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Primary Education in Developing Countries:

A System Approach to Understand the Factors that Influence the Quality

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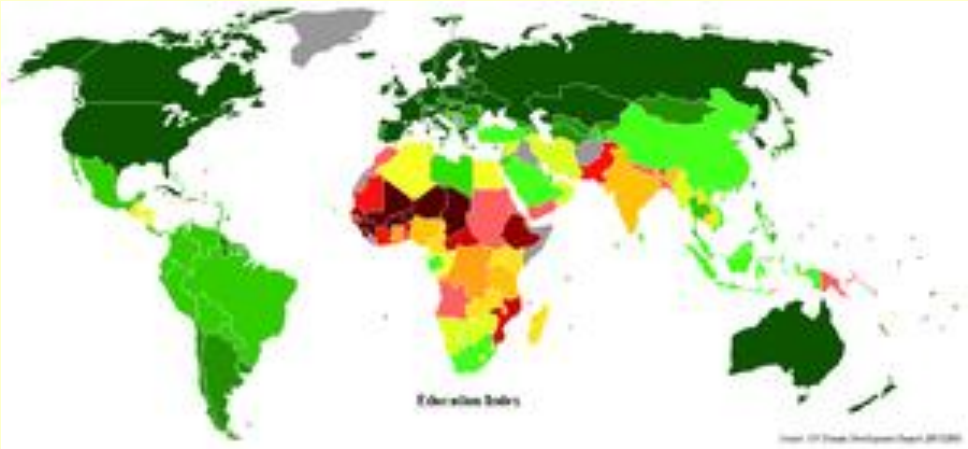
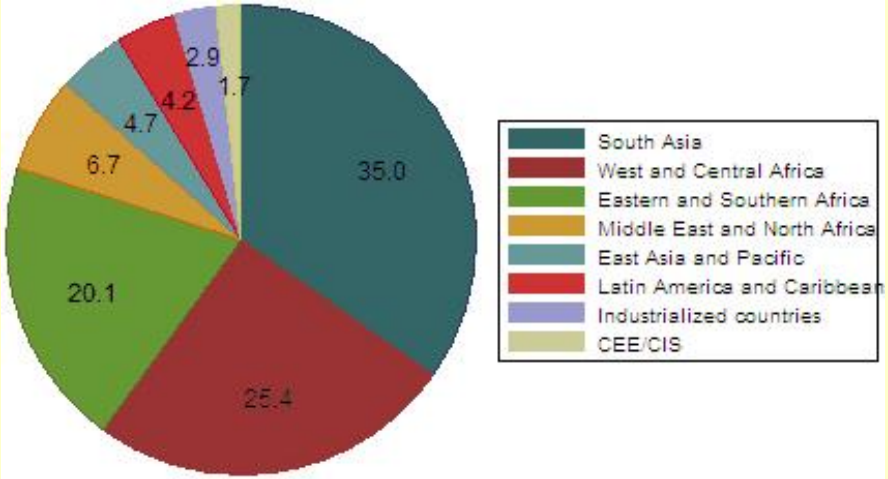
Outline

- Background
- Observations made from previous studies
- Different aspects to consider
- Proposed OR approach
- Conclusion

Background



Education Index (according to 2007/2008, Human Development Report)



101 million children of primary school age are out of school

Number of primary-school-age children not in school, by region (2007)

http://www.childinfo.org/education.html

Background

- The first stage of compulsory education is primary or elementary education.
- In most countries, it is compulsory for children to receive primary education, though in many jurisdictions it is permissible for parents to provide it.
- The transition from elementary school to secondary school or high school is somewhat arbitrary, but it generally occurs at about eleven or twelve years of age.
- The major goals of primary education are achieving basic literacy and numeracy amongst all pupils, as well as establishing foundations in science, geography, history and other social sciences.
- The relative priority of various fields, and the methods used to teach them, are an area of considerable political debate.
- Some of the expected benefits from primary education are the reduction of the infant mortality rate, the population growth rate, of the crude birth and death rate, and so on.

Observations made from previous studies

- Because of the importance of primary education, there are several models proposed to study the factors influencing the primary school enrollment and progressions.
- Various models developed to analyze issues in basic education are as follows:
  - logistic regression models [Admassu 2008],
  - Poisson regression models [Admassu 2008],
  - system dynamics models
    [Altamirano and van Daalen 2004, Karadeli et al. 2001, Pedamallu 2001, Terlou et al. 1999],
  - behavioral models [Benson 1995, Hanushek et al. 2008]
    in the contexts of different countries.
- Several factors have been identified which influence the school enrollment and drop outs.

Observations made from previous studies

- Some of the vital factors which influence school enrollment and drop outs are
  - at the macro level:
    - social, economic and logistics factors [Benson 1995, and so on],
  - at the micro level:
    - parental education, household wealth/income, distance to school, financial assistance to students and quality of schooling [Admassu 2008, Benson 1995, Rena 2007, Hanushek et al. 2008],
    - student to teacher ratio and student to class ratio [Karadeli et al. 2001 and so on],
    - poverty level of the family [Altamirano and van Daalen 2004, Akar 2008, and so on],
    - infrastructural facilities [Akar 2008].

Infrastructural facilities play a vital role for the quality of primary educational system ...
but not many models have been developed yet.

Different issues to consider

- To design a good policy, issues to be considered / understood are:

  - reason behind enrollment, drop-outs and repeaters in school,
  - perceived quality of teaching by students and parents,
  - educational level and income level of parents,
  - expectations from school by parents,
  - perceived quality of teaching by the District Educational Officer (DEO),
  - needs of different infrastructure facilities (space, ventilation, sanitation, etc.) in the school,
  - and much more … .

Goal

- to analyze importance of infrastructural facilities on the quality of the primary education system and its correlation to attributes related to the primary education system and environment including parents, teachers, infrastructure and so on (*cross impact matrix*),
- to predict the effects of infrastructural facilities on the quality of primary education system so that a discussion can be started on how to develop policies,
- to develop intervention policies using societal problem handling methods such as COMPRAM [DeTombe 1994, 2003] once the outputs of the model become known with available data.

Possible solutions

Some popular approaches are:

- system thinking approach (***cross-impact analysis***),
- system dynamics,
- mathematical modelling.

Proposed approach

A cross-impact analysis method has been proposed here to study the importance of infrastructural facilities on the quality of primary education system:

- basic entities and their relationships are described, and a list of attributes are provided,
- the *cross-impact* among attributes can be *measured* by pairwise correlation analysis.
- partial cross-impact matrix that conveys information on the *influence* of one variable over the other is illustrated using qualitative judgment,
- parameters are then fed into mathematical equations that change the level of variables throughout simulation iterations,
- significance of infrastructural facilities on the quality of primary education system can then be identified and analyzed.

Steps involved in building systems model

Step 1: *Define the system*

Systems are made of *entities*, which interact with each other and produce some outputs, which are either designed or natural.

Here, the system is *primary education system:*

a. Environment

Every system functions in an environment, which provides inputs to the system and receives outputs from the system.

Here, the environment is *society*.

b. Structure

All systems have a structure. The *body* of a system's structure is represented by the *entities* of the system and their *interrelations* or *linkages* or *connections*.

Here, entities are

- *student,*
- *teacher,*
- *parents,*
- *educational officials,*
- *infrastructure* and
- *local community.*

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Steps involved in building systems model

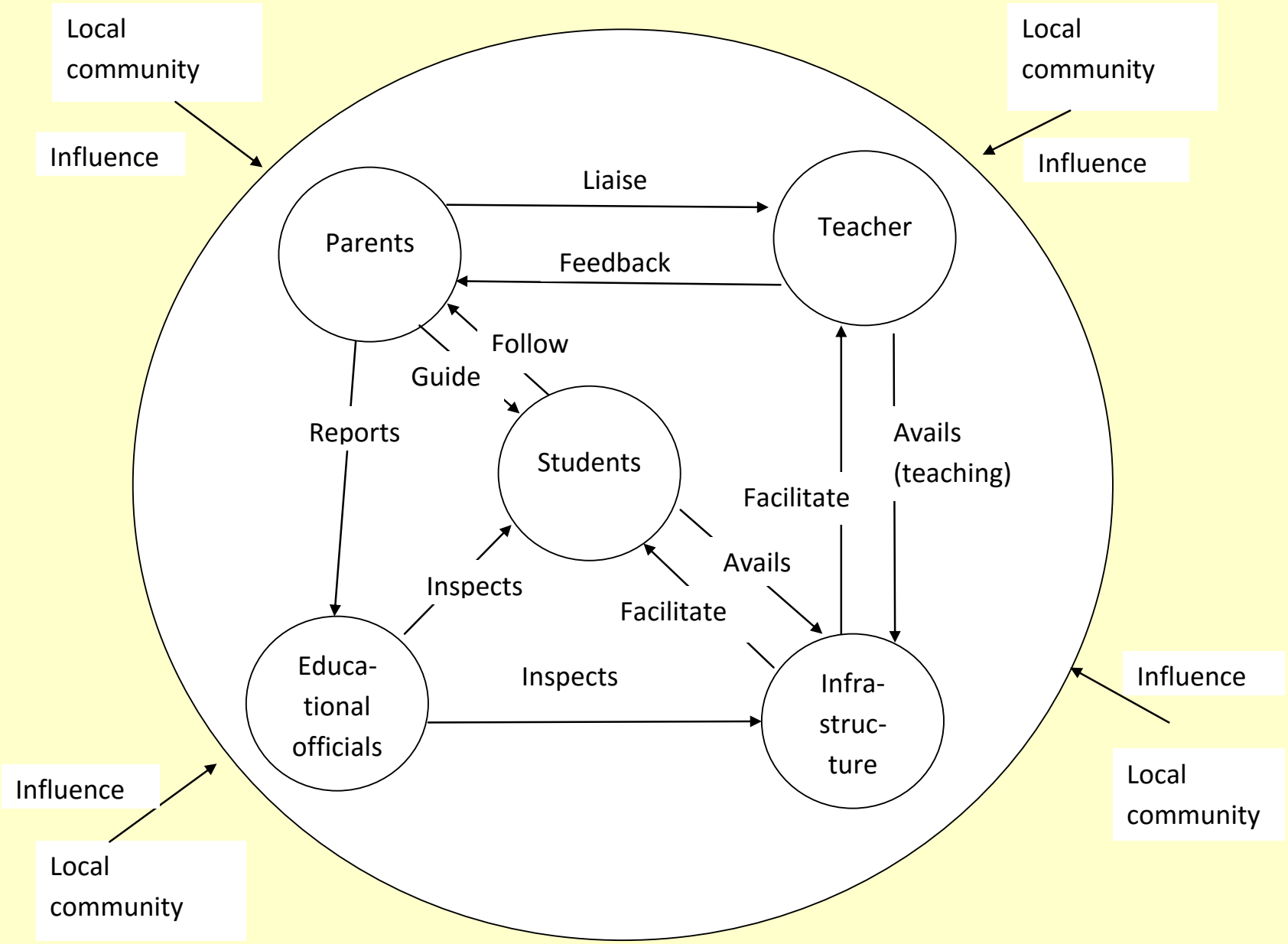
c. Linkages

- It is important to try to understand, what linkages make up the system's structure, which entities are linked with each other, and the implications of these linkages on the behavior of the entities in particular.
- The entity relationship diagram of the system is a better illustration of the relationships among the entities identified.

Here, linkages are

- *liaise,*
- *feedback,*
- *follows,*
- *guides,*
- *avails,*
- *reports,*
- *inspects,*
- *influence,* etc..

Entity relationship diagram



Steps involved in building systems model

Step 2: ***System entities and relationship equations***

- The dynamic change of the system state is referred to as system **behaviour**.
- The **state** of a system is an instantaneous snapshot of levels (or, amounts) of the relevant attributes (or, characteristics) possessed by the entities that constitute the system.
- In all systems, every entity possesses many **attributes**, but only a few attributes are *relevant* with reference to the problem at hand. Some attributes are of immediate or short-term relevance while others may be of relevance in the long run.

List of attributes:

Entity 1: ***Student:***

1.1 Level of *enrollment* (*loe*).
1.2 Level of *boys drop-outs in a school* (*lbd*).
1.3 Level of *girls drop-outs in a school* (*lgd*).
1.4 Level of *repeaters* in a school (*lr*).

Entity 2: ***Teacher:***

2.1 Level of *perceived quality of teaching* by the Students (*lts*).
2.2 Level of *perceived quality of teaching* by the Parents (*ltp*).

Steps involved in building systems model

Entity 5: ***Infrastructure:***

5.1 Level of *space and ventilation* available in a classroom (*lsv*).

5.2 Level of *cleanliness and other facilities* such as board, mats, table/chair, educational aids (maps, toys, charts, etc.) (*lc*).

5.3 Level of *sanitation facilities* for general purpose (for both boys and girls) (*ls_g*).

5.4 Level of *separate sanitation facilities* for girls (*ls_s*).

5.5 Level of *drinking water facility* available (*ldw*).

5.6 Level of availability of *playground area and other equipment* for children used in playing (*lpa*).

5.7 Level of *bad organising* in the classrooms (*lbo*):

a. Number of cases in which more than one class is conducted in a single instructional classroom.

b. Number of cases in which more than 40 people are accommodating in a single instructional classroom.

Entity 6: ***Local community:***

6.1 Level of *participation* of local community (*llc*).

6.2 Level of *awareness* of local community about educational benefits (*lale*).

Conjectures valid in systems approach

- Modeling and forecasting the behavior of complex systems are necessary if we are to exert some degree of control over them.
- Properties of variables and interactions in our large-scale system:

- System variables are bounded:

$$0 \le x_i(t) \le 1 \;\; \forall\, i = 1, 2, \ldots, N, \text{ and } t \ge 0,$$

where $x_i(t)$ is the level of variable i in period t.

- A variable increases or decreases according to whether the *net impact* of the other variables is positive or negative.

To preserve boundedness, $x(t+\Delta t)$ is modelled as:

$$x_i(t+\Delta t) = x_i(t)^{P_i(t)},$$

where

$$P_i(t) = \pm \frac{1 + \Delta t \cdot |\text{sum of } \textit{negative impact} \text{ on } x_i|}{1 + \Delta t \cdot |\text{sum of } \textit{positive impact} \text{ on } x_i|}.$$

[Julius 2002]

Conjectures valid in systems approach

- A variable's response to a given impact decreases to 0 as that *variable* approaches its upper or lower *bound*.
- It is generally found that bounded growth and decay processes exhibit this sigmoidal character.
- All other issues being constant, a variable (attribute) will produce a greater impact on the system as it grows larger (*ceteris paribus*).
- Complex interactions are described by a looped network of *binary interactions* (this is the basis of cross-impact analysis).

Steps involved in building systems model

- The choice of relevant attributes has to be made carefully, keeping in mind both *short-term* and *long-term* consequences of solutions (decisions).
- All attributes can be associated with given levels that may indicate *quantitative* or *qualitative* possession.

- When entities interact through their attributes, the levels of the attributes might change, i.e., the system behaves in certain directions.
- Some changes in attribute levels may be *desirable* while others may not be so.
- Each attribute influences several others, thus creating a web of complex interactions that eventually determine system behavior.
  In other terms, attributes are variables that vary from time to time.
- They can vary in an unsupervised way in the system.
- However, variables can be **controlled** directly or indirectly, and partially by introducing new ***intervention policies***.
- However, interrelations among variables should be analyzed carefully *before* introducing new policies.

Implementation of cross-impact analysis

Four steps of **implementation**:

Step 1. Set the **initial values** to identified attributes obtained from published sources and surveys conducted.

Step 2. Build a **cross-impact matrix** with the identified relevant attributes.

a. Summing the effects of column attributes on rows indicates the effect of each attribute in the matrix.

b. The parameters α_{ij} can be determined by creating a *pairwise correlation matrix* after collecting the data, and adjusted by subjective assessment.

c. Qualitative impacts are quantified subjectively as shown in the table. Qualitative impacts can be extracted from a published sources and survey data set.

Impact rates of variables (attributes).

Representation of Impact	Value	Description
++++	0.8	Very strong positive effect
+++	0.6	Strong positive effect
++	0.4	Moderate positive effect
+	0.2	Mild positive effect
0	0	Neutral
_	-0.2	Mild negative effect
_ _	-0.4	Moderate negative effect
_ _ _	-0.6	Strong negative effect
_ _ _ _	-0.8	Very strong negative effect

Implementation of cross-impact analysis

d. The impact of infrastructural facilities on primary school enrollments and progression become visible by running the simulation model.

e. An exemplary partial cross-impact matrix with the attributes and their hypothetical values above is illustrated as follows:

Partial cross-impact matrix

		Students				Parents		
		loe	*lbd*	*lgd*	*lr*	*elp*	*ilp*	*lefs*
Students	*loe*	*	-	-	+	0	0	++
	lbd	--	*	0	0	0	0	0
	lgd	--	0	*	0	0	0	0
	lr	--	+++	+++	*	0	0	0
Parents	*elp*	++	--	--	--	*	0	0
	ilp	++	--	--	0	0	*	0
	lefs	--	+	+	--	0	0	*

Simulating the system using cross impact analysis

Step 3. Simulate the system for ***m*** iterations (50 iterations) and tabulate the behavior of each attribute in every iteration. Plot the results on a worksheet.

Step 4. Simulate the system with identified *policy variable*.

- *Identify* a policy variable to achieve the *desired level or state* and *augment* the cross-impact matrix with this policy variable by qualitative assessment of pairwise attribute interactions.
- The policy variable introduced is infrastructural improvements, which shows positive impact on level of space and ventilation, cleanliness and other facilities such as board, mats, table/chair, educational aids, eparate sanitation facilities for girls and general sanitation facilities, available drinking water facilities, and class organization.
- Observe the system for another ***m*** iterations, and ***check*** if the desired state is achieved by introducing the policy variable. Compare the results.

Data acquisition

- The cross-impact systems model requires data from an *unbiased sample* (through selecting a particular region or state of a developing country).
- Data can be obtained from conducting personal surveys and data published from the selected developing country.
- The information obtained can be converted into meaningful qualitative and quantitative impact factors after being normalized. Then, the initial values for the attribute levels $x_i(0)$ can be set accordingly.
- Once initial attribute levels are determined from the data and cross-impact parameters α_{ij} are calculated, the model is simulated.
- These simulations illustrate the effects of infrastructural facilities on quality of primary education over time.

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The following simulation is based on **data** from ***Gujarat*** (*India*).

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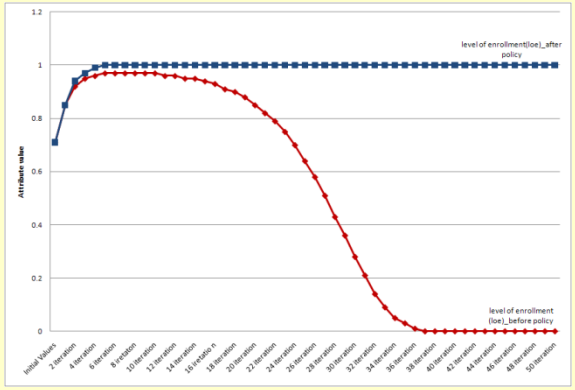
Simulation results

- **Level of enrollment (*loe*)**

Level of enrollment (*loe*)



Before implementation of policy variables (red line):

- sharp increase at the beginning phase of the simulation (first 12 iterations), and then there is steady decrease after a certain period of time (first 12 iterations).

After implementation of policy variables (blue line):

- steady increase from initial value (0.71) to unity.

Analysis:

- *increase in level of enrollment in first 12 iterations happens because of the response lag in population to bad quality school system,*
- *instant impact on the level enrollment after implementation of policy variables because students and parents are more eager to have the children attend a nice looking healthy school.*

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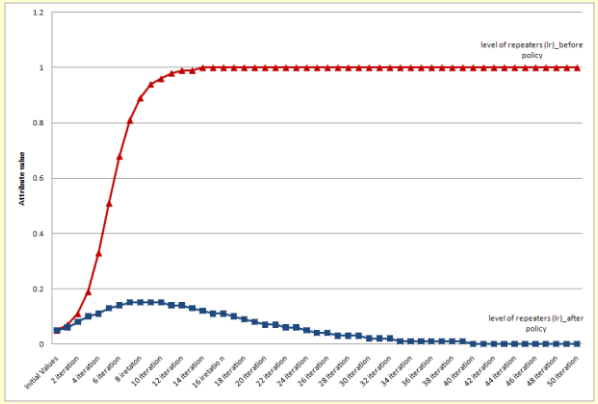
Simulation results

- **Level of repeaters (*lr*)**

Before *implementation of policy variables* (red line):
- steady increase from 0.05 to unity in 50 iterations.

After *implementation of policy variables* (blue line):
- steady increase from initial value 0.05 to 0.12 in first 14 iterations and then declined to zero in 50 iterations.

Level of repeaters (*lr*)



Analysis:

- *level of repeaters has instant impact on level of repeaters if the infrastructural facilities are bad*

  (assumption: *teachers are doing their best in teaching* – this variable is static - so variable impacted here is *teaching aids*),

- *increase in level of repeaters in first 14 iterations is because improvement in the infrastructure does not have an instant impact on the level repeaters.*

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Simulation results

- **Level of dropouts**

Before implementation of policy variables (red line):
- steady decrease from 0.2 in initial iterations and there is steady increase to unity.

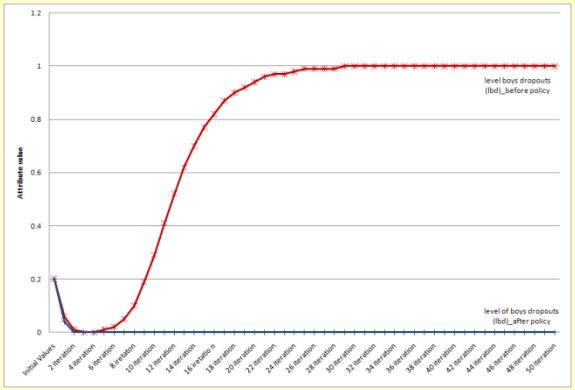
After implementation of policy variables (blue line):
- steady decrease from initial value 0.2 to zero.

Analysis:

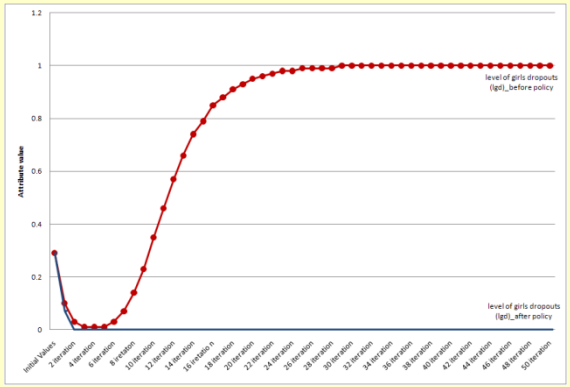
- level of dropouts is reduced in the initial iterations because students and teachers are getting adjusted to the school environment. Then there is steady increase in dropouts because of frustration from students and parents on quality of school,

- decrease in level of dropouts is because improvement in the infrastructure have an impact on the students and parents.

Level of boys dropouts (*lbd*)



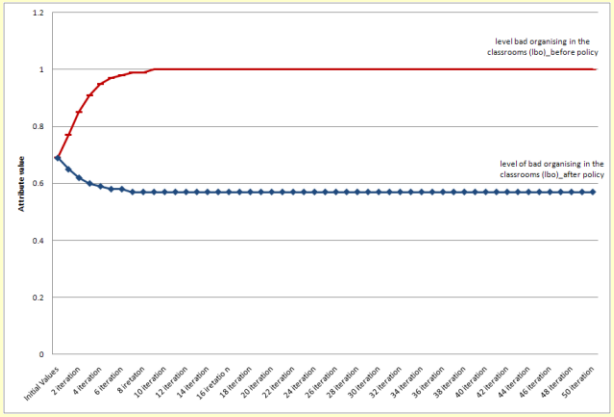
Level of girls dropouts (*lgd*)



Simulation results

- **Level of bad organizing of classroom (*lbo*)**

Level of bad organizing of classroom (*lbo*)



Before implementation of policy variables (red line):
- steady increase from 0.69 to unity.

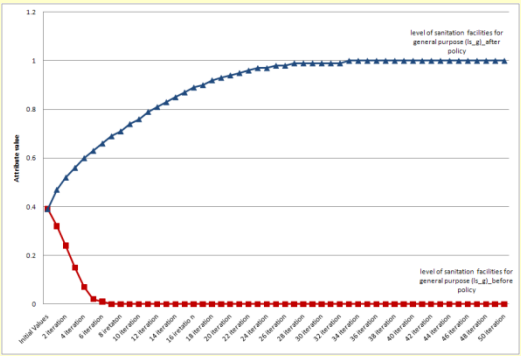
After implementation of policy variables (blue line):
- decrease from initial value 0.69 to 0.57.

Analysis:

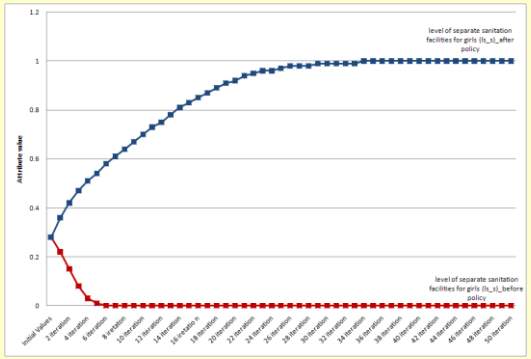
- *not greatly affected because there are several other attributes that influence this variable such as the level of perceived quality of teaching by the district educational officer and number of teachers*.

- **Other important variables**

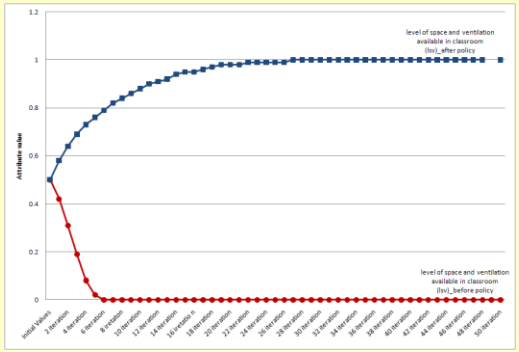
Level of sanitation facilities for general purpose (*ls_g*)



Level of separate sanitation facilities for girls (*ls_s*)



Level of space and ventilation available in a classroom (*lsv*)



Conclusions

- A cross-impact model is developed here to study the influence of infrastructure facilities on primary education enrollment and progression.
- The cross-impact matrix developed illustrates the influence of one variable over the others, and it also provided the identification of the impact variables (i.e., policy variables).
- We describe the simulation method and the data to be collected if such a model is executed.
- Impact of infrastructural facilities influence has been studied on the primary education quality.
- This study is not meant to exclude any other important variables such as gender and parental status that affect school attendance and dropouts.

- Countries considered for future application:
  - Colombia,
  - India,
  - Turkey,
  - perhaps, China, the Philippines, etc..

Conclusions

Conclusions

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Conclusions

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Thank you very much for your attention!

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