June, 1968

The Use of Graphical Analysis In Education Planning

Dr. David R. Evans

This paper discusses the use of graphical techniques as tools of analysis and projection in planning the growth of an educational system. Graphs are shown to be particularly valuable when used to investigate the implications of alternate growth patterns for various aspects of the school system. The technique is intended to precede and augment the usual forms of statistical analysis. Reasons are suggested why graphs are particularly appropriate to the rapidly growing educational systems in developing countries.

THE USE OF GRAPHICAL ANALYSIS IN EDUCATION PLANNING

David R. Evans

A recent survey by the International Bureau of Education indicates that nearly every country in the world is undertaking educational planning of some kind and nearly half of them are attempting to produce long range plans for future expansion.[1] These plans quickly immerse the reader in extensive tables of numbers—population data, school enrollment figures, figures on the educational level of the working force, on teacher qualifications, and so forth. These numbers are frequently given to as many as six significant figures, suggesting a degree of accuracy that is hard to believe.

But most striking of all, perhaps, is the almost total absence of the use of graphical techniques, either for display purposes or as part of the projection process used to arrive at the estimate. A half dozen of the basic references in the field can be read from cover to cover without encountering more than that number of graphs. This situation is puzzling in view of the advantages of graphs in such areas as display, extrapolation, and projection.

In newly developing countries, where educational planning has assumed particular importance, conditions would seem to be especially conducive to the use of graphical techniques. Government officials are frequently new at their jobs and often have only limited understanding of the process of educational development. Graphical display of the dynamic patterns in the educational system would allow the implications of various policy alternatives to be clearly and simply demonstrated. Educational and census data is typically sketchy or even completely absent. Such data severely limits the accuracy of calculations based

[1] International Bureau of Education, *Educational Planning* (Geneva: I.B.E., 1962), p. v.

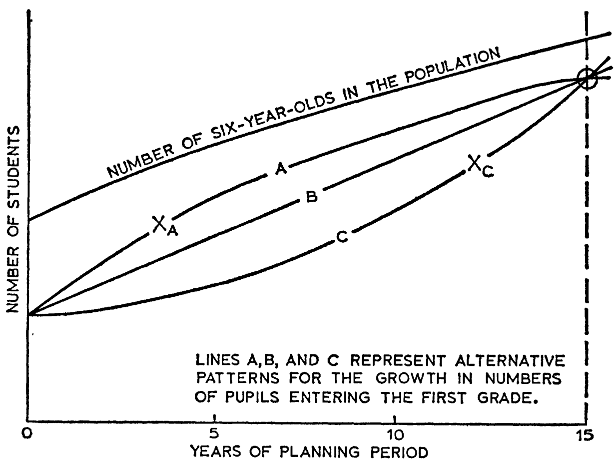
on it and argues for techniques which do not give spurious impressions of precision. Finally, the techniques of extrapolation and projection are inherently graphical anyway. Why not display them as graphs?

This paper discusses some of the educational planning problems which seem to lend themselves particularly well to graphical methods of analysis and display. It focuses on the development of an educational system to meet targets set by economists and manpower analysts and discusses the methods for solving problems such as planning the growth rate of primary schools relative to the population growth rate and determining the effects of dropout rates, the demand for teachers, and the need for teacher training facilities.

THE GROWTH OF PRIMARY ENTRANCE RATES[2]

Harbison and Myers indicate that the highest educational priority in a Level 1 country is the expansion of primary education.[3] This is particularly true of many countries in tropical Africa where less than 50 per cent of the age group is in primary school. Figure 1 is a schematic drawing of the situation in such a country. The top line represents the growth in the number of six year olds over the fifteen year planning period being considered. The lines *A*, *B*, and *C* represent three alternate paths for expanding entrance rates to primary school to meet a target enrollment percentage indicated by the circled point.

FIGURE 1.



What are the policy implications of these three growth patterns? Line *C* indicates a policy decision to use the first part of the planning period to train the teachers and accumulate the resources for a rapid expansion during the latter part of the period. The initial five years of grace would give time for the

[2] The technique discussed below originated in an analysis undertaken jointly by David B. Lewis and the author.

[3] F. Harbison and C. Myers, *Education, Manpower, and Economic Growth* (New York: McGraw Hill, 1964).

economy to expand to the point where it would be better able to support an enlarged school system. (This assumes that enough trained people are already being produced to staff such an expansion.) Note, however, the difficulty which occurs at the end of fifteen years. Either expansion must be sharply reduced or the target will be rapidly surpassed in the next year.

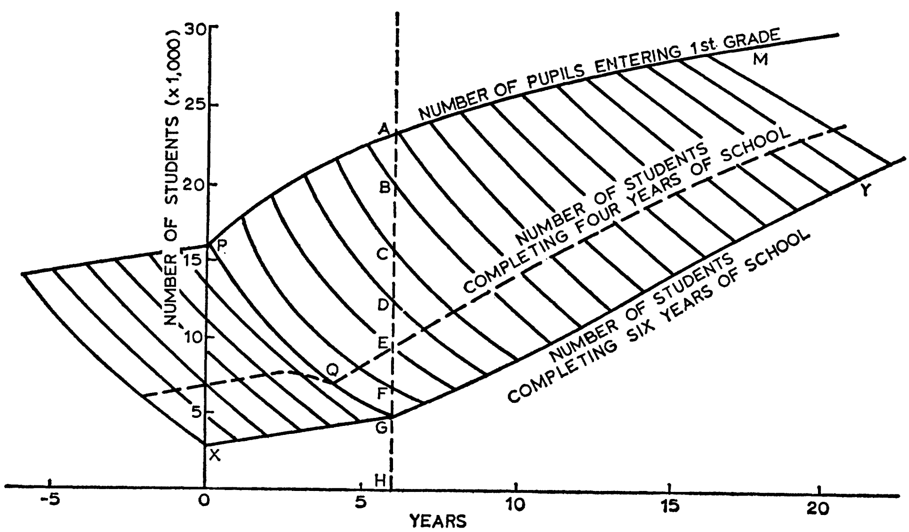
In comparison, line *B* indicates a steady rate of growth throughout the planning period. The rate of growth of *B* is less than the maximum rates of growth (indicated by *X*) for either *A* or *C*. Line *A* corresponds to a policy of rapid initial expansion to reach a position close to the target percentage and then a period of gradual asymptotic approach to the long range goal. It has the virtue of providing a pattern of growth suitable beyond the planning period. This approach was used in the rapid expansion of the primary school system in the Western Region of Nigeria during the 1950's. One of the disadvantages of this approach is that it requires a rapid expansion at the beginning of the period when the economy may be least able to support it.

The above discussion indicates the ease with which even a simple sketch graph can illuminate decision alternatives and their implications. The lines drawn are intended to represent the outer bounds of possibility. An actual plan would probably be somewhere in the region between lines *A* and *C*. It would seem preferable to begin by looking at such overall patterns before becoming immersed in detailed numerical calculations.

A DYNAMIC REPRESENTATION OF A PRIMARY SCHOOL SYSTEM

Figure 2 is a schematic diagram of the number of pupils in a primary school system over an extended time period. The top line, *PAM*, represents the number of pupils entering the first grade of primary school in each successive year.

FIGURE 2.



The shape of this line corresponds to the choice of the policy represented by line A in Figure 1. The bottom line XGY, indicates the number of students completing six years of school at any time. The functional relationship between these two lines is described by the grid of curved lines connecting them. Each of these curved lines traces the survival (or dropout) rate of a particular class.

Consider, as an example, line PQG. The class begins with 16,000 students. At the end of the first year only 13,000 are available for the second year. After the fourth year, only 7,000 remain—less than half of the entering class. Finally at the end of six years 5,000 students have made it all the way through. The shape of each survival line depends on the conditions met by that particular class during its career. The lines in Figure 2 have a shape which approximates the pattern found in many developing countries. Note that the shapes of the lines change over time as conditions change. At the beginning of the planning period depicted in Figure 2, the dropout rate increases due to the lowering of teacher qualifications necessitated by rapid expansion. As the period progresses the dropout rate falls and line GY moves closer to line AM.

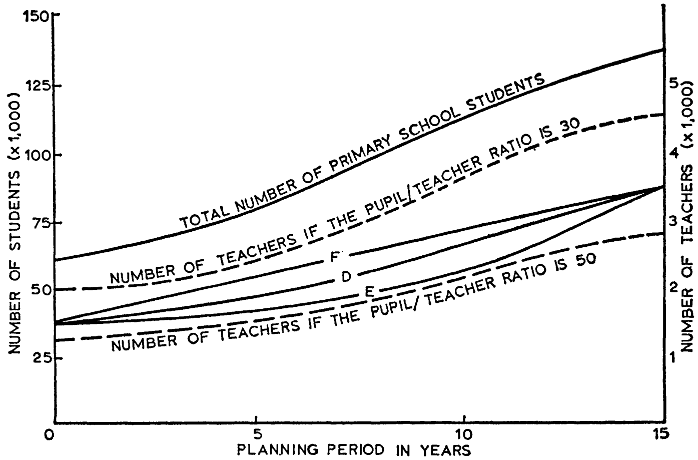
The diagram is simplified to expose the dynamic interrelationships within the system. Actual dropout lines are irregular and occasionally even cross each other. To display graphically the sometimes very serious problem of repeaters requires a more detailed method that is beyond the scope of this article. This discussion assumes that repeaters are included in the size of the entering class.

This technique can provide a picture of the system at any moment. One need only draw a vertical line such as the line AH shown in Figure 2. This line indicates the situation at the end of the sixth year of the planning period. The distance HA shows the size of the entering first grade class for the seventh year of the planning period. HB shows the size of the second grade class and so on down to HG which indicates the size of the class which has completed six years of school at this point.

It now becomes clear how the total population of the school system at any point can be computed. For instance, at the beginning of the sixth year, the total number of students is found by adding the distances representing the population of each grade, i.e., $AH + BH + CH + DH + EH + FH =$ roughly 87,000 pupils in this example. After performing this operation at several points during the planning period, one can then plot a curve showing the growth of the student population. The top line in Figure 3 represents the total population for the system shown in Figure 2. This process can be as accurate as the data permits. The choice of the scale of the graph dictates the degree of accuracy with which it is possible to carry out the transfer.

The process which has been demonstrated here for primary schools is equally applicable to the other stages of education. A detailed analysis of an educational system would include a diagram for each level of education and also for such important branches as teacher training and technical training. When

FIGURE 3.



assembled, the graphical representation allows the system to be viewed as a dynamic whole moving through time. A given entrance class can be traced throughout its whole career.

PROJECTING THE DEMAND FOR TEACHERS

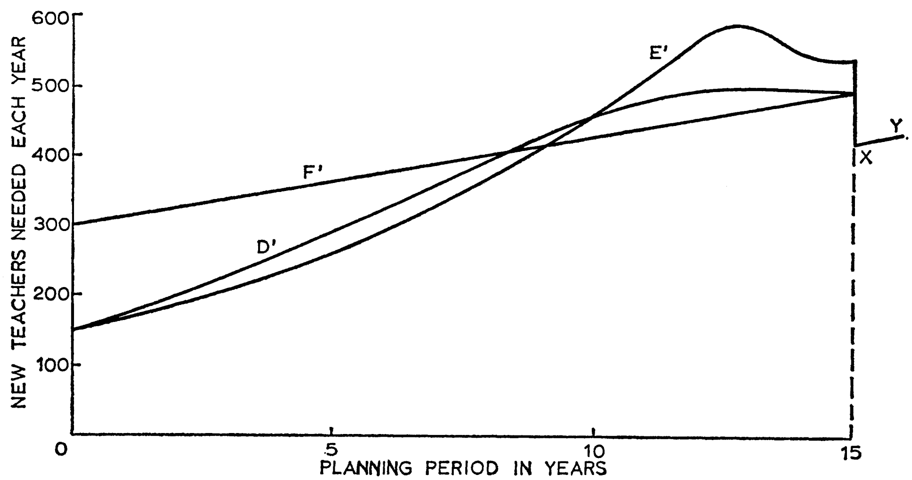
The number of teachers needed to carry out a proposed plan of expansion depends on the total number of students at any time and on the average pupil/teacher ratio at that time. In Figure 3 two guide lines have been drawn showing the number of teachers that would be required if the ratios were kept at 30 or at 50 throughout the planning period. These define the permissible area within which variations can take place. Note that the scale for any of the lines relating to teachers is on the *right-hand* side of Figure 3.

Again there are policy alternatives which can be studied graphically. It could be decided that the pupil/teacher ratio will remain at 40 throughout the planning period (line D); or the flexibility in the pupil/teacher ratio could be used as a cushion during a time of rapid expansion. For instance, line E indicates a policy which permits the pupil/teacher ratio to increase during the second five years of the plan when the rate of increase in the number of pupils is the greatest. It also has the effect of delaying the greatest rate of increase in the number of teachers until the end of the planning period, thus allowing time for extra teachers to be trained.

A third alternative is a constant rate of increase in the number of teachers (line F). This is probably the least desirable of the three because it lowers the pupil/teacher ratio during the time of rapid expansion and puts a correspondingly greater strain on the resources of the system. All of these lines assume a target ratio of 40 at the end of the planning period.

But for planning purposes it is more important to know the yearly rate at which teachers must be produced than to know the total number needed in the system. This rate of demand for teachers has two components: replacing teachers who stop teaching for one reason or another, and providing the additional teachers needed for expansion of the system. In constructing Figure 4 it was assumed for the sake of convenience that the replacement rate was 10 per cent of the number of teachers in the system at the time being considered.

FIGURE 4. New Teacher Demand Rate Lines.



The demand for teachers caused by the expansion of the system is just equal to the slope of the line in Figure 3, which gives the profile of the total number of teachers needed. For each of the three lines in Figure 3 (D, E, F) the corresponding line for total demand rate, including replacement, has been constructed in Figure 4 (D', E', F'). For example, the value of any point on line D' in Figure 4 is computed by adding 10 per cent of the value of the corresponding point on line D in Figure 3 to the value of the slope of line D at that point. Only six or eight such points need to be computed in order to sketch in the demand rate line.

The consequences of the alternatives in Figure 3 now become much clearer. The policy represented by line F is seen to require (line F') an initial production rate of some 300 teachers, or twice the capacity of the existing facilities. This rate increases steadily throughout the fifteen years, reaching a final value of 500. The policy of delaying the increase in the number of teachers until the last part of the period (line E) is found to produce a demand rate exceeding 600 at the end of the period (line E'). The policy of maintaining a constant pupil/teacher ratio of 40:1 produces a smaller maximum in the eleventh and twelfth years (line D').

In weighing these alternative proposals, it is particularly important to ask what happens after the end of the fifteenth year. If, as is quite likely, the system has reached a stable size relative to the population, then the rate of increase of the number of pupils, and consequently of the number of teachers, will be approximately equal to the rate of increase of the number of children of school age. The teacher demand rate will then consist of the replacement rate plus a small increase caused by the growth in the number of school children. This demand rate is represented by the line *XY*.

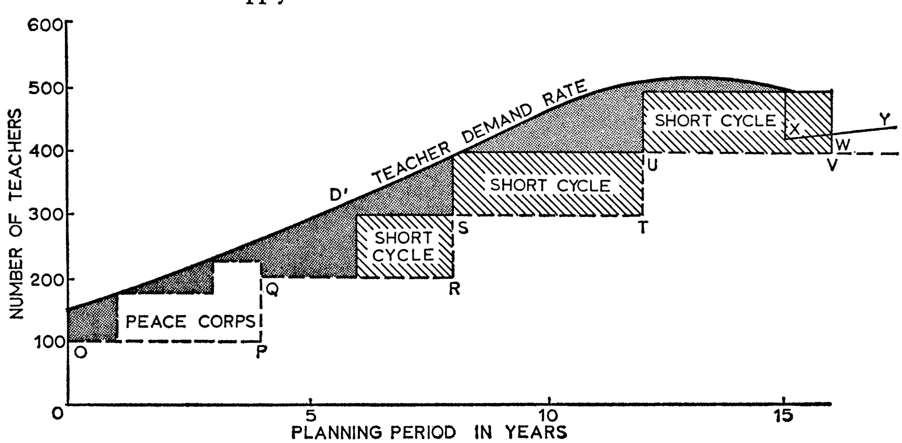
It becomes immediately apparent that construction of teacher training facilities to meet the maximum demand rates would leave the system badly over-extended. A reasonable amount of over-capacity can be justified on the grounds that the surplus would be used to replace teachers now in service who have little or no training. Thus the graphical method of analysis is able to demonstrate quickly and clearly the implications which a given choice of pupil/teacher ratio has for the demand rate of teachers.

PROJECTING THE SUPPLY OF TEACHERS

The details of teacher supply depend in part on the profile of educational attainment of the new teachers. Educational plans typically involve some stipulations about the percentage of the new teachers having specified levels of training. If the goal is to raise the average attainment level of the entire teaching staff, then new teachers must all be trained to a level above the current average.

First the supply of fully trained teachers from regular training institutions must be considered. If it takes one year to build a new training school and the cycle time is three years, then the lead time necessary for increasing the rate of supply of new teachers is four years. Therefore, if a new institution is begun in year 0 its first graduates are available to teach during the fifth year of the plan (after point *P* in Figure 5). The dotted line in Figure 5 (*OPQR . . . V*) indicates the production rate which would result if a new teacher training institute were completed every four years. The rate of supply of new fully trained

FIGURE 5. New Teacher Supply Rate.



teachers for any year is given by the vertical distance between the dotted line and the x-axis.

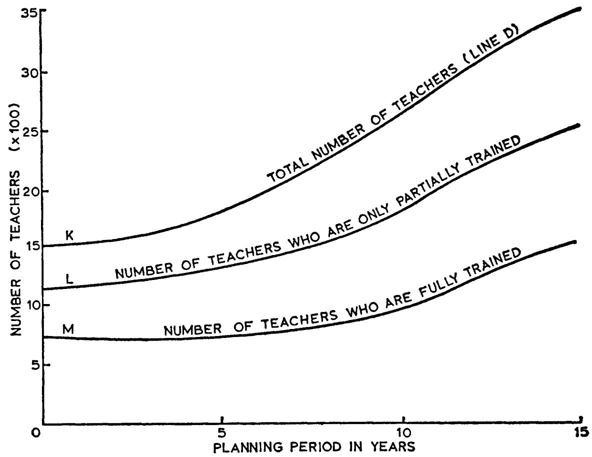
A glance at the graph shows the need for additional sources to meet the demand rate line D'. Suppose that the government introduces a temporary "short cycle" training system whereby people are allowed to teach after two years of professional training. If construction begins in the fourth year, then the first graduates appear at the end of the sixth year. The continued production of this "short cycle" institution is indicated by the boxes so labeled. Note that only one school of this kind has been built; the boxes represent its continued production for the next ten years.

For purposes of illustration, it is assumed that in the time of its greatest need, during the first part of the plan, the country appeals for international aid and is able to secure some Peace Corps volunteers. The diagram indicates that in the second year 75 volunteers arrived; in the third year an additional 75 came and raised the total in service to 150. In the fourth year 125 new volunteers were sent in addition to 75 who replaced those leaving upon completion of their two year service. In interpreting this graph one must remember that it represents only the newly available teachers each year; it does not indicate how long they serve. (The line D' is based on the assumption of an average teaching life of ten years.)

The shaded area between the top of the boxes and the line represents the number of teachers that will have to be found from other sources. To fill this gap developing countries frequently use untrained teachers or even older pupils from the school itself. The reason for not embarking on a crash building program to fill this gap becomes clear when one looks at the end of the planning period. The line XY shows the demand rate after the period of rapid expansion. The Figure indicates that the "short cycle" school has been closed and that supply capacity is quite close to the demand rate. Further expansion of training facilities will now be needed to upgrade the quality of teachers already in service, many of whom are not trained.

From Figure 5 a graph can be constructed showing the composition of the teaching staff in terms of their qualifications. A sketch of the educational profile of the teaching staff is shown in Figure 6. Line M shows the number of fully qualified teachers. The distance between L and M shows the number partially qualified, and the distance between K and L indicates the number of untrained teachers. With very accurate data this diagram could be done in the form of a bar graph with different sections of each bar indicating the amount of education. If the resulting distribution of training is unacceptable, then a new set of building plans for training schools would have to be formulated. The relative ease and speed with which graphical analysis can be done make it particularly useful where an iterative process is needed to arrive at a final solution.

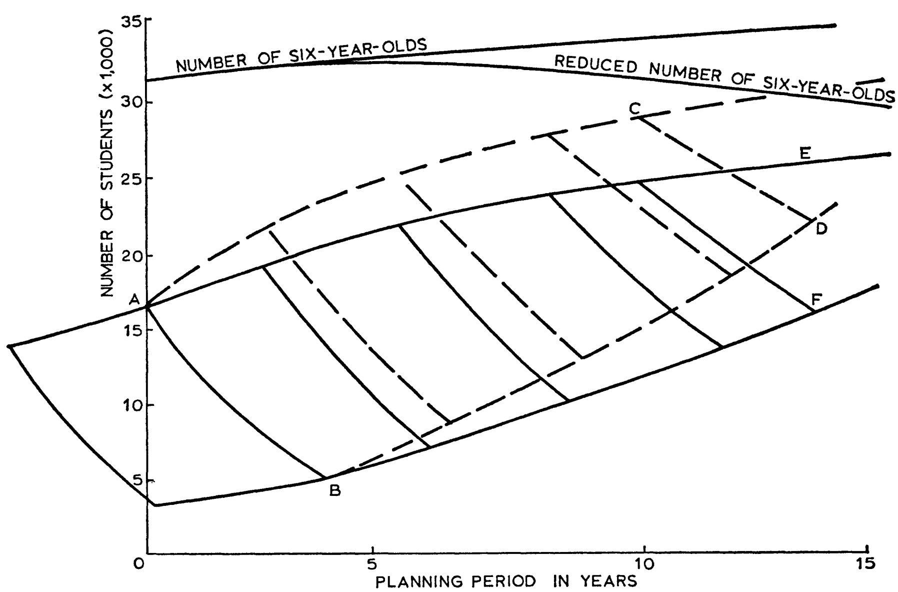
FIGURE 6. Educational Profile of the Teaching Staffs.



THE EFFECT OF A POPULATION CONTROL PROGRAM

A simple computation demonstrating the effect of a vigorous population control program can show the value of graphical techniques. For the sake of argument, it has been assumed that an extensive family planning program using intra-uterine devices would bring about a 20 per cent decrease in the number of births over a ten year period. The line at the top of Figure 7 indicates what the effects of a program beginning one year before the planning period of fifteen years would be on the number of six year olds.

FIGURE 7. The Effect of a Reduction in the Number of Births.



The expansion pattern *ACDB* drawn in dotted lines is what would be needed if no population control program had been carried out. This can be compared with the program *AEFB,* which would be sufficient with the reduced population of six year olds. From these curves it would be a simple step to calculate the costs of the two alternative patterns (assuming that total costs are directly proportional to the number of students). A very rough estimate would indicate a drop of 35 per cent in annual costs by the end of the fifteen year period.

CONCLUSION

The purpose of these simple exercises has been to illustrate the ease with which different policies can be analyzed and their various implications understood when graphical analysis is used. To approach such a problem with a desk calculator and long tables of numbers demands a great deal of work before any results are obtained. Even when the calculations are complete, the difficult problem of trying to picture the dynamic relations of a complex and interrelated system still remain. To see trends and patterns in tables of numbers is much more demanding than to understand the same information in graphical form. This is not to say that graphical analysis should replace numerical analysis, but rather to suggest the values of using graphs before undertaking complicated and unrevealing detailed calculations.