A SYSTEM DYNAMICS MODEL TO STUDY THE IMPORTANCE OF INFRASTRUCTURE FACILITIES ON QUALITY OF PRIMARY EDUCATION SYSTEM IN DEVELOPING COUNTRIES

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Abstract

The system dynamics approach is a holistic way of solving problems in real-time scenarios. This is a powerful methodology and computer simulation modeling technique for framing, analyzing, and discussing complex issues and problems. System dynamics modeling and simulation is often the background of a systemic thinking approach and has become a management and organizational development paradigm. This paper proposes a system dynamics approach for study the importance of infrastructure facilities on quality of primary education system in developing nations. The model is proposed to be built using the Cross Impact Analysis (CIA) method of relating entities and attributes relevant to the primary education system in any given community. We offer a survey to build the cross-impact correlation matrix and, hence, to better understand the primary education system and importance of infrastructural facilities on quality of primary education. The resulting model enables us to predict the effects of infrastructural facilities on the access of primary education by the community. This may support policy makers to take more effective actions in campaigns.

Keywords: system modeling, cross impact analysis, primary education

1. Introduction

The first stage of compulsory education is primary or elementary education which is preceded by pre-school or nursery education and followed by secondary 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 to secondary school or high school is somewhat arbitrary, but it generally occurs at about eleven or twelve years of age. Some educational systems have separate middle schools with the transition to the final stage of education taking place at around the age of fourteen.

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 areas, 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.

Because of the importance of primary education, there are several models proposed to study the factors influencing the primary school enrollment and progressions. There are various models developed to analyze issues in basic education are logistic regression models [1], poisson regression models [1], system models [2, 8, 12, 15], behavioral models [5, 6] in the contexts of different countries. Several factors have been identified which influence the school enrollment and drop outs from various studies. Some of the vital factors at macro level are social, economic and logistics factors [5], and at the micro level there are parental education, household wealth/income, distance to school, financial assistance to students and quality of school [1, 5, 13].

Hanushek et al. [6] shows that school quality and grade completion by students are directly linked. The World Bank published several reports on achieving universal primary education [4, 14]. Serge [14] focuses on the infrastructure challenge in Sub-Saharan Africa and the constraints to scaling up at an affordable cost. Terlou et al. [15] have developed a system dynamic model to investigate the low efficiency primary education in Latin America. This model looks at the progression through primary school and includes causal chains leading to the progression, dropout and repetition of students.

Karadeli et al. [8] have developed a model to analyze the future quality of Turkish basic educational system depending on the budget of the Ministry of National education. In this model, quality of education and progression of students is influenced by the student to teacher ratio and student to class ratio. Altmirano and van Daalen [2] proposed a system dynamics model to analyze the educational system of Nicaragua and helps in identifying and analyzing the consequences of policies that are aimed at improving the coverage of the different educational programs, reducing illiteracy and increasing the average number of schooling years of the population. This study shows that implementing literacy programs and introducing a program in which families in extreme poverty receive a subsidy has an effect on school coverage as well as on the number of illiterate people.

However, there are not many models developed in literature that study the importance of infrastructural facilities on school enrollment and progression. In fact, Akar [3] reports about the infrastructural problems at Turkish schools and their negative impact on the pupils. So, in this research work, we mainly concentrate on developing a system dynamics model that could predict the influence of various variables (especially infrastructure) on the school enrollment and progressions. In this paper, we present details about model construction and the selection of attributes.

2. The cross impact method and system definition for importance of infrastructure facilities in primary education

A cross impact method is one of the most popular systems thinking approaches developed for identifying the relationship among the variables defining systems [7, 16]. We refer to [9, 11] for more detailed information on system dynamics modeling. Next, let us first describe the steps to be followed for understanding and building a systems model.

2.1. Definition of the system

Systems are defined based on entities, which interact with each other and produce some outputs that are either designed or natural. A system receives inputs and converts them through a process and produces outputs. All the outputs of a system need not be desirable. In the present context, the system represents primary education system.

a. Environment

Every system functions in an Environment, which provides inputs to the system and receives outputs from the system. In our context, the Environment is the 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 interrelationships or linkages or connections. The entities in our system are defined as follows.

1. student,
2. teacher,
3. parents,
4. educational officials,
5. infrastructure and
6. local community.

c. Linkages

The linkages among entities may be physical (e.g., facilitates), electro-magnetic (e.g., electrical, electronic and communications systems, and so on), and information-based (e.g., influence, and so on). It is important to try and understand, what linkages exist in 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 illustrated in Figure 1. Exchange of matter, information and/or spirit between two entities causes a change in the state of both entities. This is reflected as system behavior.

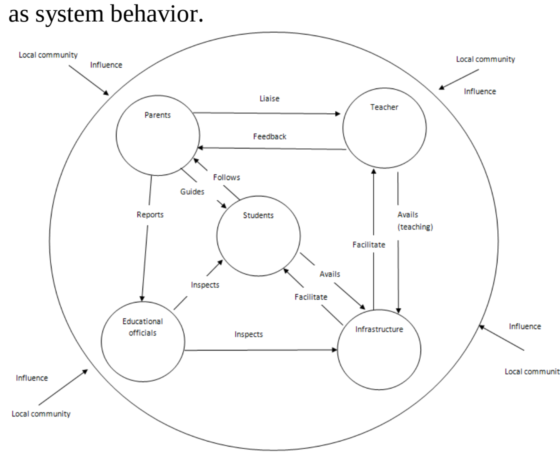

Fig. 1: Entity relationship diagram on primary education system.

2.2. System entities and relationships equations

The dynamic change of the system state is referred to as *system behavior*. 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 respect to the problem at hand. Some attributes are of immediate or short-term relevance while others may be of relevance in the long run. The choice of relevant attributes has to be made carefully, keeping in mind both the short-term and long-term consequences of solutions (decisions). All attributes can be associated with given levels that may indicate quantitative or qualitative possession. The set of attributes identified for the model is given below.

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 dropouts 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*).

Entity 3: *Parents:*

3.1 Educational level of parents (*elp*).
3.2 Income level of parents (*ilp*).
3.3 Level of expectations from school by the parents (*lefs*).

Entity 4: *Educational officials:*

4.1 Level of perceived quality of teaching by the District educational officer (DEO) (*ltd*).

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*).

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 which eventually determine system behavior. In other terms, attributes are variables that vary from time to time. They can in an unsupervised way vary in the system. However, variables can be controlled directly or indirectly, and partially by introducing new intervention policies. However, interrelationships among variables should be analyzed carefully before introducing new policies.

The following ***conjectures*** are valid in the systems approach (the following part of Section 2 is motivated by Julius [7]).

a. *Modeling and forecasting the behavior of complex systems are necessary if we are to exert some degree of control over them.*

b. *Properties of variables and interactions in large scale system variables are bounded such that*:

i. System variables are bounded. It is now widely recognized that any variable of human significance cannot increase indefinitely. There must be distinct limits. In an appropriate set of units these can always be set to a value between one and zero:

$0 \le x_i(t) \le 1$, for all $i = 1,2,\ldots,N$, and all $t \ge 0$, where $x_i(t)$ is the level of variable i in period t.

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

To preserve boundedness, $x_i(t+\Delta t)$ is calculated by the transformation

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

where the exponent $P_i(t)$ is given by

$$P_i(t) = \frac{1+\Delta t\,|\text{sum of negative impacts on } x_i\,|}{1+\Delta t\,|\text{sum of positive impacts on } x_i\,|}.$$

iii. A variables' response to a given impact decreases to zero as that variable approaches its upper or lower bound. It is generally found that bounded growth and decay processes exhibit this sigmoidal character.

iv. All other things being kept fixed (constant), a variable (attribute) will produce a greater impact on the system as it grows larger (*ceteris paribus*).

v. Complex interactions are described by a looped network of binary interactions (this is the basis of the *cross impact analysis*).

3. Simulating the system using cross impact analysis

There are four steps to follow while implementing the cross impact analysis (*CIA*) in our case. First, we should conduct the simulation by considering primary education system without human intervention. Then, we conduct the same analysis on simulation of primary education by implementing the selected policy variables such as infrastructure improvement and observe the change in system dynamics. The four steps of model construction are explained below.

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

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

Table 1. Impact rates of variables (attributes).

Step 2. Build a cross impact matrix with the identified relevant attributes. Summing the effects of column attributes on rows indicates the effect of each attribute in the matrix. The parameters α_{ij} can be determined by creating a pairwise correlation matrix after collecting the data, and adjusted by subjective assessment. In Table 1, qualitative impacts are quantified subjectively. Qualitative impacts can be extracted from published reports and surveys prepared. The impact of infrastructural facilities on primary school enrollments and progression becomes visible by running the simulation model. An exemplary partial cross-impact matrix with the attributes and their hypothetical values are listed above is illustrated in Table 2.

		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	*

Table 2: Partial cross impact matrix.

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

Step 4. Identify a policy variable to achieve the desired level or state and augment the cross impact matrix with this policy variable with qualitative assessment of pairwise attribute interactions. Observe the system for *m* iteration, and check if the desired state is achieved by introducing the policy variable. Compare the results.

4. Summary and Conclusion

A cross-impact model is developed here to study the influence of infrastructure facilities on primary education enrollment and progression. The cross-impact matrix illustrates the influence of one variable over the others and it also has a provision to identify the impact variables (i.e., policy variables). Here, we identify certain entities and attributes that might affect quality of primary education.

The proposed cross impact model enables to study the importance infrastructure facilities in school enrollment and progression for different countries and societal environments. This model can be used in achieving better management and sustainable development [10].

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