective of education development and help design a comprehensive financial framework.

II.1. Educational Policy Formation, Action Planning and Budgeting.

Compared to other socio-economic sectors, educational development involves more complex and multidimensional problems. Faced with financial constraints, governments are not able to meet the broad social demands without adopting restrictive measures within the education sector in order to rationalise the use of allocated resources. In the dynamics of educational management of student flows, as well as that of public finance, they have to make difficult decisions to regulate the utilisation of resources, without in any way leading to serious disruptions and dysfunctions. Because there are too many actors, variables and the interrelations between these, it is necessary to have not only a reliable information system but also an objective forecasting tool to facilitate policy consultations regarding financial constraints and their consequences on educational options.

Policy simulation contributes to ensuring coherence in educational planning, a better understanding of the implications of the policy decisions, and holistic educational development:

**First**, the simulation serves the formation of educational policies, which is complex by nature. A simulation model can contribute useful information to
evidence-based policy dialogue and consensus building. It is used as a tool for testing the feasibility of reform or development options of the sector. It allows, at the preliminary planning stage, to anticipate the pedagogical, physical and financial implications of the goals and policy options retained for long-term periods, thus contributing to designing feasible and coherent policies.

**Second**, the simulation model provides information on actions, inputs and resources required for educational development. It is used as a forecasting tool following the adoption of sector reform and/or development options. It makes it possible to determine the pedagogical, physical and financial implications of educational objectives. As a systemic forecasting tool, it helps in considering the dynamics of the educational system and the detection of the interrelations of a number of parameters which influence the operation and the improvement of educational services.

**Third**, as early as the plan’s preparation phase, the simulation can make it possible to establish an upstream forecast of recurrent expenditures and investments for the education sector in accordance with policy orientations. Governments, as a result, can have advance information on the annual costs required to implement the reform and development plans, foresee the budgetary gaps in relation to the possibility of States’ financing in a given period, and identify the fields for which additional resources should be sought from the national private sector and/or from external partners.

**II.2. Projection of Resources for Education Development**

A simulation can contribute immensely to identifying the necessary educational actions and resources. The projected needs for educational inputs and resources are estimated on the basis of the quantitative and qualitative objectives expressed. The simulation makes it possible to determine the nature and scale of these inputs per year for the period considered. It provides indicative information on school enrolments as well as the human, physical and financial means to mobilise, in order to carry out development actions. Presented below are some categories of educational inputs whose evaluation is carried out thanks to computer simulation.

- **Personnel.** The simulation makes it possible to estimate the number of teaching and non-teaching personnel required (managerial and supervisory staff, administrative and service personnel, technical and maintenance workers, etc.) and to foresee recruitment needs (per year, per region, and by education level) while taking into account staff attrition. It
also enables the evaluation of the training needs of these personnel, both at pre-service and in-service training level. The new requirements for teachers for a given year will indicate to the educational authorities the need to take adequate measures many years in advance (this varies according to countries).

- **Educational facilities.** On the basis of the number of students and the parameters of pedagogical management, the simulation has the potential to evaluate the number of buildings to build, on a given time-horizon. It also indicates the expenditures necessary for the purchase of necessary equipments and maintenance expenses of all kinds. The required number of classrooms and other spaces as well as the needs for new buildings are provided by the model per year and by region for all levels of teaching.

- **Instructional materials and equipment.** A simulation can allow to estimate the future needs for instructional materials and equipment and to indicate the requirements for the production and the distribution of these materials, in accordance with the national policy in this field. It can also aid to foresee necessary actions to acquire and/or renew the materials, so as to meet the curricular reform and to evaluate the recurrent costs resulting from this.

**II.3. Monitoring and Evaluation Indicators**

Faced with economic and financial difficulties, the ministries of education of many countries are under pressure from financial services (be they national or international) to prove that the resources they were provided are being used efficiency and the stated objective effectively met. These pressures have contributed to the introduction of new approaches to result-based programming and management. In the recipient countries, the external bilateral and multilateral agencies are increasingly requiring programming of development actions to be more accountable and results-based.

This new approach changes the way agencies work with recipient countries in the preparation of development plans and programmes in the education sector. These plans should now include explicitly the results (outputs and outcomes) expected of development actions in order to measure, in advance, the educational policy’s potential to achieve their objectives – thereby ensuring the wish for efficiency of external investments. The objectives and actions of development plans are thus formulated by integrating the indicators of monitoring and evaluation.
The simulation models can easily provide these means of verification in the form of quantified indicators relating to the educational system’s organization and operation. These indicators are provided per year for a reasonably long period according to the planned programme, by region and for all the levels of education and training which are examined in the simulation.
III. Designing a Policy Simulation Model

III.1. Different Types of Simulation Models

There exist two classifications of approaches in the design of simulation models. These classifications do not preclude the existence of a number of variants and subcategories which were designed by countries according to their specific needs.

**Generic model and country-specific model:** There are two types of simulation models (or approaches): the generic models which are sometimes called “ready-to-use” models and country-specific models, also called “tailor-made” models. The so-called generic approach is used in designing a simulation model which contains components common to a majority of education systems. It does not correspond therefore to any system or to any given country but represents a virtual education system. Adapted in a limited way, this model makes it possible to approximately indicate the pedagogical, physical, and financial consequences of main policy orientations. It can be useful at the stage of pre-designing education policy options and in facilitating consensus building on the main educational development goals and orientations\(^1\). The second approach is the development of specific simulation applications. Its use is generally adopted to define detailed educational development options, in particular at the preparation stage of action plans. The application designed at this stage of post-definition of educational policy takes into account the structure and specificities of a given country’s education system. Adapted to a given country, this kind of model cannot be used by another without a major reorganization and meticulous adaptation.

**Budgetary model and demographic model:** Another classification relates to two types of simulation models which planners call “budgetary” model and “demographic” model, with multiple variants in between. These two types of models are designed according to two different methodological approaches: the first uses the national budget for education as the decision variable, and another, where educational expenditures are but the results of the simulation. In the budgetary model, the planner is first concerned with determining an acceptable budget ceiling in proportion to the State’s general budget. The computer carries out calculations backwards to obtain enrolment targets. In

\(^1\) The stage of policy definition can be subdivided into two chronological phases: the pre-definition phase, and that of its adoption. The pre-definition of educational policy is a stage during which the policy-makers, in consultation with major decision-makers, set the general educational development orientations.
the case of the demographic model, the opposite logic is the one developed. Regarded as independent variables, the enrolment targets are laid down a priori and the computer calculates their corresponding financial budgets as a consequence.

III.2. Three Stages of Simulation

There are three principal stages to follow in the process of simulation modelling. These are: the organization of the baseline data to be projected, the definition of hypotheses, and the production of results. One can easily note that these three stages of simulation correspond to three stages of strategic planning. This parallelism is shown below in table 1.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Strategic planning</th>
<th>Policy simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sector analysis</td>
<td>Data (Baseline)</td>
</tr>
<tr>
<td></td>
<td>(Diagnosis)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Policy formulation</td>
<td>Hypotheses</td>
</tr>
<tr>
<td></td>
<td>(Policies)</td>
<td>(Policy assumptions)</td>
</tr>
<tr>
<td>3</td>
<td>Action planning</td>
<td>Results</td>
</tr>
<tr>
<td></td>
<td>(Plan of action)</td>
<td>(Projections)</td>
</tr>
</tbody>
</table>

In developing a simulation model, each of the stages of the above table can be conveniently presented on a worksheet of the spreadsheet application (e.g. MS Excel) in order to enter data and policy assumptions (stages 1 and 2) and to consult the subsequent results (stage 3). This facilitates the verification and the monitoring of related data and information at each stage of the simulation. In other words, the education system (Figure 1) will be displayed as it functions (figure 2) on a spreadsheet application.
Let’s examine in detail the three stages of simulation.

**Baseline data:** The first stage of simulation is data entry. It consists in establishing and arranging the data of the education sector and those on the macro-economic framework. These can be school, pedagogical, macro-economic or budgetary data. In other words: data on the school-age population, access to and participation in education, the teaching and non-teaching personnel, the pedagogical orientations, the school facilities, the economic development situation, the national education expenditures, etc. Most of the baseline data are those of the base year(s) or the most recent years. The degree of refinement and reliability of a simulation will depend mostly on
the quality of these baseline data. If some indispensable data for the construction of a simulation are non-existent or not fully reliable, additional research should be carried out. To this end, planners establish a checklist of data against which they check the availability of the baseline data in order to determine the data gaps to fill in.

**Policy options and assumptions:** Now that the baseline data resulting from the sector analysis (diagnosis) are put together, the next stage is to bring together all the policy goals, objectives and options likely to influence educational development in the form of hypotheses/parameters. This means the pedagogical, policy, organizational and even macro-economic options and choices which constitute the parameters influencing the operation and the development of education. The quantitative objectives most frequently used are the enrolment ratios, intake and flow rates, the supervision ratios (e.g. pupils/teacher ratio), the utilization rates of the education buildings and the share of education in the national budget. These parameters, often called policy hypotheses or options, are in general widely scattered in policy statements, legislative texts, sector orientation notes and economic and social development plans. Planners often establish a checklist of the policy assumptions that are necessary for simulation, against which they check the availability of these policy-related data in order to determine the policy gaps to fill in. Once assembled, the goals/objectives will be classified into decision (independent) variables and result (dependent) variables. The variables which constitute the policy assumptions in a simulation are the decision variables. Table 2 displays a set of sample decision variables used in a simulation model. The second column contains the results that can be generated by the simulation model.

<table>
<thead>
<tr>
<th>Independent (decision) Variables</th>
<th>Dependent (result) Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category &quot;students&quot;</strong></td>
<td></td>
</tr>
<tr>
<td>1. Intake rate in first grade</td>
<td>1. New entrants in first grade</td>
</tr>
<tr>
<td>2. Flow rate</td>
<td>2. Number of pupils</td>
</tr>
<tr>
<td>4. Proportion of multi-grade classes</td>
<td>4. Number of classes/classrooms</td>
</tr>
<tr>
<td>5. Proportion of double shift classes</td>
<td>5. Number of multi-grade and/or double shift classes</td>
</tr>
<tr>
<td><strong>Category “Teaching and non-teaching personnel”</strong></td>
<td></td>
</tr>
<tr>
<td>6. Turnover</td>
<td>6. Needed teachers and new requirements</td>
</tr>
<tr>
<td>7. Attrition rate</td>
<td></td>
</tr>
</tbody>
</table>
### Independent (decision) Variables

<table>
<thead>
<tr>
<th>8. Supervision rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Proportion of non-teaching personnel</td>
</tr>
</tbody>
</table>

### Dependent (result) Variables

| 7. Other personnel and new requirements |
| 8. Training and recruitment needs |
| 9. Annual attrition of personnel |

### Category “Cost and Financing”

<table>
<thead>
<tr>
<th>10. Initial index value</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Salary scale and other emoluments</td>
</tr>
<tr>
<td>12. Budgetary allocations</td>
</tr>
<tr>
<td>13. Macro-economic indicators</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>10. Salary expenses</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Recurrent expenditures</td>
</tr>
<tr>
<td>12. Investment expenditures</td>
</tr>
<tr>
<td>13. Evolution of education expenditures</td>
</tr>
</tbody>
</table>

**Projection results**: The projections are the results of the simulation of policy hypotheses in relation to the baseline data. To this end, on a worksheet of a spreadsheet application, planners prepare the required statistical formulas of the indicators for the simulation and ensure the coherence of these formulas. The preparation of formulas (and the application of the projection indicators) requires not only the knowledge of the structure and operation of an education system, but also the mastery of the relations between the hypotheses on the one hand, and of the impact they have on the evolution of the (baseline or projected) data, on the other. In general, the simulation results contain two categories of related information: the first includes the number of students and teachers, the infrastructure and equipments, the learning and teaching materials, and the second relates to their consequences on the budgetary and financial resources.

- **First of all, the forecasts are made on enrolments.** The simulation first relates either to the access to or to the participation in education. The apparent intake rate (AIR) becomes the decision variable. On the basis of the intake rate (AIR) at the first grade of primary education, it is then necessary to measure the progression of pupils from one grade to another by applying the promotion, repetition and drop-out rates, as well as the transition rate from one cycle to another, to estimate the number of pupils and students per school year and their school grades. This exercise will provide the enrolment projections per year on a simulated period (5, 10 or 15 years), and this by private or public organizing bodies, by gender (girls and boys), by area (rural and urban), etc.

- **The enrolment data will make it possible to forecast other inputs.** On the basis of the number of pupils and students per year, it is now possible
to calculate, thanks to the combination of parameters linked to the supervision ratios and the pedagogical organization: the number of teachers, classrooms, textbooks as well as all the other means necessary to the organization of education. The simulated results can calculate not only these requirements or other means, but also the new requirements on personnel and school constructions. The annual forecasts on teachers, classrooms or other pedagogical means are obtained on a worksheet of a spreadsheet application and constitute the annual targets (quantified indicators) to be attained by the education system.

- **The input mix will lead to resource projections.** The ultimate purpose of a simulation is the quantification of the resources subsequent to decisions in education policy. The simulation results in the projection of quantified human, physical, and financial resources, which will facilitate the policy dialogue concerning the technical and budgetary implications of the decisions taken by the policy authorities. The quantitative forecasts of educational development depend not only on the policy objectives, but also on the budgetary and macro-economic projections of the country. If the financial estimates relating to the education sector prove to be too high in relation to the possibilities of economic development projects, planners should start again at the beginning of the process of simulation. In consultation with relevant educational authorities and other actors of the system, they should change the parameters used and search for alternative options for educational development. The methodology of scenario design is explained below.

**III.3. Construction of Development Scenarios**

The simulation model makes it possible to construct development scenarios on which to base policy dialogue and thereby facilitate policy design. On the basis of major education policy orientations, several development scenarios can be constructed. In the process of constructing a development scenario, the simulation model is first used as a tool of *projection* in the literal sense of the word, and then as a tool of *prospection*, and finally as a tool of *forecasting*. Although there is no single pattern followed in the construction of a development scenario, we can nevertheless identify a commonly used method characterised by the following three principal stages.

- **Establishment of a baseline scenario (projection):** The first scenario, called “baseline” scenario, consists of a pure and simple projection of
It is about determining the consequences of the current education policy if this will remain unchanged during the planned period. In actual fact, it is an extremely rare case where one is satisfied with, and requires no change in the current policy. This scenario makes it possible to weigh the consequences of the laissez-faire policy, to identify and specify the desirable changes to adopt within the framework of a new sector development scenario.

**The stage of alternative scenarios (prospection):** The second stage consists in developing two or three alternative scenarios based on the objectives and parameters resulting from the application of new policies in relation to past trends. These scenarios allow policy-makers and specialists to weigh the consequences of adopting the new options for education sector development. These scenarios are developed on the basis of a given macro-economic and budgetary framework. This stage allows the prospection of options to retain and the verification of the socio-economic and financial sustainability of the education policy objectives considered, in particular by studying the effect of the different combination of parameters, on the evolution of the sector. It is in the course of this stage that the feasibility – or the degree of realism – in the policies and strategies considered, is verified. The objectives and hypotheses are evaluated in terms of financial and budgetary consequences. The results of the different scenarios inform the deliberations and the policy dialogue with the view of reaching a consensus on the objectives of education policy. Once the different options are carefully weighed, one of the scenarios will progressively acquire a certain stability and will result in what is called a reference scenario.

**The definition of the reference scenario (prevision):** The third phase is the adoption of one of the previously considered scenarios, or even a scenario resulting from the combination of several objectives and parameters coming from different sector development hypotheses, examined during the previous phase. Once verified on the policy and technical level, this scenario is refined with the degree of information which is required in the programming of actions. It becomes the reference scenario for the future education plan, making it possible to foresee development actions and the financial resources required.
Figure 3. Example of the scenario screen of EPSSim
IV. EPSSim, UNESCO-designed Generic Simulation Model

UNESCO designed EPSSim, a generic simulation model with a view to supporting national education administrations in the design of medium and long-term education policy and strategies. This model was conceived in such a way as to provide methodological support to education planners and specialists in their efforts for the formulation of credible education development plans and programmes, in particular within the framework of the Education for All (EFA) movement. Being generic, this model therefore does not correspond to any given education system. But it can be used, after some adaptation by specific countries, for rapid simulations based on their education system’s major development orientations and hypotheses. In particular, it can be used at the pre-definition stage of education policy options in so far as it can facilitate the policy dialogue and consensus building on the major orientations of educational development. This model needs careful restructuring and necessary adaptation if one wishes to use it as a tool for designing a detailed education policy or an action plan for medium and long term educational development.

In other words, EPSSim was designed to address three major requirements regarding its adaptability, its demonstrability and its user-friendliness.

Adaptability: This model can adapt to a variety of structures which characterise the different education systems in the world, and can rapidly and methodically take into account the principal data and variables, particularly at the design stage of education policy. Without major changes, it can be configured by including the national education structures, their data, parameters, modalities of operation, and provide the principal results of their simulation in an aggregate and synthesised manner. It is structured to cover all the levels and types of formal education, their principal subdivisions, the public and private sectors, etc. It can also be used in a limited application, for a single sub-sector or type of education or training.

Demonstrability: This model guides the user in the definition of the system’s structure (or that of its education sub-system) and at the different stages of the simulation’s construction, i.e. the entry of the baseline data, the definition of the simulation parameters, and the use of the forecast’s results. Thanks to the different macros used, the forecast results and scenarios are automatically constructed as soon as the raw data and the necessary simulation parameters are introduced by the user. As a demonstration tool, this model allows the rapid evaluation of the short or long-term physical and financial consequences
of policy decisions. In the course of policy consultations, it can also provide background material on the financial feasibility of policy options, and propose alternative development scenarios.

**User-friendliness:** *EPSSim* is designed to be user-friendly, in the sense that education planners and other users with a minimum knowledge of computers can easily manipulate it. It can be used to construct and test development scenarios of their education systems, by moving from one worksheet to another, to measure the impact of options, with the view of deciding whether or not a particular scenario should be maintained.

In brief, the advantage of this model is its ability to save time and provide a ready-to-use base, which is usable for a great number of education systems. Its adaptation to a given education system is carried out in an easy manner, and it is not necessary to be skilled in IT to properly perform the work of reconfiguration. In addition to the structural components which can be modified according to the given configuration of any education system, this model already contains pre-programmed macros which regulate the sequence of calculations which in turn leads to the production of the synthesis tables of the development scenarios.

Although this model has been designed in order to address the diversity of forecasting needs in a large number of education systems in the world, in some cases, particularly at the stage of developing an action plan, a more sophisticated adaptation can help address the peculiarities in many education systems. Like all application programmes in their initial stage of design, it is perfectible.
References

