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Review and Evaluation of Selected Education Projection Models in use in 2006

By Emilio Porta & Annababette Wils

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1. INTRODUCTION: WHY USE PROJECTION MODELS?

Education models have existed since at least the 1970s and the advent of computers, to assist education planners and strategists. This paper reviews four of them currently in use. They were developed by the World Bank, UNESCO (Education Policy and Strategy Simulation or EPssim), the Nicaraguan Ministry of Education and FHI 360 (Modelo de Necesidades de Financiamento or MNF) and by the EPDC (DemoEd). It would be an exaggeration to say models have been used extensively for this whole period. However, with the prominence of international education goals, the focus on evidence-based planning, as well as the wide diffusion of computer technology, education projection models are increasingly becoming a standard part of the education planning process. There are multiple models in use at this time, which differ from each other in significant aspects. It is thus an opportune moment to review and compare these models – both so that the modelers can learn from each other and to help potential users identify the model that best suits their needs.

The paper evolved because the two authors both developed new education projection models and wanted to see how their models compared to those that were already in use. Emilio Porta developed the MNF model for Nicaragua and Guatemala; Annababette Wils developed the DemoEd model. We then thought that some of the results – which include an overview of what the different models can be best used for; the structure of the models; the expertise, data, and software needed to run the models; and finally a comparison of projections using different models – would be useful to others in the field who work with models. We invited two model experts, Luis Crouch and Luc Gacougnolle, who has worked extensively with the World Bank models discussed in this paper, to review our evaluations. We are deeply indebted to their insights and corrections.

Models are used by planners in different ways and for different purposes. The main purposes are:

1) To produce input to national strategic education documents on the physical and financial resources necessary to meet targets on pupil intake, retention and learning.
2) To serve as negotiation and advocacy tools, showing stakeholders' trade-offs between different policies.
3) To serve as optimization and learning tools, allowing stakeholders to optimize policies and test assumptions on important outcome measures.
4) To advance knowledge on how to improve education systems.

All of these purposes can be an important part of the planning and policy making process. Each model reviewed here can be used for any of the four purposes outlined above but some models are best-suited for only a sub-set of them.

We review four models or model-groups. The most widely used are two Excel based models. One is used by the FTI Secretariat and the World Bank for country-specific strategic education sector plans. This model-group is based on a model used by

Bruns, Mingat and Ramatokolala for their book *A Chance for Every Child* (2003)[1]. Second, we review the Excel based UNESCO model EPSSim, which stands for **E**ducation **P**olicy and **S**trategy **Sim**ulation. Third, we review the Modelo de Necesidades de Financiamento (MNF), developed by author Emilio Porta when he was working for the Nicaraguan Ministry of Education. It has been used for negotiation, advocacy and operational planning. Fourth, the paper reviews the DemoEd model developed by author Annababette Wils at the Education Policy and Data Center (EPDC) for planning, learning, advocacy, finding leverage points and understanding the linkages between population growth, education, human capital and the HIV/AIDS epidemic. The objective of this review is to identify features within each model that are particularly useful and to discuss the context in which the models can be best applied. We do not strive for an endorsement of a particular model, as each has its distinctive use and purpose.

In this report, the models are compared in different ways. Section 2 provides a separate overview of each model. Section 3 puts the models side by side and compares the indicators calculated, presentation, data needs, skills needed to use the models, and accessibility. Section 4 compares projections for Nicaragua made by each of the four models. Section 5 summarizes the insights and results.

2. FOUR EDUCATION PROJECTION MODELS

In summary, some of the similarities and differences between the models are:

1) The World Bank model group and EPSSim are an older, more established generation of models built on Excel spreadsheets. MNF and DemoEd are a new generation of graphical and interactive models built with dynamic modeling software.

2) All four models contain a core of generic code that can easily be applied to any country. Generic code includes: school age population calculations; intake rates; progression through grades in primary and secondary via promotion and repetition; resources per pupil; unit costs of resources. Each model can be adapted to specific country issues with some additional programming. Such country-specific adaptations increase ownership and understanding, which may be critical components of the modeling exercise.

3) All of the models calculate pupils and physical and financial resources needed for the education system at the primary and secondary levels. Assumptions can be changed about the future paths of many variables, including, for example, users can change assumptions about intake rates, repetition, teachers hired, teacher salaries, etc.

4) The World Bank model group and EPSSim are programmed in Excel, with which many users are familiar. Results, for one projection at a time, are mainly presented in summary tables. DemoEd and MNF are system dynamics models[2] programmed with

[1] Bruns b., Mingat A. and Ramatokolala (2003) *A Chance for Every Child (PUBLISHER)*

[2] "System dynamics is a methodology for studying and managing complex feedback systems, such as one finds in business and other social systems. In fact it has been used to address practically every sort of feedback system. While the word system has been applied to all sorts of situations, feedback is the differentiating descriptor here. Feedback refers to the situation of X affecting Y and Y in turn affecting X

a graphical software that makes it much easier to understand links within the education system and to compare the impacts of different policy options. Results are presented mainly in graphs for multiple projections or scenarios at a time.

5) All four models can be used for national or provincial level projections and major budget items such as teacher salaries, book costs, building costs, library costs. They are not appropriate tools for micro-level planning at the school or district level.
6) The World Bank model group is most easily adapted to any country-specific issues by all users who are familiar with Excel. Programming changes to MNF and DemoEd are simple, but the user must have some knowledge of the software, obtain a license ($700) or work with technical experts.
7) The World Bank model group and EPSSim have the simplest data needs; DemoEd and MNF require some information that has to be estimated or requested from the country's Ministry of Education.
8) **Specific strengths:** The MNF model has the greatest school resource detail, and can be used for the most detailed planning. DemoEd links education to health and economic productivity and vice versa. Some of the World Bank models include more detail in the projection of GDP and budget available for education.

Table 1. Summary of four education projection models' suitability to different purposes and goals, platform, and accessibility.

	World Bank group of models	EPSSim	MNF	DemoEd
Main Purpose				
National level projection of resources and budget needs	Yes	Yes	Yes	Yes
Negotiation and advocacy tool	Partly	Partly	Yes	Yes
Optimization and learning tool	Partly	Partly	Yes	Yes
Analysis	Partly	Partly	Yes	Yes
Other Purposes				
Calculate the impact of education trends on human capital development.	No	No	No	Yes
Calculate intersectoral relationships between education, health (HIV/AIDS), economic and demographic growth	Yes (to GDP only)	No	No	Yes
Calculate teacher training needs.	No	No	No	Yes
Platform	Excel	Excel	iThink	Vensim
Accessibility	From World Bank	Online	From developer	Online

perhaps through a chain of causes and effects. One cannot study the link between X and Y and, independently, the link between Y and X and predict how the system will behave. Only the study of the whole system as a feedback system will lead to correct results." From the System Dynamics Society homepage, http://www.systemdynamics.org/, accessed on Feb 21, 2006.

2.1 The World Bank group of models

The World Bank model group has become well-known mainly due to its use in Bruns, Mingat and Ramatokolala (2003) *A Chance for Every Child.* It has been applied to countries on a case by case basis to support the development of Fast Track Initiative plans. These models have been primarily used for national level strategic planning to estimate necessary inputs for the school system over a period of 5-15 years.

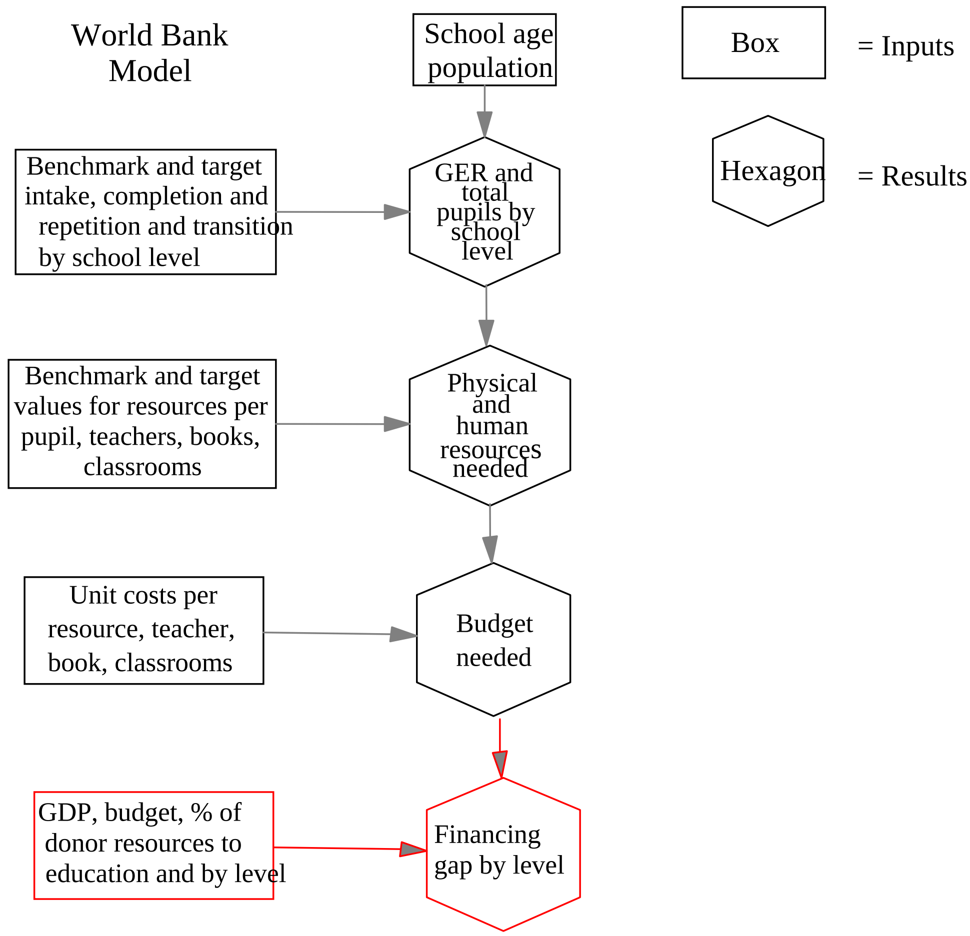
The basic flows of this model group are represented in Figure 1. The rectangular boxes are for input and assumptions; the hexagons are calculated results. The model produces three levels of results: GER, total pupils, physical resource needs, and budget needs, by year, to the defined final year. Various country-specific adaptations include specific pupil groups such as those in private or public schooling, in different provinces, or in different school levels.

The school age population trends come from the starting school-age population increasing at a constant, user provided, growth rate. The future school flows – completion, intake, repetition rates, or grade-specific promotion rates – are set as projected input by the user (typically on a linear path to a target year, or with a constant growth rate). In some country-specific applications of the World Bank models, a coefficient can be used in the GER calculation to take account of differentials in drop-out rate by grade.

From the school-age population and the school flows, the models calculate the number of primary pupils separately for males and females, and in some countries where strong differences in structure or behavior are witnessed, for sub-national states or provinces. The physical resource calculations are based on the goals for the ratio of each resource (books, teachers, classrooms) to pupils. In the case of teachers, targets can be set on the proportion of various types of teachers – civil servants, contract teachers, community teacher, etc – typically associated with different levels of remuneration. For example, a user may set a target pupil-teacher ratio of 40. This target is applied to calculate how many teachers would be needed given the calculated enrolled students. It is then relatively simple to translate the physical resource needs into a projected budget by multiplying the required resources with their projected unit costs and summing all the cost items to produce the bottom line school system budget.

Usually, these models consider recurrent and investment costs by school level, and within each school level, the costs for teachers and other school inputs. On the available resource side, the models project the growth of GDP and the portion of GDP to be allocated to education. Available resources can be compared to the estimated costs, in order to estimate shortfalls and if necessary, decide on trade-offs.

Figure 1. Schematic representation of the World Bank education projection model.



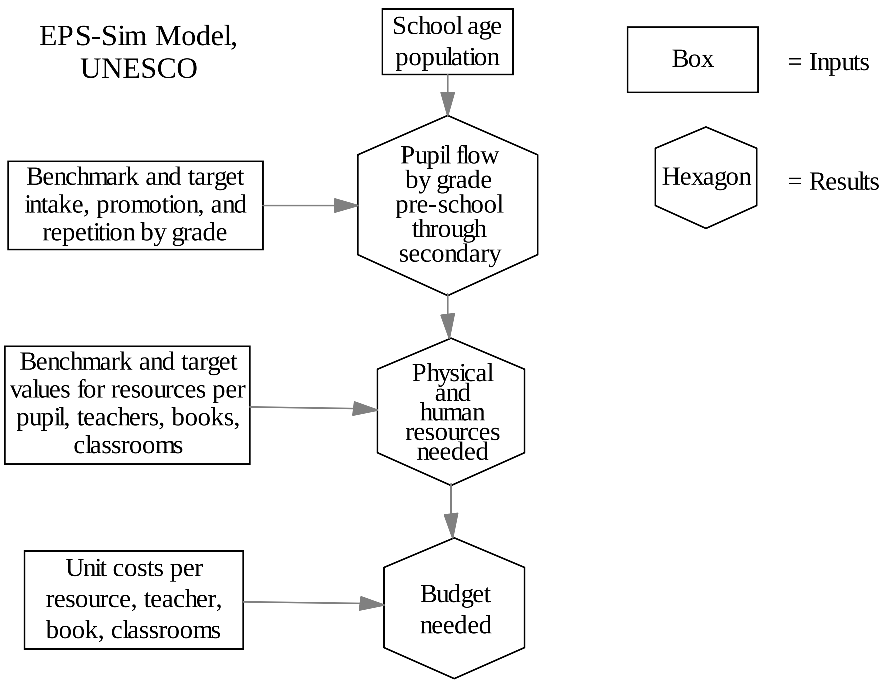
2.2 The UNESCO Education Policy and Strategy Simulation model - EPSSim

EPSSim is a generic simulation model developed by UNESCO in 2001 to provide countries involved in developing action plans for Education for All (EFA) a planning tool. At one time it was probably the most widely used education projection model, although we cannot say for certain as we did not undertake a global review of the countries that have used projection models.

The basic flows of this model are sketched in Figure 2. Like the World Bank models, it produces three levels of results: pupils and repeaters by grade, physical resources needed, and financial resources needed.

In each year (after the starting year) the new first grade pupils are calculated as the product of the assumed gross intake rate and school entry age population (the starting school-age population growing at a fixed rate, as in the World Bank group of models). First grade repeaters are added (last year's first grade multiplied by the assumed repetition rate) to get the full first grade. The second grade students are the product of last year's first grade and the assumed promotion rate plus repeaters. And so forth for each grade and for each year's new assumptions on promotion and drop-out rates. The students are divided into males and females in public and private schools with separate flows for each group. Future needs for school resources – physical and financial – are calculated almost identically to the World Bank group of models.

Figure 2. Structure of EPSSim model[3]



2.3 Modelo de Necesidades de Financiamento - MNF

The MNF model, the first in the new generation of graphical and interactive models, was developed in 2003 by a team at the Ministry of Education of Nicaragua, led by co-author Emilio Porta, to determine the financial requirements of the Nicaraguan government to achieve its education policy and goals. In Nicaragua, the MNF allowed the Ministry of Education to improve its planning capacity and establish a budget with a results-based approach. The MNF became an essential instrument to facilitate policy dialogue between donors and government in the establishment of a Sector Wide Approach (SWAp). The Nicaraguan education SWAp led to the mobilization of more than 100 million dollars in international grants to support the implementation of the Common Work Plan (CWP) that was put in place by using the MNF. In 2006, it was also applied to Guatemala with some new capabilities and updates.[4]

[3] Chang Gwang-Chol (2004) "Designing an Education Simulation Model", UNESCO
[4] The model developed for Guatemala uses Ithink 9 capabilities and can be updated using a link between the model and Excel sheet. The model interface was also improved and easily allows the creation of different scenarios. More information can be obtained from Emilio Porta or from: Modelo de Simulación para Planificación Estratégica Educativa: Una herramienta para la planificación y el diálogo. (*Simulation*

MNF uses the system dynamics approach, which has been applied successfully in the business world as well as in ecological modeling. The system dynamics approach is characterized by the inclusion of feedback mechanisms. It also requires the developer to break the system down into smaller constituent pieces, each of which may be relatively simple on its own, but which, together, produce a complex, dynamic system. The software used is specifically designed to simulate such a system.

The commercial software, iThink, is used for the model. IThink allows the developer to build the model as a flow-diagram, with boxes and arrows that represent live variables and algorithms. The results are displayed in line and bar charts (tabulations are also possible). The graphical approach facilitates, both for the modeler and user, tracking the assumed relationships. The user can change assumptions and display multiple simulations on the graphs, showing trade-offs between alternate future developments. The tool also allows a modeler to perform a sensitivity analysis to identify which variables in a system are most important to a particular outcome.

The core of the MNF model is a set of student-flow calculations like that of EPSSim (following assumptions on intake, promotion and repetition, the model calculates the flow of students through each grade). For future values of intake, promotion and repetition, there is no linear interpolation between the benchmark and target value, as in the World Bank model and EPSSim; rather, the users are presented with a time-series graph on which they can draw the assumed future trend.

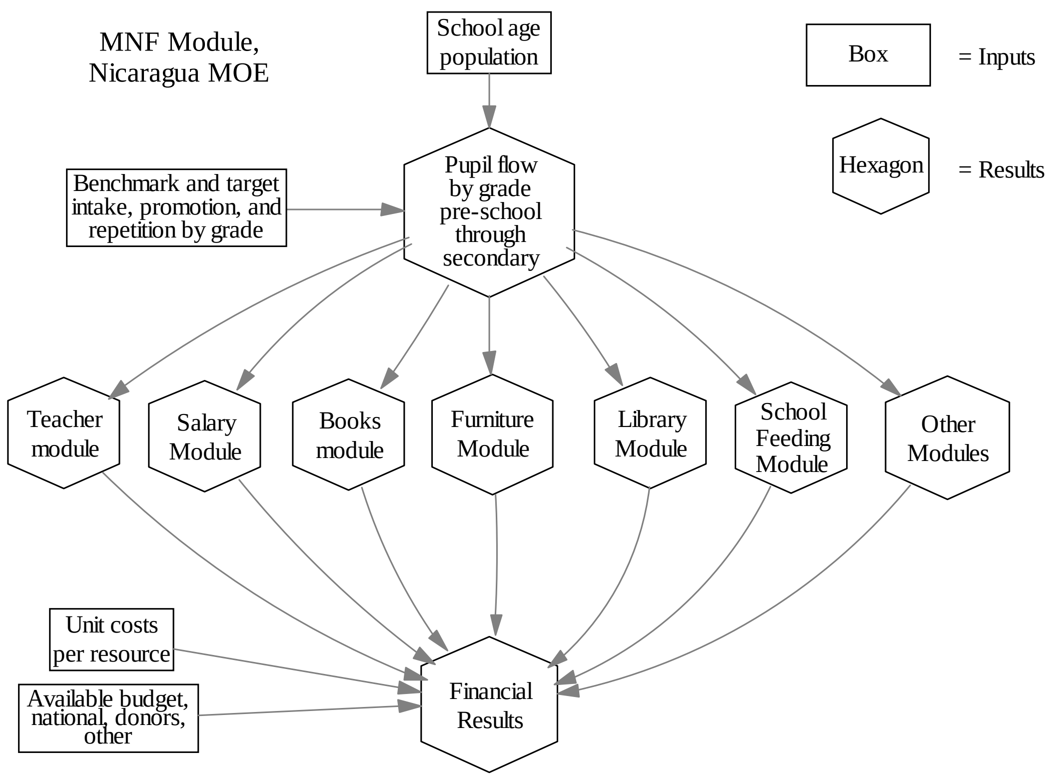
The unique structural feature of MNF is its fine operational detail in the calculation of physical resource requirements and costs and the dynamic graphical presentation of results. In both applications (to Nicaragua and Guatemala), the close collaboration with the Ministries in Nicaragua and Guatemala resulted in customized models that represent categories that are of greater interest to a particular country and thus tend to have greater “verisimilitude” and tend to generate more interest. While each application contains unique aspects and was built with the respective Ministries, they also both share a large set of core equations.

The Nicaragua application of MNF contains 27 sub-models that, together, reproduce the essential relationships of the Nicaraguan Ministry of Education budget by school program and school type. The different sub-models of MNF estimate the financial needs for: school furniture, infrastructure, expansion of school autonomy, legalization of school properties, food programs, scholarship programs, school libraries, students text books, school supplies, teachers salaries, incentive program for school and teachers, teacher training, recurrent school expenditures, school transfers, pensions, teachers social benefits, adult literacy program, special education program, supervising, monitoring and evaluation of school system, administrative cost, social communication campaigns and pedagogical innovations. A high-level aggregation of all the sub-models provides the total education budget for the Nicaraguan Ministry of Education. All of this is schematically presented in Figure 3.

Model for Strategic Educational Planning: A Tool for Planning and Dialog) Proyecto Diálogo para la Inversión Social en Guatemala, FHI 360/USAID-Guatemala, 2006

The detail and dynamic graphs have made MNF a powerful negotiation and planning tool. In planning sessions, participants have been able to voice their assumptions or goals and see the implications directly on a projected screen. The result has been better planning, successful negotiation of trade-offs between stakeholders and successful advocacy for financing. The model can be applied to different countries by taking many of the relationships from the Nicaragua and Guatemala versions, and then making special adaptations for the new countries.

Figure 3. Schematic representation of the MNF model



2.4 EPDC DemoEd Model

DemoEd, also of the new generation of education models, was developed in 2004-2006 by co-author Annababette Wils at the EPDC to provide an improved, national and regional level planning tool for education. Like MNF, it is graphical and interactive, providing users with the flexibility to easily make changes to assumptions about variables and compare the outcomes of different policy options. Its interface makes it useful for learning, planning, negotiation, optimization, and advocacy, like MNF. Like the other three models, DemoEd has a core structure that can be carried over generically from one country to another, but it can be adapted for specific country-interests and ownership-building, with some additional programming.

DemoEd, like the other models, contains a core of pupil flows by grade, determined by intake, repetition and promotion, as well as calculations for a set of resource needs – in DemoEd's case, teachers, books, school meals, and classrooms at the primary and secondary levels. As in the other models, resource needs are calculated on the desired pupil-ratios for each resource. The available budget for education (separated into recurrent, capital, training budgets) is determined exogenously by the user.

Like MNF, DemoEd is modeled in a visual simulation language with the model drawn like a flow diagram and results for multiple simulations presented in graphs, which allows users to see the impacts of different policies. The software used for DemoEd is Vensim, a sister-product to iThink. The benchmark data are entered in an Excel sheet linked to the modeling software.

DemoEd is explicitly designed with the intention of passing the model on to other users. It is available on the EPDC website, along with a model-reader version of the software and an online video-training course. The interface of the model is designed to be relatively easy to learn so users can interact with the model directly and create their own scenarios.

Some of DemoEd's unique features include the endogenous calculation of intake, promotion and repetition as well as re-entry flows, teacher training and the human capital component – population, health, and education.

DemoEd's student flow calculations are unique in that new school intake is limited by the available pool of children who have never been to school and that the phenomenon of re-entrants is included. Re-entrants are students who leave school during the school year and enter the next year, or later, as new enrollers in the same grade as they were last in. Re-entry is a hidden, unrecorded form of repetition that has been little explored in studies. Re-entrants are not only children who leave in the middle of the year and then re-enter. They are also children who sit in grade 1 for 2-3 years because there is no early childhood program. Parents have incentives to enroll their children in grade 1 early because it is a free or inexpensive source of childcare and in some systems principals have an incentive to accept these children because they are rewarded for large enrolment.

Hidden re-entry is exposed by DemoEd's population-based structure – the intake of new pupils into school cannot exceed the number of children who have not been to school yet. This condition limits the number of new intakes. In mature school systems, the intake rate is around 100. An intake rate in excess of 100 can occur briefly if there is a surge of new pupils, for example following the elimination of school fees or after a period of unrest. However, long-term gross intake and enrollment rates in excess of 100 mean that there is repetition, or the population is under-estimated, or enrollment is over-reported. If we use the assumption that population and enrollment data that are entered into DemoEd are reasonable (it is up to the user to ensure reasonable data), then repetition remains as an explanation for the high gross rates. In many countries, recorded intake rates are 130 or higher for years on end, far higher than explained by official repetition.

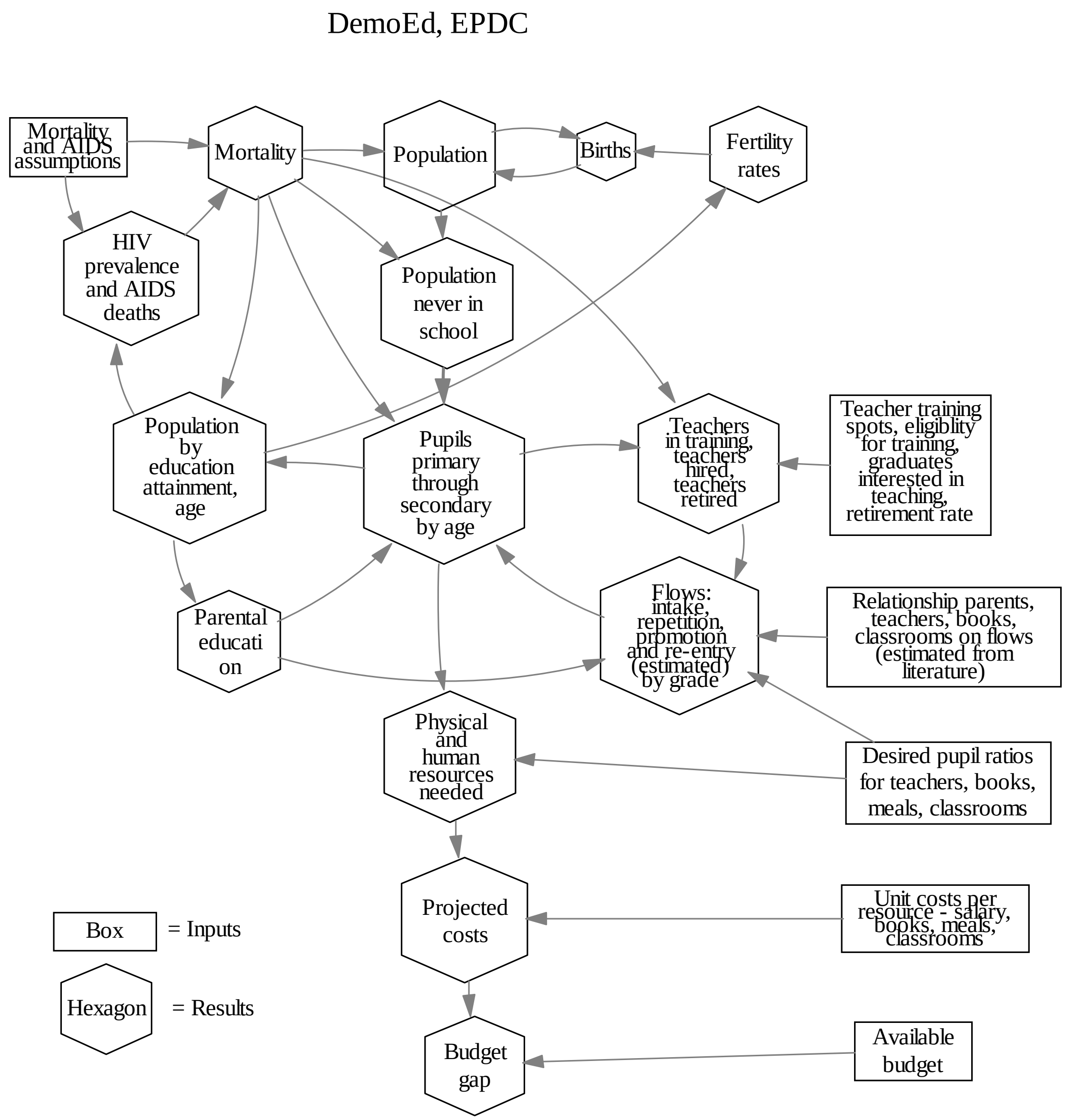
In the case of high published intake rates and no corresponding repetition, the user has to estimate the rate of re-entry to fit the intake rates. This is a calibration process that takes a few iterative simulations – the user sets a re-entry rate, runs the model, and checks in the results if the recorded intake rates are generated. If not, the user repeats the process. In some countries in order to generate the published class sizes of grades 2 and 3 the user also has to estimate re-entry at those levels.

Another unique feature is the teacher-chain and feedback-loop. In DemoEd, users can set how many teachers are trained annually and the budget for teacher training. The number of applicants to teacher training colleges is constrained by the number of eligible graduates from secondary schools and the attractiveness of non-teaching professions. The pool of teachers is affected by hiring but also by retirement and death. With this module, planners can optimize teacher training and hiring.

Beyond these core calculations, DemoEd has a wider scope than the above three models – it incorporates population projections, HIV/AIDS projections, as well as changes in human capital over time. One advantage of the more comprehensive model is that DemoEd can be used for purposes beyond education, but more importantly for the education community. This means that DemoEd can incorporate some of the social factors that influence education systems, and conversly some of the impacts of schooling on social change. Moreover, the inclusion of inter-sectoral relationships potentially improves the accuracy of the projections. For example, by having the population and AIDS deaths calculated endogenously, the model automatically includes the impact of AIDS on teachers and pupils. Another example is the way in which parental education affects school retention – as the education levels of the parent generation (age 20-49) increase, retention increases (users can specify how strong this relationship is).

With the teacher module and the link of parental education to retention, DemoEd includes a feedback loop that education begets more education. Children of more educated parents are more likely to be in school and remain there. So, if today's generation of children receives a better education, they will pass that effect on to their children, who will pass it on to theirs, and so forth. Second, better trained teachers and lower pupil teacher ratios have been correlated to more retention and better test scores in some countries. Today's pupils form the base population for tomorrow's teachers, which affects the enrollment flows of tomorrow's pupils, who in turn can become the following generation of teachers. This loop has a generation-long delay, which means both that it is difficult to jump-start education enrollment growth without prior education of a generation of teachers, and once started, it is difficult to stop. It also means the real, cumulative impacts of education are seen over a long period of time, typically multiple decades.

Figure 4. Schematic representation of the DemoEd model.



3. COMPARISON OF THE MODELS BY VARIOUS MEASURES OF USEFULNESS

This section looks at the four models by various measures – the indicators calculated, the presentation, data needed to run the models, skills needed to run the models, and accessibility.

3.1 Variables Calculated

One aspect of a user's choice of model will depend on the variables that are included. Table 2below summarizes the key variables calculated in each model.

All four models calculate primary and secondary pupils; EPSSim, MNF and DemoEd also calculate pupils by grade, as well as repeaters and graduates. MNF and DemoEd track drop-outs as well, and DemoEd also includes re-entrants.

Table 2. General calculations of five education projection models.

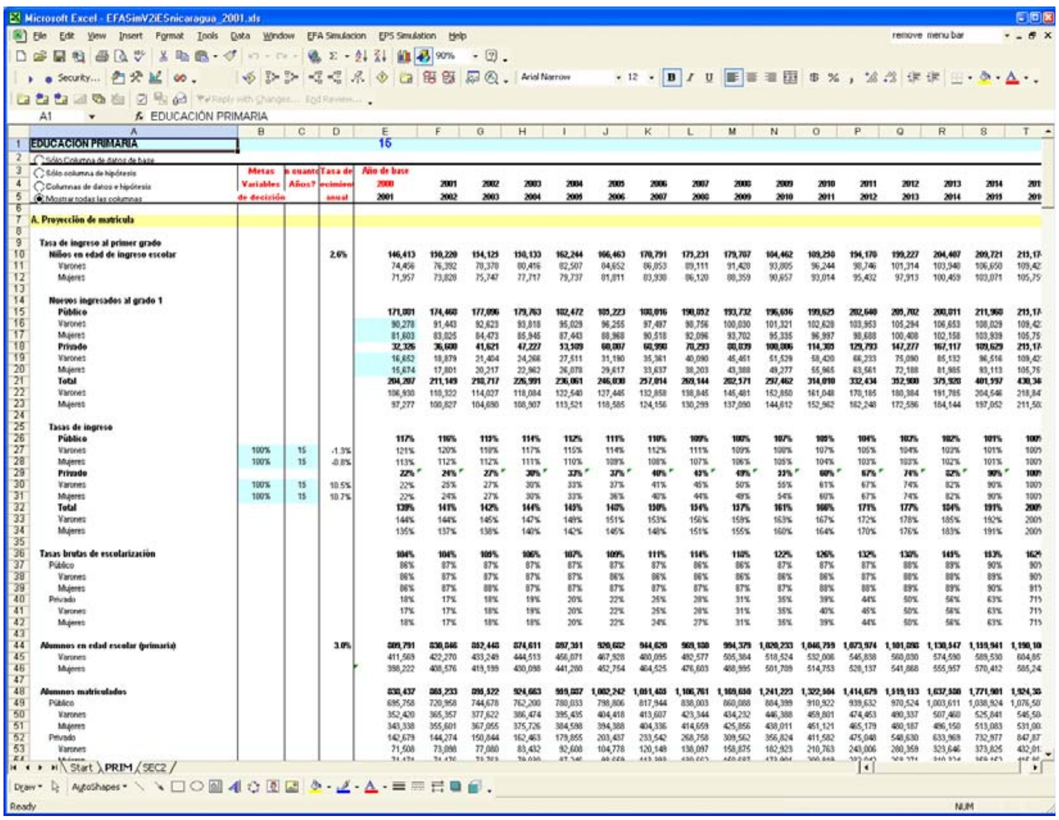
	Calculations	**World Bank**	**EPSSim**	**MNF**	**DemoEd**
Pupils	Pre-school pupils	✓	✓	✓	
	Pupils by Grade or level	✓	✓	✓	✓
	Repeaters by Grade		✓	✓	✓
	Re-entrants by grade				✓
	Drop-outs by grade			✓	✓
	Graduates by level		✓	✓	✓
Population	Population by age, sex, and education				✓
	School-age population	✓	✓	✓	✓
	Population by age				✓
	Births and Deaths				✓
HIV/AIDS	HIV prevalence by age				✓
	AIDS deaths by age				✓
Human Capital	Adult population by highest grade				✓
	Portion of adults with secondary				✓
Physical Resources	Teachers needed	✓	✓	✓	✓
	Books needed	✓	✓	✓	✓
	Classrooms needed	✓	✓	✓	✓
	Furniture needed	✓*		✓	
	Administration needed	✓*		✓	
	School feeding needs	✓		✓	
	School transportation	✓*		✓	
Budget needs	Estimated costs	✓	✓	✓	✓
	Detailed estimated costs			✓	
	Available budget	✓	✓	✓	✓
	Budget gap	✓	✓	✓	✓

3.2 Presentation

The models differ from each other not only in structure, but also in their presentation. With regards to the results presentation, the World Bank and EPSSim model are in one category of Excel models presenting the results in spreadsheet tabulations and the MNF and DemoEd model are in another category with line graphs, simultaneous presentation of multiple simulations, as well as optional tabulations. The results presentation of the MNF model is particularly strong. The model has separate pages for key results graphs and parameter-setting boxes on those tables to make quick changes to assumptions and see immediate results. The attention to results presentation was without a doubt the key to MNF's success as a negotiating and advocacy tool.

The World Bank and EPSSim models both have a typical Excel interface, showing numbers in rows and columns, highlighted by coloring of cells (e.g. blue background for input cells; white for results) and font size (large for section headings, small for calculations). The user enters new assumptions and benchmark data in the input cells, and the results are immediately calculated in the spreadsheet and are shown as new values or in charts created by the user. The interface is familiar to many users because it has a typical Excel presentation. In the EPSSim model, the user can also see graphs for selected key indicators. The World Bank also has graphs, albeit showing key indicators for one simulation at a time. While this type of interface looks familiar to Excel users, it is very difficult to see the relationships between variables from such screens.

Figure 5. Interface for setting primary school scenario in EPSSim.



The MNF and DemoEd model are both more visual and intuitive. The relationships are shown as a flow diagram on the screen with arrows connecting the variables. Behind the arrows are the model algorithms – which can be viewed by clicking on the variables. The visual interface helps modelers draw their conceptual model fully. It invites users to look and learn to understand the model logic. Figure 6 shows one of seven DemoEd screens with pupil flows. Similar screens exist for MNF. The results are also presented graphically (there is also an option to see tabulated results), with developments over time in line graphs – considerably more intuitive than a row of numbers. Moreover, the user can have multiple simulations with different assumptions presented simultaneously on the graphs.

Figure 7 shows an example of a results page from the MNF model. The red line is primary pupils in the "business-as-usual" simulation; the blue line shows a simulation with higher pupil intake.

An important aspect of presentation is how scenarios or policy simulations are set. In the two excel models, policy variables (ones that can be set by the user) are marked in green or blue. The user can simply enter a new value, and the spreadsheet shows the new results. In the two dynamic models, the user clicks on the policy variable to be changed (policy variables are also highlighted by a different color). An interactive window pops up where the user can edit the value. For some policy variables, the window is a simple box where the user enters one value. For other policy variables, the users can set a time trend, which may be non-linear. Such a more complex box is shown in Figure 8.

Figure 6. Pupil flow screen in the DemoEd model**.**

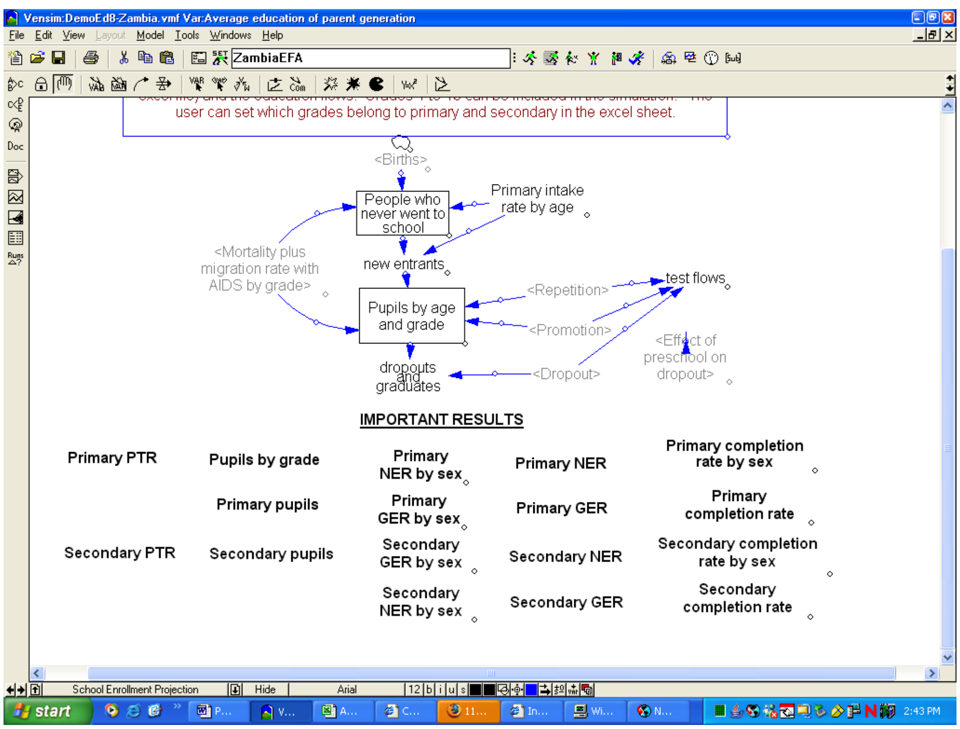


Figure7. Screen shot of MNF-model results of final need vs. budget projection in two simulations. The green and blue boxes on the bottom half of the screen are buttons to adjust assumptions.

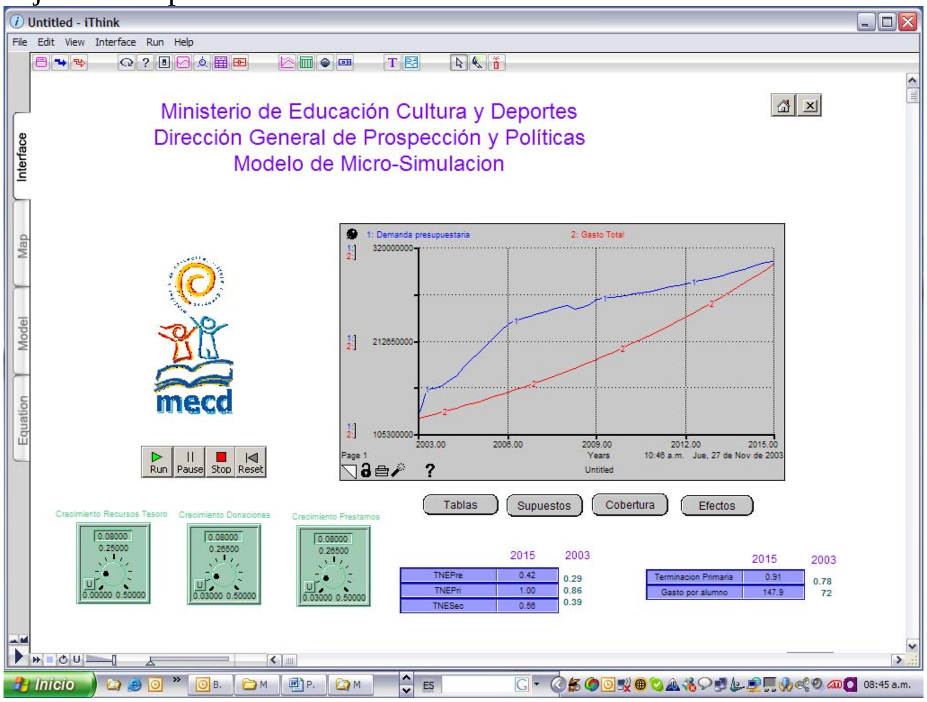


Figure 8. MNF interface for setting trends in dropout rates by school level, over time. Note the non-linear development.

3.3 Resources needed for using the models – data

Another factor in the choice of model concerns the data required – in some countries or regions limited data will eliminate some of the models. Table 3 below shows the data needed for each model.

Most of the data needed to run the different models can easily be obtained from Ministry of Education websites and documents, from National Institutes of Statistics, from downloadable household surveys, or from the UN Population website[5]. The EPDC has most of the data needed by DemoEd for a number of countries in its online database. As mentioned before, MNF is the model with greatest physical and financial detail and the data needs go beyond what is generally published. To run most of the financial modules, the modeler needs to obtain special data and adapt the modules to fit each new country. For a quick adaptation with limited data, iThink allows users to run the model by sector, so modelers can use the enrolment forecast module and make simulations while adapting financial modules and obtaining data.

The specific data needs of the World Bank model are the lowest of all four models as shown in Table 3, an attractive feature of this model.

The EPSSim, MNF and DemoEd model all need pupils, repetition and promotion or drop-out by grade -- more detailed data than the summary measures used by the World Bank model. However, the numbers of pupils are often the most easily available education numbers. Promotion and repetition rates are commonly available as they come from the same source of data as enrollment, the national EMIS system. But they are also often notoriously wrong, for example repetition rates are almost always under-estimated, often by as much as 50% (this under-estimation can be corrected by using the re-entry feature in DemoEd).

The population requirements of the models differ. The World Bank model, EPSSim and MNF have simple population requirements, needing only the starting population, the portion of the population of school-age, and the population growth rate, but as shown below, the simplicity of the population projections makes them potentially less accurate. The DemoEd model, which projects population endogenously, requires the starting population by age and sex, generally available from national sources, and projections of fertility and mortality, which can be taken from the UN Population Projections.

DemoEd is the only model that includes HIV/AIDS. The most important data required is the historical time-series of the HIV prevalence level because this is used to calculate how quickly the pandemic will spread. This time series, simple and important as it may seem, is not easy to obtain and often the modeler or user is left with making a best estimate. Sometimes the country itself provides the time series, and it can be pieced together from a series of UNAIDS annual reports[6] (however, UNAIDS warns that its past estimates may have been too high). The other data needed, average time from HIV infection to AIDS onset, AIDS mortality rate, and the age-pattern of HIV infection are

[5] http://www.un.org/popin/
[6] www.unaids.org

typically not available on a country-level but can be approximated by using data from other places.

Table 3. Data needs for five education projection models.

Data Needs	World Bank	EPSSim	MNF	DemoEd
Enrollment and School Flows				
Gross intake rate	✓	✓		
Completion rate by school level	✓			
Pupils by grade		✓	✓	✓
Pupils by age and grade				✓ (optional)
Repetition by school level	✓			
Repetition rate by grade		✓	✓	✓
Promotion rate by grade		✓		✓
Drop out by grade			✓	
Re-entry rate by grade				✓
Population				
Population of school-entry age by sex	✓	✓	✓	
Future population growth rate	✓	✓	✓	
Starting population by age, sex			✓	✓
Starting Education attainment by age, sex			✓	✓
Starting and projected birth and death rates by age				✓
HIV/AIDS				
HIV prevalence past 10 years				✓
Average time to AIDS outbreak				✓
Average mortality of AIDS patients				✓
Estimate of HIV infection age pattern				✓
Resources for schools				
Present pupil-teacher ratio	✓	✓	✓	✓
Textbooks per pupil	✓	✓	✓	✓
Teachers by certification or status	✓	✓	✓	
Classrooms per pupil	✓	✓	✓	
Furniture in schools			✓	
Administration			✓	
School feeding programs			✓	
School transportation programs				
Budget needs				
Teacher salary	✓	✓	✓	✓
Cost of books	✓	✓	✓	✓
Cost of building classrooms	✓	✓	✓	
Furniture costs			✓	
Administration costs			✓	
School feeding costs			✓	
School transportation costs			✓	
Macro-economic data				
GDP and projected growth	✓			
National budget (global, education, by level)	✓			
Summary	Data needed is common	Data needed is common	Special access to data required	Most data needed is common

3.3 Skills required to use and adapt the models

An essential skill for running any of the four models is a reasonable understanding of education statistics. Without this skill, the user cannot recognize numbers that are clearly wrong. On the other hand, modeling, as a practice, can teach people about, and sensitize them to the nature of data and the problems caused by bad data. Furthermore, to work with any of the models, the user has to have an understanding of the education system. They will need to be familiar with intake, promotion, and repetition, and how these affect flows of pupils through the system. They will need to understand resource needs per pupil, and costs for education systems. Without this understanding, a user may learn to press the buttons and get different simulations, but will not be able to make meaningful choices on which parameters to change, nor be able to interpret the results. The MNF and DemoEd models, because of their higher complexity, may require a deeper knowledge of education systems than the other models.

For the World Bank and EPSSim model, the only other additional skill is proficiency in Excel. The more adept the user is at Excel, the better he or she will be able to interpret the results, make graphs and other representations of results, and play with alternative assumptions.

To run the MNF and DemoEd models, users need to acquaint themselves, to a limited extent, with iThink and Vensim software, respectively. Running the models requires only knowing how to change parameter values and how to call up and interpret results, so learning time is not necessarily long, and there is an online course for DemoEd.

One of the most important reasons to use models is to learn about the education system. The advantage of the Excel models is that in seeing how a model is put together in Excel, a user can put together their own mini-version or add their own modules that focus in on some particular issue and start to learn about dynamics. On the other hand, Excel, while more accessible because more users know it, is more limiting. Whereas systems dynamics software is less common, yet more powerful. Users can learn about the education system by testing different policies and seeing the results, they can “test drive” their education system in the virtual cockpit of the model. To make their own models, users have to learn to use iThink or Vensim, or work with a trained technician, who will make models according to their specifications (in fact, that is how software of this type is most often used).

In the authors’ views time invested to develop the skills to run MNF and DemoEd is worthwhile. The features in these models – breaking the problem into small sub-components, feedback loops, richer structure, visual representation of internal logic and results, make them a more powerful tool for planning, policy dialogue, and learning.

Table 4. Skills needed to use the models.

Skill Needs	World Bank	EPSSim	MNF	DemoEd
Entering Benchmark data	Excel	Excel	Some iThink and understanding of model logic	Excel
Setting targets and assumptions	Excel	Excel	Some iThink	Some Vensim
Reality check on parameters	Understand education statistics	Understand education statistics	Understand education statistics	Understand education statistics
Interpretation of results	Excel, make graphs in Excel	Excel, make graphs in Excel	Can read line graphs	Can read line graphs
Change and adapt models	Excel	Excel	iThink	Vensim

3.4 Accessibility of the models

All of the models are available for use and adaptation, but in varying degrees of ease. The World Bank model can be obtained with a hard copy of *A Chance for Every Child* or from any country using it, as well as from its designers (rrakotomalala1@worldbank.org or lgacougnolle@worldbank.org). The EPSSim model can be downloaded from a UNESCO webpage (we found the quickest way to get to the webpage is to do a Google search for "Eppsim UNESCO"). The MNF model can be obtained from the modeler, Emilio Porta, and can be run using a free download of iThink (http://www.iseesystems.com/). DemoEd can be obtained from the EPDC website (www.epdc.org go to Tools/Education Projections) and can be run using the free VensimReader software. To make changes to the structure of MNF and DemoEd licenced versions of iThink and Vensim are necessary, which are available at reduced costs to users who are working in the public domain.

Table 5. Accessibility of the models.

Accessibility	World Bank	EPSSim	MNF	DemoEd
To use existing model	From developers	Online	From developer and free download of iThink Reader	Online in 2006, Excel, and free download of Vensim Reader
To make changes to model	Excel	Excel	iThink Model licence	Vensim Model licence

3.5 Results presentation

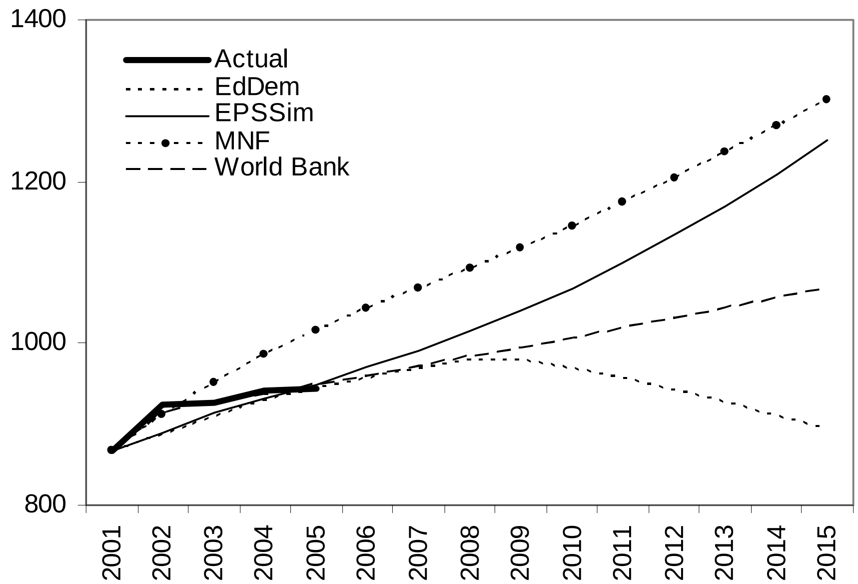
Table 6. Comparison of the results presentation.

Results presentation	World Bank	EPSSim	MNF	DemoEd
Tables of results	Yes	Yes	Yes	Yes
Graphs of results	No	Yes	Yes	Yes
Can compare multiple simulations with different policy or trend assumptions	No	No	Yes	Yes
Can trace causal paths of results	Difficult	Difficult	Yes	Yes

4. APPLICATION OF FOUR MODELS TO NICARAGUA

In this section we add some substance to the somewhat abstract exposition of model differences in the two previous sections. This section shows projections using all four models. The choice of country is Nicaragua. We compare only the core indicator, primary pupils, as it turns out to be illustrative. The simulations are for the period 2001-2015, to make a basic projection. Although 2001 is already five years past at the time of writing, this provides the additional benefit that the projections can be compared to a short period of historical developments (data up to 2005 are available). Figure 9 shows the simulation results for the four models and the historical data for the total number of primary pupils. The first observation is that the models project different paths through most of the parameters were synchronized. MNF, the World Bank models and EPSSim all project a continued increase in the number of primary school pupils, while DemoEd projects a decline in numbers from 2008 onwards. What is causing the differences?

Figure 3. Actual and projected number of primary and secondary pupils enrolled in Nicaragua, 2001-15. Historical data from the Ministry of Education, projections using the World Bank model, EPSSim, MNF and DemoEd.



Population: In the World Bank model, MNF and EPSSim, the population grows constantly at 2.2%. The starting pupils and school age population are identical in all four models. In the DemoEd model, population is calculated endogenously, following the UN 2004 projections. The UN projects that the fertility rate in Nicaragua, already falling, will continue to decline, which slows down the growth of the younger age-categories entering primary school even within the next decade, making the number of primary pupils peak and then fall after 2008. This difference in population assumptions is the primary cause for the divergence between the different models.

Intake rates: The models differ in the calculation of intake rates. The intake rates for the World Bank, EPSSim and MNF model are taken as: (*first graders minus first grade repeaters)/population age 6.* In 2001, the intake rates thus calculated are 139%, which implies that a high number of non-6 year olds are entering first grade. In the order to fit with the historical data from 2001-4, we set the intake rates to decline to 120% by 2015 (only a linear decline to a set target year is possible). This continued high level of intake rates is in line with the historical intake rates, which have been around 130 since the 1970s. As discussed above in section 2.4, over the long-term such high intake rates are not really possible and indicate some fault in reporting: either repetition is grossly under-reported repetition (including re-entry) or population, or enrollment grossly over-reported. We use the DemoEd model to test the high repetition hypothesis.

Starting Pupils and School Flows: The models all start with the same number of pupils. The initial promotion rates are 84% in 2001 rising to 95% by 2015 in all the models. The initial repetition rates are set at 8% in the MNF, EPSSim and DemoEd models, and decline to 1% by 2015. With the World Bank model, setting the repetition rate at the officially recorded 8% in 2001 would result in a dip in the number of primary pupils from 2001 to 2002 (not in line with the historical development). The cause for this drop is the low value for coefficient in the GER calculation. The World bank model calculates this coefficient by using the pupil by grade numbers. In Nicaragua, there is a sharp drop-off in the number of pupils by grade in the early school years. To get a better fit to the historical data, a higher initial repetition rate of 11% was used in the simulation. It is likely that this higher repetition rate is more realistic than the officially recorded one. Thus the World Bank model contributed to a correction of the data in its projection.

High hidden repetition or re-entry: DemoEd also uncovers higher, unrecorded repetition, and, beyond that, we find that the hidden repetition is concentrated in the lower grades, in particular in grade 1. In DemoEd, high intake rates are only possible for a very short period because the incoming pupils come out of the sub-population that has never been in school. With an intake rate of 139% (even one that is declining slowly), the never-in-school population is rapidly depleted and subsequently, the intake rate must fall. In Nicaragua, however, the recorded “intake rate” has been around 130% for years (even decades). We propose that this number has remained so high because it includes re-entrants – children who leave during the school year, and re-enroll later, not as repeaters, but as new students. With this assumption, we can set real intake close to 100% from today through 2015. To calibrate the model to the historical trend, re-entry was estimated to be around 29%, and set to remain constant up to 2015.

In this particular example, the DemoEd model was used to obtain some insights that the other models are not set up to show as easily. First there is an explanation for the excess of first graders compared to 6 year olds - re-entry. Second, in this particular country, the DemoEd model suggests that the primary pupil population is nearing its peak because it uses a more realistic population projection – fertility rates in Nicaragua are falling and if they follow trends of many other countries around the world, will continue to decline gradually. These insights can be inserted into the other models as assumptions (as higher repetition rates, and falling numbers of young children), but DemoEd makes it easier to obtain the insights in the first place. This example does not highlight the strengths of the MNF model, which lie in the detailed calculation of physical resources and its interactive screens, discussed earlier.

5. CONCLUSION

Models must be useful, representing essential aspects of the real world, so users can learn from them and improve planning. Results should be plausible. Models that are intended for use by a wider user-group should be packaged in a format that is transparent to the users and easy to learn. The data requirements should not be overly burdensome; in the best case, only data that is commonly available and accurate should be required. The user should be able to compare different simulations which can facilitate better identification of what factors influence education growth, resource needs, and budgets. Models serve different purposes. For example, a model that is aimed at showing where Nicaragua is relative to Guatemala and relative to Colombia and Mexico needs to be very different from one that shows one how to plan the education system in Nicaragua.

A high-level summary of our comparisons is provided in Table 7. All of the models reviewed in this paper are powerful and useful. As shown in the tables above, each model has advantages and limitations. To choose one over the other, the modeler must consider: a) the purpose of the modeling exercise; b) the time and data available to build the model; and c) his or her expertise in building models and in educational statistics.

Anybody who understands that a model can help make better decisions about the allocation of the education budget – potentially millions of dollars – should invest time in the exercise, to clarify the country's objectives and constraints, to obtain data, to become familiar with the model, and to adapt the model as necessary to the peculiarities of the situation at hand. To this extent, we believe that the new generation of models (MNF and DemoEd), using visual and graphic software, has real comparative advantages for national planning. Nonetheless, there are reasons to use the Excel based models as well, which have a lot to do with limited capacity in some developing countries to learn new software or work with more complex data needs. Also, for answering certain specific questions (like how much might it cost if we assume all children are in school by 2015?) the Excel models are an accessible and quick tool.

Table 7. High-level comparison on model usability according to multiple criteria, model software platform shown in parentheses**.**

World Bank model (Excel)	EPSSim (Excel)	MNF (iThink)	DemoEd (Vensim)
Accessibility of the model			
Available with a hard-copy of the book *A Chance for Every Child* or from the model architects. Runs in Excel.	Accessible online and runs in Excel	Available from model developer. Free download of iThink needed to run simulations.	Online at www.epdc.org Free download of Venism needed to run simulations. Online training course.
Ease of parameter setting			
Easy to set a limited number of targets in the spreadsheet.	Easy to set a limited number of targets in the spreadsheet.	Easy to set parameters in various interface boxes	Easy to set parameters that are highlighted in the model.
Results presentation			
Large tabulations in Excel rows, not differentiated by key variables. Different simulations on separate worksheets. No graphs with multiple simulations.	Large tabulations in Excel rows, not differentiated by key variables. Graphs for limited variables for multiple simulations available.	Highly developed and customized graphical presentation allows users to see impacts of assumptions on critical outcome variables.	Graphs of all variables and multiple simulations plus causal tracing allow user to quickly see impacts of different assumptions and to evaluate results.
Ease of use			
Easy to use for those familiar with Excel.	Easy to use for those familiar with Excel.	Easy to use once the user has been trained in using the software	Easy to use once the user has been trained in using the software. Somewhat cumbersome switching between Excel for input and Vensim to simulate.
Clarity of presentation of modeler's conceptual model			

Does not allow for easy interpretation of links and underlying logic.	Does not allow for easy interpretation of links and underlying logic.	Easy to see architect's conceptual model in model presentation as a flow diagram.	Easy to see architect's conceptual model in model presentation as a flow diagram.
Ease of updating and adapting model			
Once the user understands the model, it is easy to add new features in Excel, but it is difficult to keep track of relationships.	Once the user understands the model, it is easy to add new features in Excel, but it is difficult to keep track of relationships.	Easy to construct new links, break the problem into smaller sub-components, and to visualize conceptual model. Requires a license and training.	Easy to construct new links, break the problem into smaller sub-components, and to visualize conceptual model. Requires a license and training.
Data requirements			
Requires commonly available data, although the completion rate required is one of the less reliable education indicators.	Requires commonly available data, which is regularly produced by EMIS systems.	Requires some commonly available data and much detail on school resources and costs available only within Ministries of Education.	Requires commonly available data from different sources, which sometimes have conflicting information. In this case, requires expert judgement to benchmark the model.