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ABSTRACT

Proceedings of a 1971 conference held to evaluate the use of the Simulation Option Model (SOM) in educational planning are presented. Following a general discussion of simulation models and educational planning processes, specific attributes and applications of SOM are considered. A case study of SOM's use in France--including examples of the information generated by the system--is provided. Potential applications of SOM in other national contexts are also discussed. (DGC)

centre for educational research and innovation

THE USE OF SIMULATION MODELS IN EDUCATIONAL PLANNING

A critical evaluation of S.O.M.

technical report

OECD ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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INTRODUCTION

Activity of the Centre for Educational Research and Innovation (CERI) concerning educational growth and educational opportunity consists of three interrelated projects:

(i) alternative strategies for equality of educational opportunity;

(ii) strategic decision-making problems;

(iii) alternative educational futures.

In the context of the project on strategic decision-making problems, CERI is trying to develop new approaches to educational planning that will be characterised by an organisational pattern integrating planning more closely with the decision-making process. This project is of course concerned with the planning techniques likely to be generally used for educational planning in the next decade. An initial experiment with simulation techniques has been carried out by the Secretariat. After the publication and testing of this model, it was necessary to investigate the use of this kind of technique for problems of long-term educational planning. For this purpose the Secretariat organised a meeting of a group of technical experts on the 6th and 7th July, 1970 in Paris.

The following technical report, which is in two parts, contains the most significant papers presented at this meeting. In the first part the authors of the model compare it with alternative techniques, describe its field of application and make a special study of the French educational system. The papers in the second part deal more specifically with the critical evaluation of the model and draw attention to its potential applications in various national contexts.

SUMMARY RECORD OF THE MEETING

Discussions on the first day mainly covered problems relating to the use of models for long-term educational planning, and participants concentrated on four major themes.

The first discussion developed around the problem of evaluating a particular model, i.e. whether evaluation criteria could be formulated. It was first emphasised that communication between planners and decision-makers was difficult and sometimes impossible and, as decision-makers had little or no understanding of the significance of the alternatives proposed by the planners, it seemed difficult to define criteria that would be meaningful to both parties. From a purely technical standpoint, two criteria might be used to evaluate a given model:

- the coherence of its structure;

- the degree of approximation to the reality that it represents.

According to R. Durstine, it would be advisable to adopt a more general position and try to formulate a real "economics of models" relating their cost to their utility. Depending on the situations this "economics" would offer a set of criteria for selecting the most appropriate model.

As conditional predictions can be made with simulation models, it was expedient to analyse their usefulness in the planning process. Participants first emphasised that there was a difference between predictions and projections. All predictions are conditional and, by integrating non-quantifiable factors, seek to answer questions of the type: "what will happen if this?", whereas projections consequent on an observation in time propose only an identical future development. According to P. Armitage, conditional predictions as practised were likely to be a relatively gratuitous exercise for the decision-maker who, in fact, was seeking information on propositions of a symmetrical type: "If this is the situation, what action should be taken?" ("what-if" vs "if-what"). More precisely, it could be said that planners have so far tried by using ingenious sets of assumptions to cover the range of potential future situations without analysing possible action to meet these situations. This naturally led on to a discussion of the concepts of the control theory, in particular feed-back couplings, which the SOM ignored. The reply to this was that the long-term planning process could not integrate the concepts of the control theory because the education system is in continuous development and its specifications eluded analytical description. However, P. Alper pointed out that the latest developments in the control theory show that the "observability" and "controllability" sub-systems can easily lead to a system that is neither observable nor controllable; it would therefore seem difficult to use the control theory in modelling the education system.

Since a simulation model attempts to construct alternatives relative to different sets of assumptions, the problem thus consists of choosing among these alternatives. The cost of constructing the latter is high and it is not easy to see what criterion to use for the choice. The statement of these alternatives could serve as a first filter. Moreover, the lack of objective function in the model might be offset by the use of a series of different criteria to reject unacceptable alternatives (from the standpoint of a given policy).

The use of a model based on the concept of transition coefficients depends on the determination of the latter. In this connection, participants described two attempts at statistical evaluation.

- The first (Heidelberg University) was related to the use of a system of individualised data and made it possible to construct series (3-4 years) relating to entrance, death and migration coefficients by sector and by age; according to the authors, such an investment is not as valuable as had been thought a priori for long-term planning.

- The second attempt (Canada) was more particularly concerned with following a cohort of 19,000 pupils in the same age-group; this study shows that transition coefficients (primary/secondary) are dependent variables and it appears that the analysis of "flows" is more rewarding than that of transition coefficients.

On the second day it was possible to discuss necessary improvements in SOM to eliminate most of its weaknesses. Furthermore, participants generally agreed on the need for decision-makers to have at their disposal low-cost models which are easy to use.

(a) The lack of a preference function in the model precludes easy choice among the alternatives constructed. The introduction of cost constraints or "filters" would make it possible to discard unduly costly alternatives.

(b) The definition of a simplified version of SOM, utilising only the Flow and Indirect Resource Submodels, would enable administrators to become familiar with a fairly uncomplicated tool.

(c) Modification of SOM so that it can be used without the Flow Submodel, calculating student stocks outside the model by another forecasting method.

(d) To change or adjust the algorithm of the restricted entry section, as the pattern is probably not consistent with democratic rules: for example, women are usually discriminated against.

(e) To introduce into the model behavioural relationships making it possible to estimate the future trend of transition coefficients.

(f) To calculate in the Resource Submodel the cost of replacing worn-out equipment and to introduce capacity depreciation.

The participants then considered the utilisation of this type of model and guidelines for CERI's work in this field. They made the following proposals:

1. Efforts should now be concentrated on applications. Modifications to the model should be introduced only in relation to application studies.

2. Applications should be directed towards the countries concerned, with technical assistance from CERI, if necessary. The participating countries which had already expressed immediate interest (Netherlands, Ireland, Germany) were already familiar with comparable models.

3. The subsequent completion of case studies should be accompanied by descriptions which are sufficiently explicit to be used by high-level decision-making administrators. This could lead to a considerably better understanding of long-term educational planning.

PART I

THE USE OF SIMULATION TECHNIQUES IN EDUCATIONAL PLANNING

by

Brita SCHWARZ

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1. INTRODUCTION

1.1 Educational Planning

1. Planning is meant here as the development of general guidelines for the future development of the planning object (i.e. the educational system or part of it) and a programme of action for the implementation. Long-term planning (5-15 year plans) is sometimes called strategic planning as compared to short-term planning: tactical planning.

2. A significant difference between short-term and long-term planning is that many factors that are unchangeable in the short run are variables in the long run. This is true, for instance, for regulations, organisational structures, partition of decision-making power and responsibilities between central and local centres and higher and lower decision-making levels.

3. In the educational system a large number of variables are quantifiable such as the number of pupils or students in various branches, various types of monetary and physical resources required, and the demand of qualified manpower of various categories. In strategic planning it is, therefore, necessary to deal with a large amount of data, often uncertain and interrelated in a complex way. Only some 15 or 20 years ago the educational system was considered as a principally static one only now and then in need of some minor reform. There has been, however, a growing recognition of the importance of consciously developing the system in accordance with educational objectives and continuously adapting it to a changing society. Along with the increasing emphasis on educational planning there has, naturally, been an increasing use of various mathematical methods and models to deal with the quantifiable factors. Mathematical procedures of varying simplicity have been applied such as additions, multiplications, matrix inversions, linear programming, differential equations, deterministic or Monte Carlo simulations, etc.

4. Some general definitions concerning models are given below as a background for the subsequent discussion of the role of simulation techniques as compared to other techniques in the analysis of educational planning problems.

1.2 The Model Concept

5. A model is a theoretical description of certain aspects of a real-life process or system. In science, models have long been used more or less explicitly. The study of data from some process might indicate some kind of regularity. The description of this regularity, e.g. in terms of a mathematical function, gives a hypothetical model of the process. The use of the model may indicate conclusions,

the validity of which can then be investigated. An example is the development that led to Newton's laws of motion and gravitation.

6. This way of constructing and using models has also been significant in operations research and economic theory. In connection with long-range planning and forecasting problems the model concept is, however, used slightly differently. No data can be collected about the overall performance of future systems or processes. Models concerned with the future development of a system have therefore to be based on theoretical analy[illegible]of relationships between components and causal relati[illegible]e model takes account of, more or less accurately, [illegible]n characteristics of the system but omits others. The choice of characteristics taken into account as well as the degree of accuracy aimed at, depend upon the types of problems the model is meant to help analyse. It is, therefore, always uninteresting to discuss the realism of this type of model *per se*. The point that matters is whether the influence of various factors on the output of the model is described accurately enough for the problem area for which the model is developed or applied.

1.3 Classification of Models

7. Models can be classified in a number of different ways depending on their structure and on the features emphasised. Models may, for instance, be divided according to the process or system they embrace, or according to the level of disaggregation or decision-making level they concern. A survey of classification principles are given in "The Role of Analysis in Educational Planning".(1) For the purpose of this paper it is more convenient to classify models according to their mathematical structure, and thus for example distinguish between analytical and simulation models, stochastic and deterministic models and between manual and computerised models. To facilitate a discussion about the use of simulation techniques in educational planning, definitions of some different types of models may be useful.

8. *Deterministic* models are characterised by the fact that they describe processes without statistical variations or without taking account of such variations. *Stochastic* models include random variables and give the statistical distribution of the outcome.

9. *Analytical* models express directly by formulas the influence on the outcome of the different input parameters. They may be deterministic or stochastic. Even with fairly schematic descriptions of systems including random elements, it may be difficult in practice to derive expressions for the probability distribution of the outcome. It is, therefore, usual to change to another type of model, the "*Monte Carlo*" model, for descriptions or *simulations*

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(1) B. Schwarz: "The Role of Analysis in Educational Planning", Background Study No.9, for the OECD Conference on Policies for Educational Growth, STP(70)13.

of more complex chains of events in which probabilistic elements play a prominent role.

10. Manual gaming is distinguished by the idea of play, the decision function being performed by human beings at some stage of the calculations. Usually the Monte Carlo method is used, but average values may also be formed. There are many different forms and fields of application of manual gaming. Political games, for instance, are used for studies of conflict situations between nations in order to provide a basis for political decisions. There are also different types of management games for studies of competition, price policy, etc.

11. Monte Carlo models simulate chains of events in chronological order. These chains have a number of branches, each of which is given a number representing the probability of choosing that branch. When faced with a choice of route, a random number is used to decide which branch to take. Monte Carlo simulations are sometimes carried out manually. For statistical reliability the simulation often has to be repeated a large number of times, which sometimes is possible in practice only if a computer is used. Monte Carlo models are sometimes divided into time-step and event-store simulations, depending on how time is treated. In the time-step method one divides the duration of the simulated period of time into a number of successive time intervals. In the event-store method, on the other hand, after a given event has occurred, one determines and "stores" a set of future events and the times at which they will occur and then selects and determines the outcome of the earliest.

12. A computer model is a model programmed for an electronic computer. When designing a model which is to be programmed for a computer, computer capabilities as well as the intended use of the model have to be taken into account in order to obtain an efficient computer programme.

Whether or not it is preferable to use a computer for the calculations depends on the extent to which the expenditure of time and cost on programming the model is made up by the greater speed of calculation. If, for instance, the outcome of a process, as described by a model, is to be determined for many different sets of input data, computer models are often preferred even if the programming work is time-consuming. If, on the other hand, the outcome is only to be determined for a few alternative sets of input data, one may prefer to carry out the simulation or the calculations "manually", possibly with a desk calculator.

13. Linear programming is a technique for maximising linear functions, subject to a number of constraints in the form of linear inequalities. During recent years methods have been sought for a wider class of optimisation problems, such as the maximisation of different types of non-linear value functions subject to linear (or non-linear) constraints. Mathematical programming is the name given to techniques for solving this more general type of optimisation problem.

14. A simulation model often means a Monte Carlo simulation model, but it may also be a deterministic model. To "simulate" means to duplicate the essence of the system or activity without actually attaining reality itself. In the broadest sense, any applied mathematics or analytic formulation of a problem is a simulation; however, analytical treatment is normally excluded from the meaning of the term "simulation".

15. The most traditional use of simulation has been in the engineering sciences, where analogue simulation devices have long been used for scientific prediction of system performance (hydraulics, electrical network). Large-scale digital simulations came into use at the end of the 1950's in various types of military studies but have since then been applied in many different operations research fields. A reason for applying simulations is to avoid analytical difficulties. G.W. Morgenthaler(1) has discussed some other reasons:

- The task of laying out and operating a simulation of a process is a good way to systematically gather the pertinent data about the process. It makes necessary a broad education in the process or operation being simulated, on the part of all who participate seriously in the simulation.

- Simulation of a complex operation may provide an indication of which variables are important and how they relate.

- Simulations are sometimes valuable in that they afford a convenient way of breaking down a complicated system into subsystems, each of which may then be modelled by an analyst or team which is expert in that area.

- Understanding gained through simulation may enable human judgement to intuit a good solution.

- Simulation gives a control over time. In fact, it is a way of incorporating time into an analysis of an essentially dynamic situation.

2. CHOICE OF MODEL

2.1 Systems Characteristics

16. When designing a model the characteristics taken into account are chosen with regard to the problem area for which the model should be used. From this one could conclude that the question is not so much one of choosing a model, but rather of specifying the characteristics of the process which should be taken into account and defining the relationships between available data and the quantities to be determined. The set of relationships thus obtained

(1) G.W. Morgenthaler: "The Theory and Application of Simulation in Operations Research", Progress in Operations Research, Vol.I., ed. Russel L. Ackoff.

then constitutes the model which should be used. There are, however, other aspects relevant to the choice of method or model. This will be discussed below.

2.2 Sub-problems

17. It is usually not a matter of designing a model for one specific problem. There may be a set of present and future problems of similar character for which the same model can be used. It is also usually advantageous to analyse the problem carefully and try to break it down into sub-problems, which may then be dealt with separately by using different approaches.

2.3 Application or development of a model?

18. A common approach is to apply existing methods or models rather than develop new ones. Obviously, this saves time and enables the use of personnel with less advanced methodological knowledge. There are, however, some well-known disadvantages. The choice of model may depend more on what kind of models the analyst is familiar with than on the characteristics of the system or process which should be taken into account. It may also happen that no existing model is convenient for the problem at hand. Even if a new model is developed the knowledge of the analyst may cause biased results. The specialist on probability theory will tend to over-emphasise random elements in the process, the specialist on linear programming will try to squeeze it all into a linear programming model, etc.

19. Simulation model is a general notation for a very wide category of models, which may contain any type of mathematical relationships. When faced with a new type of problem or process it is thus usually not a matter of looking for an existing simulation model to apply, but to develop a new one when needed. This may be time-consuming but has the advantage of forcing the analyst to try to fit the model to the problem and not the problem to a fixed model.

2.4 Analytic or simulation model?

20. If a problem can be formulated analytically, for instance as an optimisation problem, this is usually preferable to a simulation model as the influence of various factors on the result is explicitly described. Analytical treatment is more likely to be feasible when the problem concerns:

- part of the system rather than the entire system;
- one objective rather than multiple objectives;
- the efficiency of an existing system rather than the future development of a system.

21. Even when it is a matter of pursuing multiple objectives it may be possible to formulate the problem analytically if the preference function for the different objectives is known beforehand explicitly. This is, however, usually not the case. It is often only when the policy-makers are presented with information on the extent to which various policy alternatives influence the achievement of the objectives that they can specify their preferences. In this context simulation models may be useful for consequential analyses of the implications of various policies.

2.5 Deterministic or Stochastic Model?

22. The development of the educational system contains certain stochastic features such as the choices of the individual pupils or students of branch of study and occupation or profession. The fact that these "choices" often turn out to differ between schools and regions is, however, mainly due to inhomogeneity in the compared students groups (e.g. due to different socio-economic background) and not an expression for the statistical distribution of the outcome of a random process. For forecasting purposes it is, therefore, usually more important, particularly in long-term planning, to use models that take this inhomogeneity into account than to include stochastic variations. The flow of students within or out from the educational system is usually described by transition coefficients that denote the ratio of students who repeat, drop-out or continue to different branches of study. To delete stochastic variations in the sense mentioned above does not mean that these transition coefficients are assumed equal to 1, but that the stochastic variations of the outcome around these ratios are not taken into account.

2.6 Treatment of Uncertainty

23. A basic feature in long-range planning is uncertainty. This does not mean that long-range planning cannot be carried out but that uncertainty has to be taken into account explicitly in the planning process. Procedures for such explicit consideration of uncertainty are, for example, the use of rolling plans, sensitivity analysis and contingency planning.

24. Rolling plans means that the plans are updated at regular time intervals and the planning horizon extended so that the plan continues to cover the same number of years. A four-year plan, for instance, is usually rolled each year while a ten-year or fifteen-year plan may be rolled less often. The use of rolling plans makes it possible to take new information about the system into account regularly.

25. Sensitivity analysis means an analysis of how the result depends on some parameters. These are varied within the range of uncertainty and the result is calculated for parameter values within this range or for the minimum and maximum value of the parameter. Sensitivity analyses are sometimes carried out prior to the final data collection. If the result is not sensitive to the parameter in question, less effort is required for the

determination of this parameter. If, on the other hand, the result is sensitive to the investigated parameter variations, there are two possibilities. Either larger effort in the parameter determination will acceptably reduce the influence of remaining uncertainty on the result, or the uncertainty is "genuine". Such genuine uncertainty may, for instance, concern the future environment of the system or the choice of objectives or measures of effectiveness.

26. Contingency planning is an approach to the treatment of genuine uncertainty. In contingency planning the ranking of the alternatives to be compared and evaluated are calculated for different "contingencies" and an alternative is sought which has a high ranking for all relevant contingencies without being necessarily optimal in any case. This may be accomplished by some kind of mix of the original alternatives or by the design of a new alternative. Generally speaking, the contingency planning approach puts the emphasis on flexible and adaptable solutions, that is the selection of solutions which will be fairly efficient, perhaps after later adaption, for a variety of actual outcomes of the uncertain parameters.

27. Some examples of genuine uncertainty in educational long-range planning can be given.

28. The number of school-age children in the country as a whole and in various regions can never be forecasted exactly because of migrations and uncertain estimates of future birth-rates. This type of uncertainty can to some extent be taken into account by adaptability, for instance by building schools which, for a relatively small additional cost can be re-arranged or enlarged so as to fit changes in the number of students or in the subjects taught.

29. Educational objectives and priorities between them differ between countries but most countries consider it of some importance that the educational systems should "produce" enough qualified manpower to meet the requirements of the development of the economy. The development of various economic sectors and the corresponding educational profile can, however, never be accurately forecasted because of innovations changing the production process, uncertainties concerning the development of foreign trade, etc. Both flexibility and adaptability of the educational system are of importance to meet the lack of accurate forecasts of future manpower requirements. Increased adaptability may be obtained by reducing the time between the student's choice of more specialised general or vocational training and the time of entry in the labour force. This will create a quicker response to changes in manpower requirements. It may also be important to increase the flexibility of the educational system by making specialist education more general and adequate for wider occupational areas.

30. The need for dealing explicitly with uncertainty in long-range planning has some consequences which may influence the choice of model. The use of sensitivity analysis and rolling plans requires the same type of calculations to be carried out repeatedly. This has to be considered when choosing between a manual model and a

computer model and may actually sometimes be the decisive cause for computerising a model. Sensitivity analyses can be considerably facilitated (less preparation of inputs, savings in computer time, etc.) if the computer programme is specially designed for variations of parameters. This, however, requires that the parameters to be varied are known before the programming. The obvious way to facilitate sensitivity analyses is, of course, to insert loops in the computer programme. How this is done may, however, sometimes be crucial. If part of the calculations in the programme are untouched by the parameter to be varied, this part can be left outside the loops and only run through once before its results and the uncertainty alternatives are combined. This approach is of specific importance in Monte Carlo simulations as they often have to be repeated a large number of times for statistical reliability. Here considerable gains in computer time can be obtained by inserting the parameter variations inside the "Monte Carlo" loop. (This is a variance reducing method termed "correlated ampling".)

31. Contingency planning puts the emphasis on flexibility and adaptability. A smooth development of the educational system in accordance with educational objectives and the general development of society usually requires changes in scale (enrolments, etc.) to be combined with structural changes. Such complex changes can more easily be incorporated in a simulation model than in an analytic model.

2.7 Qualitative or Quantitative Analysis

32. Long-range planning usually involves considerations that cannot be handled quantitatively. This fact has sometimes been used as an argument against all uses of quantitative analysis. The usual answer to this is that quantitative analysis serves to translate relevant quantitative information in a form more useful to the decision-maker who therefore can integrate more easily the intangible factors with the quantitative part of the problem when he forms his decisions. It is, however, not only the final evaluation that involves qualitative factors.

33. Educational objectives can usually not be directly defined in quantitative terms though it may be feasible to use quantitative measures of effectiveness for certain planning problems, especially in short-term planning. The number of enrolments in various branches of the educational system and the number of graduates are examples of such quantitative measures of effectiveness that in some cases may be relevant. As responsibilities and decision-making power are divided between central and local levels and the students themselves have a considerable freedom of choice, the implementation of a reform may often involve difficulties that have to be taken into account when different solutions are analysed. This may have as a consequence that not directly quantifiable elements must be taken into consideration even in an inquiry for which it has been possible to define a quantitative measure of effectiveness.

34. Operational educational objectives need not necessarily be expressed in quantitative terms. As a minimum requirement, however, they should be so specified that a ranking between alternative

solutions is possible. Such a specification may not be feasible *a priori* but may result from the formulation of alternatives and a feed-back of their evaluation to the setting of objectives. Here iterations involving the formulation of new alternatives may be necessary.

35. The design of different educational alternatives to be evaluated may involve studies of changes in curricula, acceptance rules, financial incentives, creation of new branches, etc. Consequential analyses of the future implications of the alternatives may give ideas concerning the formulation of new alternatives. Educational long-range planning can thus be considered an iterative feed-back process which in each iteration may require innovations and both qualitative and quantitative considerations. An inter-disciplinary approach with a close co-operation between "qualitative" and "quantitative" analysts may therefore be essential. This co-operation may be easier to establish when simulation models are used, as they break down complicated situations into a series of simple interactions. The language of a simulation is closer to our ordinary language and thus more easily understandable to people without an advanced quantitative background than the language of a mathematical analysis.

3. SIMULATION MODELS IN EDUCATIONAL PLANNING

36. Simulation models may be appropriate whenever it is a matter of studying the development of a system over time. In education, this is the case when one wants to estimate the future number of students and graduates in various branches from knowledge about the state of the present system and change mechanisms. Student flow models have therefore in a number of countries been developed in the form of simulation models.(1) Both Monte Carlo and deterministic simulation models have been developed. With some simplifying assumptions the model may be reduced to analytical form. When features such as restricted entry branches, transition coefficients that change over time, etc. are taken into account, the outcome is no longer directly expressable in analytic form and it becomes necessary to use a simulation model. For a detailed description of the educational system (many different branches and types of schools) a computer model should be more convenient than a manual model.

37. Here we will use "SOM"(2) as a reference model for further discussions about educational simulation models.

38. With the terminology introduced above, SOM can be said to be a time-step deterministic computer simulation model. It simulates

(1) Part II of "Mathematical Models in Educational Planning", OECD, Paris, 1967.

(2) "SOM. A Simulation Model of the Educational System", Technical Report, OECD, CERI, Paris, 1970.

the flow of students through the educational system and makes conditional forecasts for a future period of time of educational output and teacher supply as well as educational resource requirements, i.e. teacher demand, building space requirements and educational expenditures. The estimates are made for each year of a future period of time, that is the basic time-step unit is one year.

39. SOM does not calculate future manpower requirements, nor does it calculate the return of investments in education. As it does estimate future educational outflow and educational cost, it provides some of the data needed for comparisons between supply and demand of qualified manpower, as well as data needed for rate of return analyses. SOM is mainly a tool for sensitivity analysis and consequential analysis. The output data do not directly present a solution to the problem under study, but should rather be seen as information which has to be further evaluated.

40. The limitations of SOM seem to be typical for a simulation model. As it does not include all quantitative aspects of potential importance for educational planning problems it does not substitute other types of models but should be seen as a complement. Nor does it substitute qualitative analyses but may serve as a framework for such analyses. On the other hand, SOM has certain advantages which are typical for simulation models, compare the quotations above of Morgenthaler (page 20).

4. IMPROVEMENTS IN EDUCATIONAL PLANNING

41. As the purpose of this paper was to evaluate the use of simulation models, as compared to other models, in educational planning, the presentation may have given a biased impression as to what improvements in educational planning are the most important ones. Reforms of the planning process and the planning organisation to enable the performance of planning broadly conceived may be of prime importance. The planning function must be fully integrated in the decision-making process. Models start becoming useful in practice only when certain minimum environmental requirements are fulfilled. Such requirements concern, for example, information channels, co-ordination between responsibilities and decision-making and implementation power, availability of trained analysts in or closely attached to planning units with executive power, etc.

APPLICATION FIELD OF SOM

by

Marc NUIZIÈRE

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I. INTRODUCTION

1. It is assumed in this paper that the principal features of the SOM Simulation Model are known to the reader. Let us merely point out that the model is neutral as regards educational objectives and that it is capable of simulating all or part of the educational system with a descriptive unit ranging from one year of study to a full educational cycle. In addition, we should define what is meant by an "option" model. This term in fact covers two quite distinct meanings, namely:

- Owing to its structural flexibility, SOM can be adapted to the problems studied and the available input data. There is hence a real choice between the configurations of the various input data needed for the model.

- A choice between the various possible configurations for SOM. The diagrams on page 33 depict these various configurations.

  These diagrams are by no means exhaustive but combinations 2-3, 2-4, 3-4 and 3-5 cover the set of alternatives.

2. It is not the intention in the following sections to give all the possible applications of the model, since there is, in fact, a specific application for each problem. We have, therefore, confined ourselves to the field of potential applications without illustrating the report with real examples. Moreover, the variables defining the SOM structure are known to be mostly exogenous, and calculation of their values and future development raises serious theoretical and methodological problems (and sometimes policy problems) which must be solved before embarking on any one of the applications mentioned below.

3. The following sections divide the field of application of SOM into two: first, the "sectoral" applications, which analyse all or part of the educational system in order to reply to specific questions and second, the "global" applications which are directly incorporated in the planning process.

II. SECTORAL APPLICATIONS

II.1 Forecasting Tool

4. The set of submodels that make up SOM can easily be considered as a forecasting tool. Its use can be confined to the Student Flow submodel alone if we wish to forecast future student cohorts. These forecasts can only be made on the basis of a well-defined body of assumptions.

5. These assumptions reflect the development of the parameters of the model for the whole simulation period. The development of the transition coefficients, drop-out rates and graduation rates can be constructed either from observed past series or by determining two limiting curves between which lies the true, unknown development of the parameter. The first approach leads to spot forecasts and the second to confidence intervals for future student stocks, since the initial assumptions are too restricting to justify acceptance of a series of values for stocks ignoring the relevant degree of uncertainty.

6. The same remarks also apply if we wish to ascertain the resources requirements and the number of available teachers for the simulation period.

7. There are also parameters such as the number of places available for each year in a restricted unit, which depend on the inertia of the system and the political decision to widen or narrow the restriction. In ignorance of future policy two kinds of approach may be adopted:

- One takes an "<u>a priori</u>" position, introducing two limiting sequences for the number of available places in each restricted unit, in order to get an upper and lower limit for the true policy.
- "<u>a posteriori</u>" position, first constructing a reference solution in which restricted units are eliminated; future policy is then envisaged in the knowledge of the sequence of the number of places desired for each restricted unit.

8. For completeness, we must also mention the possibility of constructing "what-if" type forecasts. For instance, what will be the development of the educational system if a particular structural change is undertaken.(1)

II.2 Programme Budgeting Tool

9. One of the advantages of the Resources Submodel is that it can group costs by programme. A programme may consist of a vast aggregate such as secondary education, or a more specifically-defined institution such as schools for handicapped children. A programme for the model is a block of units. Each programme is defined by its maintenance and capital costs, the latter related to the base year of the simulation period.(2)

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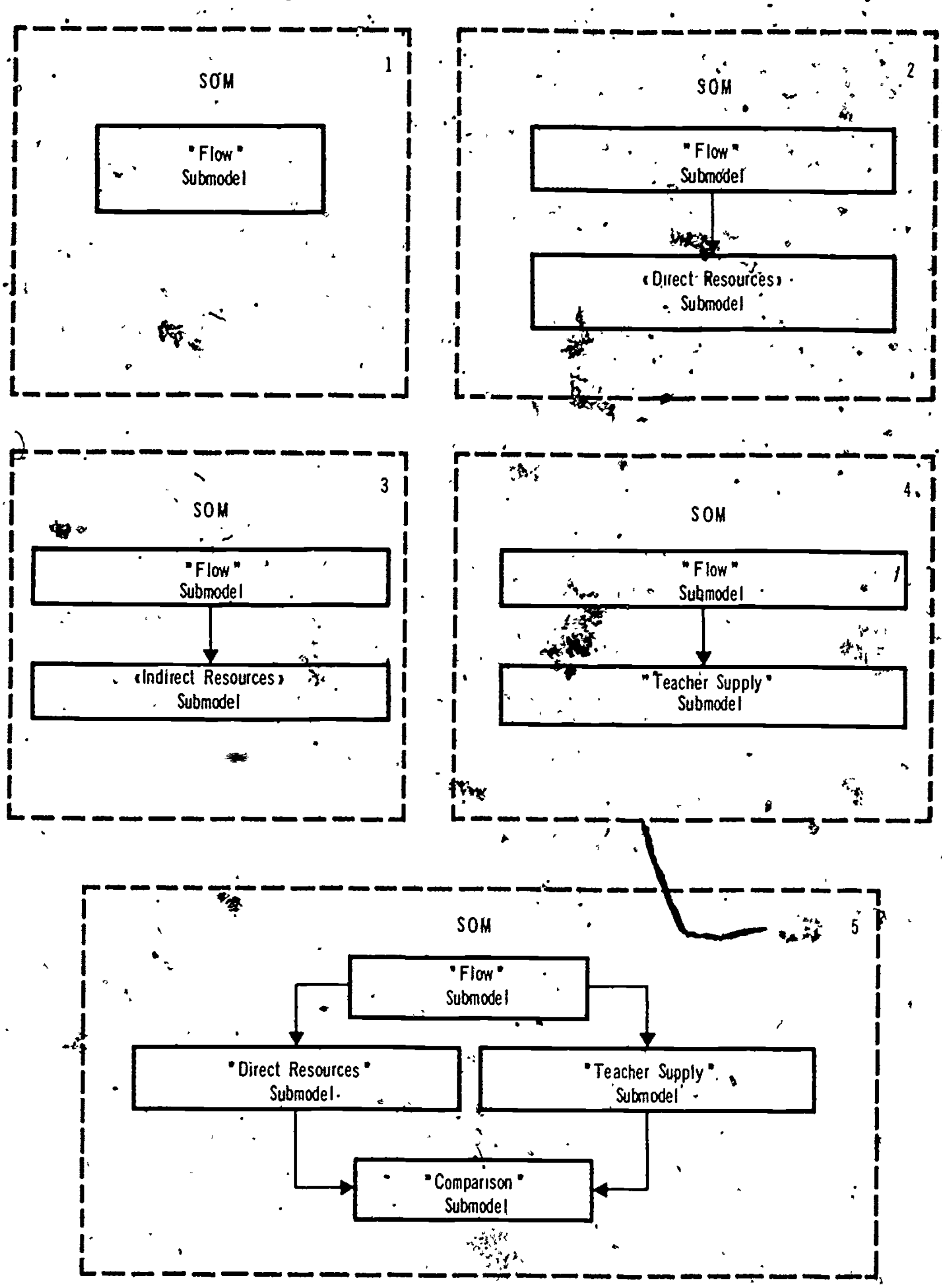
(1) "SOM Application Study - The Case of France", CERI/EG/DM/70.06.

(2) "SOM - A Simulation Model of the Educational System", CERI/OECD Technical Report, Paris 1970, pp.53,54.

Figure 1



SOM
1
"Flow"
Submodel
SOM
2
"Flow"
Submodel
"Direct Resources"
Submodel
SOM
3
"Flow"
Submodel
"Indirect Resources"
Submodel
SOM
4
"Flow"
Submodel
"Teacher Supply"
Submodel
SOM
5
"Flow"
Submodel
"Direct Resources"
Submodel
"Teacher Supply"
Submodel
"Comparison"
Submodel

10. More detailed knowledge of these budgets can be obtained by analysing the various expenditures for each of the units forming the programme. This possibility is of unquestionable interest when attempting to analyse how part of the system responds to experimental conditions, such as a reduction in class size, installation of audio-visual aids, etc. This type of analysis implies two working stages:

(i) construction of a reference alternative;

(ii) construction of a second alternative in which the new equipment or environmental standards are applied, showing the programme's impact on costs;

(iii) or, construction of a second alternative which takes account, by means of an analysis external to the model, of changes in student behaviour (transition coefficients, etc.), corresponding to these programmes and the modifications introduced in (ii) above.

11. These methods of analysis do not eliminate one of the main weaknesses of any simulation model, namely, the lack of any explicit feedback mechanism. Transition coefficients in our problem depend on social, educational and economic variables. However, if these relationships have been known and taken into account explicitly in the model, it would have been constrained to a certain rigidity, and we think that it is more flexible to provide feedback mechanisms through a sociometric analysis external to the model.

12. The variation of the budget compared to the reference alternative will show the real cost of implementing a new method of education. It is also possible to analyse the relative weight of this budget compared to programmes corresponding to a set of comparable educational units.

II.3 Exploratory Tool - Sensitivity Analysis

13. Sensitivity analysis is the procedure whereby variation in the outputs of the system can be measured when one of its parameters is caused to vary. For instance, for the flow submodel, the amplitude of the response will have to be observed over the whole of the periods following the excursion in the chosen parameter and compared against a reference alternative. The outputs whose value has changed will represent the sensitivity field for this parameter.

14. It is then natural to rank the parameters with the same sensitivity field, and those which provoke the highest response for a given variation are called "critical". To the extent that these parameters can be explained by means of variables accessible to decision-making, the separation of the critical parameters will enable specific changes to be introduced into the development of the educational system.

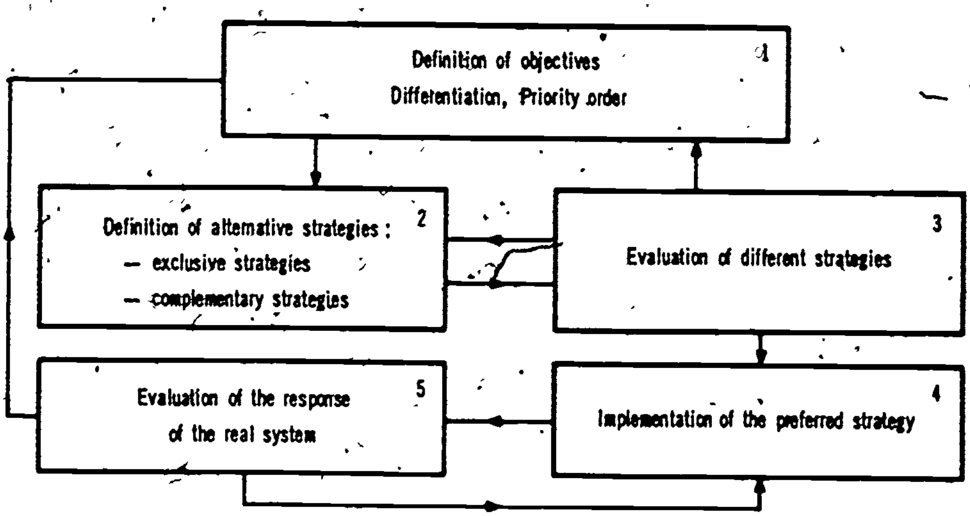
15. The same approach is implicitly used by the Teacher Supply model, where the parameters defining the inflow of new teachers may vary within certain limits. The model calculates the variations in the stock of available teachers as a result of separate or simultaneous variations in the parameters.(1) The computer programme thus seeks to scan the possible variations in the number of available teachers according to the values of the "decision" parameters (rate of "success") and the values of parameters involving a certain degree of uncertainty (rate of "choice").

III. GLOBAL APPLICATIONS

III.1 Planning Tool

16. Much more generally, one can demonstrate how the model can be used in the planning process. The following diagram locates the model at the level of "Evaluation of different strategies".

Figure 2



17. The above diagram situates the use of a model at stage 3, but feedbacks to stages 1 and 2 are needed if the evaluation of the different strategies is to be a true pre-decision stage. It is then clear that use of SOM in the planning process is no longer a matter merely for technicians, but should include a number of iterations between technicians and policy-makers.

III.2 Strategies for the Model

18. A strategy consists of the sequence of application of a set of decisions in order to achieve predetermined objectives. We must, therefore, study how the structure of SOM can be used to

(1) Op.cit. p.5., p.76.

simulate a strategy and in particular, what strategies are possible. The strategies which will be discussed below are ones which can be simulated by the model. The requisite methodology for any strategy can already be described.

19. Firstly, the educational system is simulated for the horizon selected on constant structure assumptions and/or transitions at the same rate displayed by past trends, thus building a reference alternative. It should be noted in the first place that SOM contains a number of "implicit" strategies, e.g. alternatives for the number of available teachers in the "Supply" submodel and short-term balancing strategies used by the Teacher Comparison submodel. We shall start with a description of the "explicit", exogenous strategies of SOM.

1. Explicit Strategies

20. There are practical advantages in defining a strategy as a combination of "pure" strategies of known definition.(1) For the sake of clarity, we can separate pure strategies into two groups - quantitative and qualitative strategies - though we are well aware that this distinction is sometimes fictitious.

(a) Quantitative strategies

21. These are known as quantitative because they result in a modification of the number or distribution of students, teachers, or other resources in the educational system.

1. Action on a transition coefficient assimilated to a decision variable.

   This type of strategy equates in reality to a sensitivity analysis for the model giving the relative weight of a particular transition coefficient on the development of stocks during the simulation period.

2. Action on the sequence of available places in a restricted entry unit.

   The response of the system to this type of action indicates the period when the restricted unit will cease to exist and the change in the distribution of students between the various branches below the restricted unit.

3. Change in the socio-economic distribution of students within a branch or a grade (unit).

   The model can easily simulate the implications of this type of strategy which may, for instance, correspond to the objective of democratisation through "Equalisation of Educational Opportunities". Were such a strategy to be implemented, it would result in a variation of the transition coefficients by socio-economic group and would

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(1) In the Games Theory sense.

presuppose the implementation of a policy of scholarships or grants, a change in staffing standards and a complete overhaul of the curricula (for instance, individualised study programmes).

4. Changing the number of available teachers by acting on the retirement age.

   This strategy could easily be applied if it is a question of reducing retirement age; the reverse strategy would certainly raise more problems.

22. We must stress that these pure strategies are, in fact, assumption tests corresponding to the likely response of the structure of the educational system when the strategy is applied.

(b) Qualitative strategies

23. These "qualitative" strategies mainly affect what are conventionally called staffing standards and educational content, these terms being limited to their measurable component.

1. Change in curricula (duration and content) in a given unit. When confined to the model, this strategy is assumed to have no effect on drop-out rates or transition coefficients for the relevant unit; as this is not the case for a real strategy, this strategy must be combined with an (a) type strategy. Its outcome is measured by the variation in the current expenditures for the unit, representing the cost of implementation.

2. Change in class-size. The number of students in a classroom is an input of the Resource Submodel and governs the student/teacher ratio. The consequences will be reflected in the number of teachers needed and capital expenditure, the scope of which will be measured by comparison with a reference alternative. The model contains the implicit assumption that this change in the student/teacher ratio has no effect on the output of the educational system, since transition coefficients and drop-out rates for the units considered are completely exogenous parameters.

3. Change in the required teaching qualifications. This strategy may correspond either to a shortage of teachers with certain qualifications, or to a desire to improve the quality of teaching by raising the level of qualifications required. It should nevertheless be noted that the reverse strategy is more common; pressure of demand generally leads to the recruitment of teachers who are under-qualified by current standards. In any case, the outcome is a new distribution of the teachers needed in accordance with the various qualifications. The results could be tested by analysing to what degree they fit the number of available teachers for each qualification.

2. <u>Implicit Strategies</u>

24. For completeness, let us recall that the Teacher Supply and Teacher Comparison submodels include implicit strategies.

1. Change in the inflow of new teachers coming from the educational system. This strategy can be applied by using two different policies:

   (a) Changing the passing rules for teaching diplomas. This policy is fairly easy to simulate, since it can be applied without inertia by acting on the rate of "success" parameters.(1)

   (b) Changing teachers' salaries. This type of strategy can be constructed, but it requires preliminary studies to describe the functional relationship between the marginal variation in salaries and the variation in the rate of "choice" parameter.(1) Furthermore, this type of policy has a response time which must be evaluated before the strategy can be simulated.

2. Short-term balancing strategies between the "demand" for teachers and the "supply" of teachers. This strategy in fact simulates the probable response of the educational system to a state of imbalance between teacher supply and demand. Two possible approaches are programmed:

   (a) The "demand" approach

   Assuming that the available teacher stock remains constant, this consists of changing the school parameters (or standards) to adjust demand to supply. The comparison submodel uses two "decision" variables: class-size and the weekly teaching load. Naturally, the variation of each variable is bounded.

   (b) The "supply" approach

   This equates to using the alternatives in the number of available teachers generated by the supply submodel. The rate of "success" parameter is considered accessible to policy decisions (see above). Also, the rate of choice parameter is assumed to vary between two limits expressing the uncertainty of the evaluation. The strategies for each teacher category are called respectively the "more graduates strategy" and the "less graduates strategy".

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(1) The rate of "choice" is the proportion of graduates in a given category who choose teaching.

The rate of "success" translates the proportion of graduates from a given unit belonging to a given category.

IV. CONCLUSIONS

25. The foregoing is an attempt to describe the potential applications of SOM. It should, however, be stated that the builders of the model are fully aware of the limitations inherent in simulation techniques, namely the absence of optimisation procedure, and in particular, the lack of feedbacks.(1) Nevertheless, they are convinced that thanks to its flexibility of use, SOM is a necessary step towards the elaboration of a more rational decision-making process.

(1) See Control Theory ("SOM and Control Theory"), by Paul Alper, Reference CERI/EG/DM/70.02.

A S.O.M. APPLICATION STUDY

CASE OF FRANCE

by

Marc NUIZIERE

in collaboration with

Tör KOBBERSTADT

TABLE OF CONTENTS

A S.O.M. APPLICATION STUDY: DEVELOPMENT OF SECONDARY STUDENT STOCKS BY SOCIAL ORIGIN - THE CASE OF FRANCE FROM 1966/67 TO 1975/76

I. DESCRIPTION OF THE STUDY

The purpose of the study is to elucidate the functioning of the educational system allowing for the social origin variable which almost never features in official statistics but which has been shown by many surveys or studies to be an important factor governing the progress of students through the system and their chances of access to higher education.

Once the necessary data base has been built, the SOM(1) calculates the development of secondary education up to 1975/76.

For each year of the simulation period, the "Flow" and "Direct Resources" submodels give stocks by social origin, teacher requirements (regardless of category), staff costs, other current expenditure and investment requirements. These forecasts are available for all units (or classes) in secondary education.

Use of the simulation option model (SOM) has been deliberately confined to two of its submodels. Higher education is not described in the present study, and the use of the "Teacher Supply" and "Teacher Comparison" submodels(2) is not appropriate.

After concise comments on the development of the student stocks and resource requirements in secondary education, the study will endeavour to measure the development of the level of participation of each social group and to assess the share of resources available to

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(1) SOM = Simulation Option Model, which is comprehensively described in OECD-CERI 1970 publication "SOM - A Simulation Model of the Educational System."

(2) These two submodels respectively describe:

- the variation in the number of available teachers in each period, by training or professional grade;
- structural imbalances between teacher supply and demand in each category, with analysis in each period of simple balancing "policies".

them. It should be noted that the distribution of resources among the various groups must be calculated for secondary education as a whole (or for well-defined parts), since the distribution of expenditure per group is proportionate to the participation level in each unit. This initial study will serve as a reference for an alternative development of the secondary system which will take account of the structural changes that are to occur during the simulation period. The Vth Plan provides for the phasing-out of the primary terminal classes and the three-year short vocational course (in 1972/73 and 1974/75 respectively), thus creating a common core for all students up to the "3e" (fourth year of secondary studies).

These two alternatives will subsequently be designated as follows:

Alternative A - corresponding to a structure that remains constant over time and assuming constant transition coefficients;

Alternative B - corresponding to the implementation of the reform mentioned above. The assumptions concerning the variation of the transition coefficients for the classes to be phased out are given in Part II.

It seems interesting to measure the variations in stocks and resources provoked by the implementation of these structural changes. Moreover, the influence of such changes on equality of opportunity in the socio-economic groups should be measured. One can try to ascertain whether there has been any improvement in the situation described in the reference alternative. The first point is therefore to define a yardstick for equality of opportunity. Without going into lengthy discussion to define what is meant by the concept of "equality of opportunity", let us simply say that a system is all the more "egalitarian" the more closely it approximates to the structure of the active population at all levels (that is to say, a system with small differences between the levels of participation of the socio-economic groups is more egalitarian than one with larger differences). For this purpose, the only data available are the levels of participation by social group for all secondary education classes, and the structure of the active population. A general coefficient can be formulated from the sum of the squares of the deviations from the structure of the active population, which we propose to term the "disparity" coefficient.

$$E = \sum_{i=1}^{15} \sum_{j=1}^{3} \left[p_j(i) - m_j \right]^2$$

where: $p_j(i)$ = level of participation of group j in unit i, and

m_j = proportion of active population in group j.

This coefficient should be considered as an approximation (through lack of information) of a more representative coefficient that could be expressed as follows:

$$E_1 = \sum_{a,i,j} (p_j^a(i) - m_j^a)^2$$

$p_j^a(i)$ = proportion of students of age a in unit i belonging to social group j

m_j^a = proportion of population of age a belonging to social group j

A completely "egalitarian" system would result in E = 0, so the best system, in terms of our definition, at a given moment is the one with the lowest value of E. Naturally, much caution must be exercised in interpreting this measure, which reflects only relative differences in participation. For example, a system in which only 10 per cent of children were attending school and where E = 0 would be considered more egalitarian than a system covering 90 per cent of children but where $E > 0$.

The participation levels of the various social groups can be used to measure how resources are distributed among these groups. Assuming that the distribution is proportional to the level of participation of each group in each unit, we then have the following expressions for staff costs and other current expenditures:

$$\alpha j = \frac{\sum_i p_j(i)\, w(i)}{\sum_i w(i)}$$

where w(i) = Staff costs for unit i

$$\beta j = \frac{\sum_i p_j(i)\, C(i)}{\sum_i C(i)}$$

where C(i) = Other current costs for unit i.

These coefficients are formulated for each year. A distribution coefficient for total current costs could be defined in the same way, but it would closely approximate to αj since $w(i) > C(i)$ for all units. By comparing these coefficients with the overall level of participation for the system as a whole, we can see, for instance, whether the least favoured social group is not subjected to additional segregation in respect of its resource utilisation.

As regards investment, the development will reflect the efforts needed to carry out the structural reform.

II. DESCRIPTION OF INPUT DATA

The simulated part of the educational system consists of the last years of primary education, namely CM2 (2nd year intermediate course) and "Fin d'Etudes" (terminal primary), short vocational education given by the "CET's" (Colleges of Technical Education) in two-year or three-year courses, and secondary education proper, at the "CES's" (Colleges of Secondary Education), "CEG's" (Colleges of General Education) and lycées (see graph 2.1).

The study by A. Girard and H. Bastide (1) has enabled us to break down the school population into three major groups displaying relatively coherent behaviour, i.e. the progression of the socio-occupational categories belonging to a given social group is at much the same rate (see following table).

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(1) A.Girard and H. Bastide: "Orientation et sélection scolaires. Cinq années d'une promotion de la fin du cycle élémentaire à l'entrée du second cycle élémentaire du 2ème-degré". (School Guidance and Selection. Five years of transition from the end of the primary cycle to the beginning of the second cycle of the second level). Population, 1969, No's 1 and 2.

Breakdown by social origin of a class five years after completing CM2

	Work	Short vocational training (C.E.T.)	C.E.G.	Lycée	Total	Group No.
No occupation and miscellaneous	55.2	19.3	9.2	16.3	100	
Agricultural wage earners	55.6	18.6	9.1	16.7	100	1
Self-employed farmers	40.1	26.2	11.7	22.0	100	
Industrial and general workers	42.8	25.5	11.8	19.9	100	
Craftsmen and shopkeepers	25.3	20.4	15.2	39.1	100	
Clerical workers	22.7	22.6	16.1	38.6	100	2
Middle-level executives	9.7	13.4	14.8	62.1	100	
Professional workers	7.8	8.8	9.7	73.7	100	
Higher executives	2.7	8.2	12.3	76.8	100	3

Source: Population 1969 No2, p.201.

II.1 Flow Submodel

New enrolments

Each year, the simulated educational system receives new pupils entering the CM2 classes from the primary education. The calculation of these new entrants calls for a number of data on which assumptions have been made.

The population forecasts, which give the numbers of children of CM2 entry age (age from 9 to 13 (1)), must be converted into a CM2 inflow by applying the participation coefficients for each age group. These coefficients have been calculated from the CM2 age distribution observed in 1967-1968 (2), which is assumed to be constant throughout the period studied. In the breakdown by social origin, it is assumed that the structure is the same as that of the active population, thus depicting a non-discriminatory primary education.

Base year stocks

The stocks for each unit were obtained from the statistics for the 1966-67 school year. The pupils were broken down by social origin, assuming the same distribution as that observed in the Girard-Bastide study; this is a very high assumption, since a normal class stock comprises several cohorts whose social origins can differ quite appreciably from the observations used (see Table 2.II).

Transition matrix

In order to describe the student flow in each period, one must know the matrix of the transition coefficients for the various units of the system. First, we shall describe the ideal input data for correct evaluation. The stocks data should be supplemented by the following two dependent variables:

(a) school origin;

(b) social origin; these three-dimension tables must cover several years to determine the probable transition coefficient pattern over the simulation period.

If the study is confined to testing assumptions about the structure observed for the base year, the statistics needed relate only to the base year and the following one. Existing statistics, however, fall well short of such descriptive precision: though data on stock are sound, data on the scholastic and social origins of the pupils are available only for certain classes and are invariably produced independently.

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(1) Source: INSEE working paper from the "Population and Families" department (not published).

(2) Education statistics 4-2 (67/68). Breakdown of pre-primary and primary pupils.

We have had to refer to the Girard-Bastide study which followed a representative sample of CM2 pupils for five years, starting in 1962 (1). From this cohort study, the transition coefficients for the different socio-economic groups can be calculated, but these values are not the ones desired, since they represent the transition coefficients of students who have never repeated. Moreover, the calculated values are all the more biased when the original stock is small (which is the case for the final years covered by the study - "3e" and 2e"). Consequently, the coefficients calculated do not form the transition matrix sought, but only enable us to evaluate the relative differences in the progress of the socio-economic groups studied.

By using the 1967 and 1968 (2) statistics whenever information on the scholastic origin of the pupils was available (3), it was possible to calculate overall transition coefficients and then break them down into transition coefficients by socio-occupational group by using the relative progression differences for each group.

Where there was no information available on the scholastic origin of the pupils, the transition coefficients estimated from the cohort study were adjusted (maintaining the same pattern of relative progression) to generate the stocks observed in 1968 from those of 1967.

In the absence of information (description of the two types of CET and terminal classes of the secondary second cycle, we assumed the same rate of progress for each of the three groups.

The following is the value of the transition matrix for the two alternatives:

Alternative A: The transition matrix remains constant throughout the simulation period. See Table 2.III.

Alternative B: The value of the transition matrix varies with time. There is a linear variation, within the time intervals set by the Vth Plan, in the transition coefficients for the classes which are to be eliminated (CET three-year course and primary terminal classes). See Table 2.IV.

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(1) Op.cit., p.50

(2) Informations statistiques du Ministère de l'Education Nationale - No's 101, 107.

(3) Origine scolaire des élèves de l'enseignement public du second degré, 1967-1968. (Scholastic origin of pupils in second-level public education).
Note d'information No.11, Ministère de l'Education Nationale.

II.2 Direct Resource Submodel

Input data, evaluated from various sources and under the following assumptions, were needed for the calculation of resource requirements. Let us first of all recall that the submodel calculates staff costs, other current costs and investment requirements for each year.

It has been assumed in this study that expenditures for each unit were strictly proportional to the number of students in the unit. This assumption is relatively sound for current staff costs, but is less so for other current costs such as maintenance costs, which are more directly linked to the size of capital stock (space and equipment).

The investment calculation is based on the assumption that capital stock relates to requirements for the base year. As calculation of resource requirements is proportional to the stocks, calculated investment by block of units (representing a cycle of education) will therefore be strictly proportional to the increase in students' stock for this block, and where these are decreasing, investment will be assumed to be zero.

The required input data was built in two stages.

The various statistical sources generated the costs per student for the staff, maintenance and building cost headings. These costs per student were then converted into input data for the model using parameters, the majority of which were set in the absence of relevant information.

Costs per student reflecting staff expenditures were converted into average salary per teacher, thereby implying all expenditure engendered by the teaching function alone, and defining only one type of teacher for each education cycle. Building costs per student were converted into costs per square meter using the following identity for the base year:

$$CAP_o^i = c_i s_o^i = C_i n_o^i$$

$$c_i = \frac{C_i n_o^i}{s_o^i}$$

where c_i = cost per square meter for block of units i

C_i = cost per student for block i

n_o^i = number of base year students

s_o^i = base year floor area used

The value of s_o^i was estimated by assuming an arbitrary average classroom floor area of 50m2. See Tables 2.V and 2.VI.

II.3 Quality of Input Data

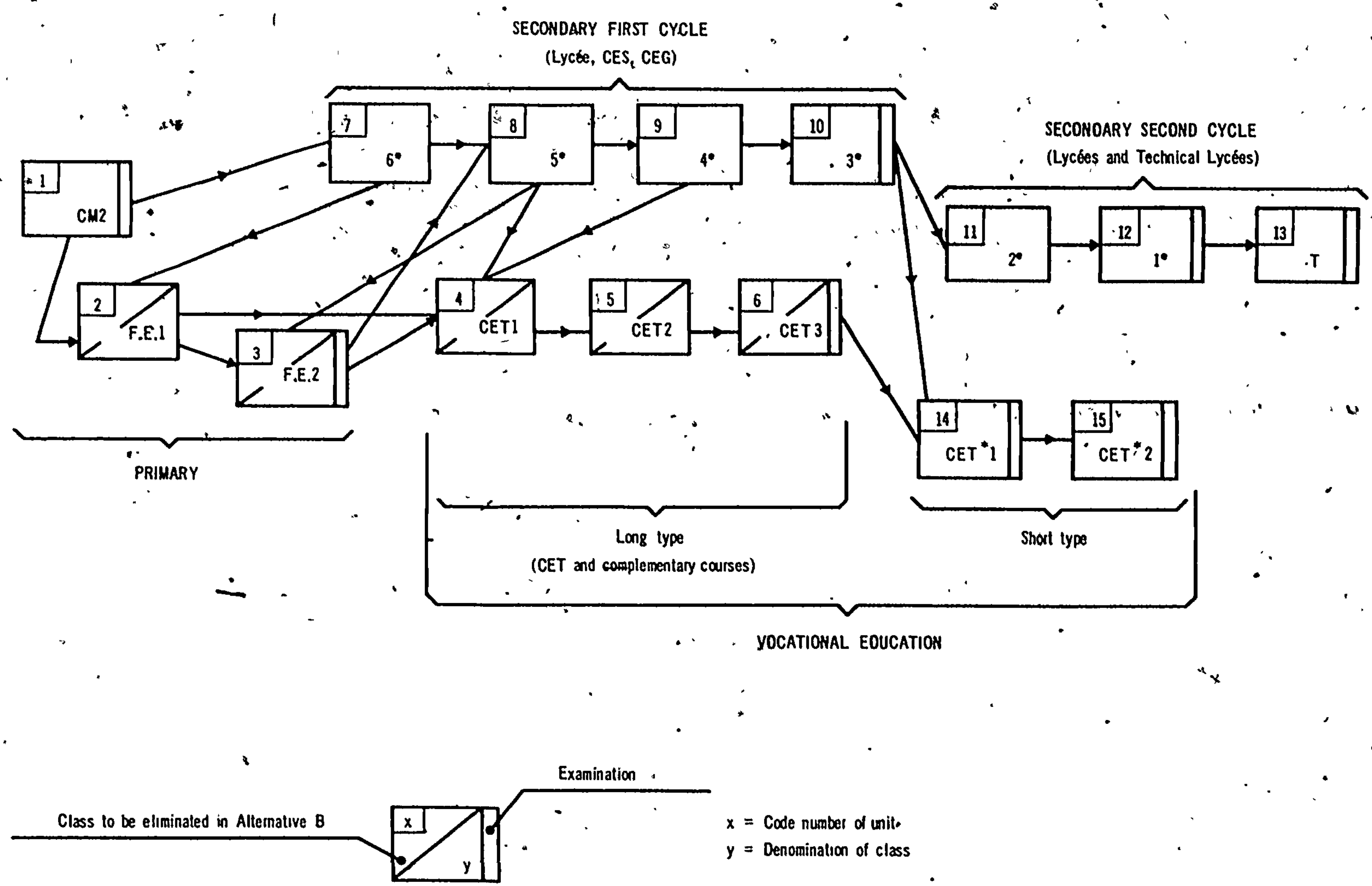
Unfortunately, it is impossible to quantify the error introduced by using the simplifying assumptions described in section II.

Moreover, the linearity adopted is no disadvantage when comparing two variants such as alternatives A and B, since the problem is relativised and the aim is to measure the magnitude of disturbance in relation to a stable reference system (constancy assumption).

Furthermore, we shall see that the chapter on interpretation of the results quickly disposes of the forecasting possibility of the model (in its conventional meaning of a single estimate) and concentrates on the comparison of the two alternatives.

Diagram 2.1

DESCRIPTIVE DIAGRAM OF FLOWS OF THE SIMULATED SYSTEM



2.II Student stocks by social origin

Base year: 1966/1967

Unit	Study class	Social origin			Total
		1	2	3	
1	CM2	555,644	247,372	119,994	923,030
2	Primary terminal 1	176,862	47,706	8,145	262,713
3	" " 2	226,816	71,382	10,815	309,013
4	CET 1	147,369	54,679	1,220	203,268
5	CET 2	114,651	42,539	949	158,139
6	CET 3	102,957	38,201	852	142,010
7	6e Lycée, CES, and CEG	257,629	201,162	129,403	588,194
8	5e "	238,599	176,800	121,986	537,385
9	4e "	193,485	144,451	103,369	441,747
10	3e "	165,364	123,543	94,768	383,675
11	2e Lycée	122,408	91,074	79,360	292,842
12	1e "	99,162	76,072	67,809	243,043
13	T "	89,457	70,433	66,583	226,473
14	CET (short) 1	31,881	9,185	3,523	44,589
15	CET 2	21,077	6,073	2,329	29,479

Source: Informations Statistiques No.101 March 1968
(Public primary education)
(Private education)

No.104 June 1968
(Technical education)

No.107 November 1968
(Public Second Level education)

2. III TRANSITION MATRIX 1967-1968

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	out
1	1	.182	.253					.515									.050
	2	.177	.140					.664									.019
	3	.039	.094					.856									.011
2	1		.036	.820	.107												.037
	2		.036	.890	.066												.008
	3		.036	.860	.096												.008
3	1			.241	.459				.065								.235
	2			.270	.312				.254								.162
	3			.213	.312				.415								.060
4	1				.033	.751											.216
	2				.033	.761											.206
	3				.033	.796											.171
5	1					.028	.873										.099
	2					.028	.917										.055
	3					.028	.917										.055
6	1						.031								.054		.915
	2						.031								.054		.915
	3						.031								.054		.915
7	1		.030					.164	.776								.030
	2		.050					.159	.744								.047
	3		.070					.128	.791								.011
8	1			.005	.020				.158	.763							.054
	2			.010	.039				.184	.757							.010
	3			.018	.071				.118	.790							.003
9	1				.031					.180	.734						.055
	2				.076					.170	.734						.020
	3				.051					.140	.805						.004
10	1										.175	.570			.181		.074
	2										.190	.630			.144		.036
	3										.164	.814			.013		.009
11	1											.140	.665				.195
	2											.185	.710				.165
	3											.156	.732				.149
12	1												.160	.678			.162
	2												.185	.683			.132
	3												.156	.728			.114
13	1													.270			.730
	2													.250			.750
	3													.240			.760
14	1														.010	.839	.151
	2														.010	.839	.151
	3														.010	.839	.151
15	1															.028	.972
	2															.028	.972
	3															.028	.972

2.IV. Changes in transition coefficients for Alternative B

1. Phasing-out of primary terminal classes

CM2	$p_1(1,2) = 0.$	$p_1(1,7) = .768$		
	$p_2(1,2) = 0.$	$p_2(1,7) = .814$		
	$p_3(1,2) = 0.$	$p_3(1,7) = .960$		
6e	$p_1(7,2) = 0.$	$p_1(7,7) = .171$	$p_1(7,8) = .807$	
	$p_2(7,2) = 0.$	$p_2(7,7) = .177$	$p_2(7,8) = .811$	
	$p_3(7,2) = 0.$	$p_3(7,7) = .177$	$p_3(7,8) = .852$	
5e	$p_1(8,3) = 0.$	$p_1(8,4) = 0.$	$p_1(8,8) = .162$	$p_1(8,9) = .784$
	$p_2(8,3) = 0.$	$p_2(8,4) = 0.$	$p_2(8,8) = .194$	$p_2(8,9) = .796$
	$p_3(8,3) = 0.$	$p_3(8,4) = 0.$	$p_3(8,8) = .128$	$p_3(8,9) = .866$
4e	$p_1(9,4) = 0.$	$p_1(9,9) = .186$	$p_1(9,10) = .759$	
	$p_2(9,4) = 0.$	$p_2(9,9) = .184$	$p_2(9,10) = .796$	
	$p_3(9,4) = 0.$	$p_3(9,9) = .148$	$p_3(9,10) = .848$	

The above values correspond to zero transition coefficients for the primary terminal classes in 1969/70.

The model calculates the values for the intermediate years by linear interpolation.

2. Phasing-out of the first two years of CET (long course)

The third year is assimilated to the first year of the two-year CET programme.

- the transition coefficients from primary terminal classes (FE) are phased out in 1971/72.

FE 1	$p_1(2,4) = 0.$	$p_1(2,7) = .107$
	$p_2(2,4) = 0.$	$p_2(2,7) = .066$
	$p_3(2,4) = 0.$	$p_3(2,7) = .096$
FE 2	$p_1(3,4) = 0.$	$p_1(3,8) = .524$
	$p_2(3,4) = 0.$	$p_2(3,8) = .566$
	$p_3(3,4) = 0.$	$p_3(3,8) = .727$

- the third year of the CET three-year course is assimilated to the first year of the CET two-year course in 1972/73.

CET 3:

$p_1(6,6) = 0.$ $\quad p_1(6,14) = .085$

$p_2(6,6) = 0.$ $\quad p_2(6,14) = .085$

$p_3(6,6) = 0.$ $\quad p_3(6,14) = .085$

$p_j(l,m)$ denotes the transition coefficient from unit l to unit m for group j.

2.V Costs per student - (French francs)

Education \ Type	Staff	Maintenance	Building
Primary (CM2, FE)	853 (3)	56 (3)	3,644
Secondary First cycle	1,422 (2)	89 (2)	9,310
Secondary Second cycle	2,448 (2)	128 (2)	17,858
Vocational Short (CET)	1,834 (2)	355 (2)	18,504

(1) Source: 5th Plan, Estimate in 1968 Francs.

(2) Source: document 3495, (Ministère de l'Education Nationale, Service Etudes et Conjoncture).

(3) Source: Budget Fonctionnel de l'Education Nationale Statistiques Financières.

Note: The heading 'Building' covers building costs, purchase of land, and the necessary equipment.

2.VI. Input Data for Resources Submodel

Unit	NBLOCK	NOACT NSPACE	CLSZ	WHC WU	WHT	AA m^2	SAL F	COSTPS F	CAPP F
1 CM2	1	1	35	22	22	50	29,853	56	2,458
2 FE_1	1	1	35	22	22	50	29,853	56	2,458
3 FE_2	1	1	35	22	22	50	29,853	56	2,458
4 CET_1	3	4	30	29	22	50	41,740	355	11,080
5 CET_2	3	4	30	29	22	50	41,740	355	11,080
6 CET_3	3	4	30	29	22	50	41,740	355	11,080
7 6e	2	2	30	22.5	18	50	28,240	89	5,575
8 5e	2	2	30	22.5	18	50	28,240	89	5,575
9 4e	2	2	30	25	18	50	28,240	89	5,575
10 3e	2	2	30	25	18	50	28,240	89	5,575
11 2e	2	3	30	27	18	50	61,148	128	10,693
12 1ère	2	3	30	27.5	18	50	61,148	128	10,693
13 T	2	3	30	27.5	18	50	61,148	128	10,693
14 CET_1^*	3	4	30	29	22	50	41,740	355	11,080
15 CET_2^*	3	4	30	29	22	50	41,740	355	11,080

NBLOCK - Code number of block of units sharing the capital costs.
NOACT - 'Activity' code number (one activity per unit).
NSPACE - Code number of type of space required.
CLSZ - Class size (number of students per class).
WHC - Weekly hours of instruction.
WU - Weekly hours of classroom utilisation.
WHT - Weekly teaching obligations (hours)
AA - Classroom area.
SAL - Annual teacher salary (francs).
COSTPS - Maintenance costs per student (francs).
CAPP - Building costs per m^2 (francs).

III. RESULTS

First, here is a reminder of what each social group contains:

Group 1	(Agricultural wage-earners (Self-employed farmers (Industrial workers (No occupation
Group 2	(Craftsmen (Shopkeepers and clerical workers (Middle-level executives
Group 3	(Professional workers (Higher executives

Also:

Alternative A: Development of the simulated educational system; structure remains constant over time.

Alternative B: Development of the system allowing for implementation of structural reform, i.e. phasing-out of terminal primary education and short vocational training three-year course.

III.1 Student Stocks

It can be seen in the reference alternative that stocks are increasing slightly in the CM2 and terminal primary classes are declining slightly in the three-year short vocational training (CET). On the other hand, the long secondary course seems to reflect the first effects of wider opportunities of access to this type of education, as measured by the transition matrix based on the 1966/1967 and 1967/1968 observations; the 1st cycle stock increases at an average rate of 2.6 per cent each year, while the 2nd cycle stock increases at 4.9 per cent - i.e. almost twice that rate (corresponding to appreciably the same gradient).

Turning now to the development of stocks by social origin, we observe that group 3 remains at about the same level, whereas groups 1 and 2 increase at an average annual rate of 2.7 and 2.0 per cent respectively; hence there is an overall narrowing of representation disparities.

The explanation of the stability of the group 3 stock is that this group is characterised by a high transition/repetition ratio, which gives it a more rapid rate of progress than the other groups. This leads to a shorter response time (maximum stock in 1971/1972) in relation to the CM2 inflow rate (appreciably constant over the period studied); moreover, the higher repetition rates for groups 1 and 2 imply longer response times, and hence slower growth for 1972/1973 and 1974/1975 respectively.

This observation enables us to interpret more accurately the narrowing of the representation disparities during the simulation period; this phenomenon reflects a temporary situation due to the variation in group response times, and we can reasonably consider that this tendency will diminish somewhat if the simulation period is extended (see Tables 1, 2, 3 and 4).

Implementation of the reform leads to major disturbances in the trend briefly commented upon thus far. Graph 3 shows the phasing-out of the primary terminal classes and the post-primary short vocational training (three-year course). The assumption of a linear decrease in the transition coefficients to these unit groups makes stocks drop sharply from 1967/1968 to 1971/1972, the terminal classes being eliminated by 1973/74 and the CET classes by 1975/76, i.e. a year later than planned, because of repetition.

The stocks in these units (primary terminal classes) are directed to the 6e and 5e classes of the lycées, CEG's and CES's and produce an immediate rise in the first cycle as a whole, at a rate of 14.3 per cent during the first five years.

Graph 2 compares this development with that shown in the reference alternative; it also shows that the influence of the reform on second cycle stocks only begins to make itself felt in 1969/1970 and less sharply than for the first cycle. While the first cycle is rebalanced by 1973/1974 (i.e. same growth as the reference alternative), the second cycle has not absorbed the whole of the disturbance by the end of the period studied.

The net outcome of the implementation of the reform is an increase in overall stocks in the system studied, which was to be expected, since it was assumed that students who formerly completed their schooling in the primary terminal classes would follow the same pattern as first cycle pupils of lycées, CES's and CEG's, where the drop-out rate is lower.

The following is a breakdown of the increase in stocks for 1975/1976:

Variation in stocks compared to the reference alternative 1975/1976

Type of education	CM2+ Primary Terminal	3-year C.E.T.	1st cycle	2nd cycle	2-year C.E.T.	TOTAL
Variation in stocks (thousands)	-508.2	-477.6	+1066.1	+477	+ 68.9	+597

III.2 Representation disparities

The disparity index mentioned in Part I provides a means of measuring the extent of the disparities in the two alternatives. This index was calculated for three years in the period: 1967/68, 1971/72 and 1975/76 (with linear variations between these years).

We note first of all a decline of over 50 per cent in the index between 1967/68 and 1975/76 for the reference alternative. There is hence an appreciable improvement in the representation of the least favoured group, though this may be only temporary and reflect a swing in the system. It should therefore be compared with the trend in the index corresponding to the change in structure.

Trend of the disparity index

Index \ Year	67/68	71/72	75/76
E_A	0.517	0.351	0.231
E_B	0.517	0.460	0.145

This table shows that the reform does indeed achieve one of its objectives in the horizon year, namely to reduce inequality of representation by creating a common core.

We still have to explain why $E_B > E_A$ between 1967/68 and 1971/72. Calculation of the index to type of education shows that this is due to the phasing-out of the primary terminal classes and the 3-year CET course: students from groups 2 and 3 are the first to disappear from these classes, which leads to over-representation of group 1 and hence an increase in the value of disparity index E_B. Nonetheless, alternative B is preferable between 1971/72 and 1972/76 (see Table 5).

III.3 Teachers

The graphs showing the development of teacher requirements for each education cycle resemble those of student stocks to within a homothesis (see Table 6).

The effects of the reform are therefore approximately similar, except that primary terminal and specialised vocational teachers can seldom, if ever, be substituted for 1st and 2nd cycle secondary teachers. This considerably slows down implementation of the reform, as is illustrated by the following table.

Variation in teacher requirements as compared with Alternative A

	67/68	69/70	71/72	73/74	75/76
CM2 + F.E.	0	- 5,270	-12,280	-13,876	-14,497
Short vocational C.E.T.	0	- 4,845	-14,703	-18,592	-17,959
1st cycle	0	12,773	36,192	46,334	47,040
2nd cycle	0	215	2,441	11,453	22,572
TOTAL	0	2,873	11,650	25,320	37,156

III.4 Resource Requirements

(a) Current expenditures

There are two types of expenditure: salaries of teachers and administrative staff, called staff costs, and other current expenditures, called maintenance costs.

Graph 4 plots these two types of expenditure for each alternative. As might have been expected, the implementation of the reform increases staff costs by 17.1 per cent compared with alternative A in the horizon year, the increase being linear from 69/70. We shall not comment on the variation in expenditures per education cycle, since these are by assumption directly proportional to the variations in teacher requirements.

Maintenance costs are calculated from costs per student, and these costs are much higher for post-primary vocational education than for secondary education (Frs. 335 as compared with Frs. 100). The disappearance of the CET 3-year course results in lower maintenance costs than for alternative A over the period in question as a whole.

Let us now see how these costs are distributed by social group. For this purpose, αj and βj have been defined as follows:

αj = the proportion of staff costs attributable to social group j;

βj = the proportion of maintenance costs attributable to social group j.

The following are the values of these ratios for 67/68, 71/72 and 75/76, together with their values for alternatives A and B respectively.

Distribution ratios of current costs by social group

Ratio \ Year		67/68			71/72			75/76		
	j	1	2	3	1	2	3	1	2	3
αj	A	.506	.301	.193	.506	.303	.191	.529	.301	.170
	B	.506	.301	.193	.507	.303	.190	.524	.294	.164
βj	A	.563	.290	.147	.550	.292	.159	.565	.290	.145
	B	.563	.290	.147	.544	.296	.160	.569	.289	.142
pj	A	.534	.295	.171	.543	.294	.163	.555	.293	.152

This table shows that βj does not vary by an appreciable amount from one alternative to the other - the initial and final values are about the same, while the intermediate variation is small, and we may conclude that the distribution of maintenance costs remains stable. In both alternatives, the ratio αj remains constant over the first five years, after which group 1 increases its consumption at the expense of group 3, while the distribution ratio for group 2 remains constant over the whole period. Overall, the cost and student distributions do not coincide, as is shown by the final line in the table (except for group 2). The explanation of these differences in distribution is that students in group 3 mainly belong to the secondary long cycle, whereas group 1 provides most of the student stocks for vocational courses. Staff costs differ from other costs by a factor of 10, from which one can conclude that the most under-represented group is even worse off in respect of its share of expenditure; while accounting for 56 per cent of the school population in 75/76, it generates only 53 per cent of the staff costs, whereas for group 3, the proportion is inverted (15 per cent and 17 per cent respectively).

(b) Investment

If we consider only total investments requirements over the period in question, we see that for alternative A they decline steadily, whereas they reach a maximum in 70/71 for alternative B. The additional effort made also reaches its peak at the same date and represents F.2.9 billion. A different pattern emerges with respect to capital requirements by type of education. In alternative A, primary and short vocational education need little investment, while in the secondary sector investment requirements for the first cycle decline from Frs.1.3 to 0.15 billion, and for the second cycle reach a peak of Frs. 1.04 billion in 71/72. In alternative B these investments relate only to the secondary long course, and graph 5 shows the pattern compared with alternative A. Implementation of the reform calls for considerable additional investment, reaching a maximum of Frs.2.7 billion in 70/71 for the first cycle and Frs.2.5 billion in 74/75 for the second cycle. These additional investments are certainly higher than the amounts which will actually be needed, since the programme does not provide for the re-utilisation of the capacities freed by the disappearance of the primary terminal classes and the CET 3-year course.

IV. CONCLUSIONS

The assumption of structural changes at the rate advocated by the Vth Plan will result in considerable overloading of long secondary education; there will be no increase in the maintenance costs of the system, but staff costs and especially capital requirements will be much higher. The main difficulty, as we have seen, stems from the considerable number of CET teachers who will suddenly become redundant. There are various possible technical solutions to this type of problem, namely:

(i) retraining of CET teachers;

(ii) slower phasing-out of CET 3-year course so that the 2-year CET's can absorb the equivalent stocks;

(iii) adjustment of qualifications to permit CET teachers to teach in the "practical" sections of CES's and CEG's.

In practice, it seems necessary to combine solutions (i) and (ii) if the same system of teacher qualifications is to be retained. Solution (iii) is a hasty "makeshift" solution and conflicts with the desire to create an education system of the same quality for all 1st cycle students.

Observation also shows that former students of primary terminal classes do not cross the bridge (or not to any great extent) between the short stream (practical sections of CEG's and CES's) and the long stream (classical and modern sections of the lycées). Unfortunately, the narrow statistical base prohibited simulation of these different streams.

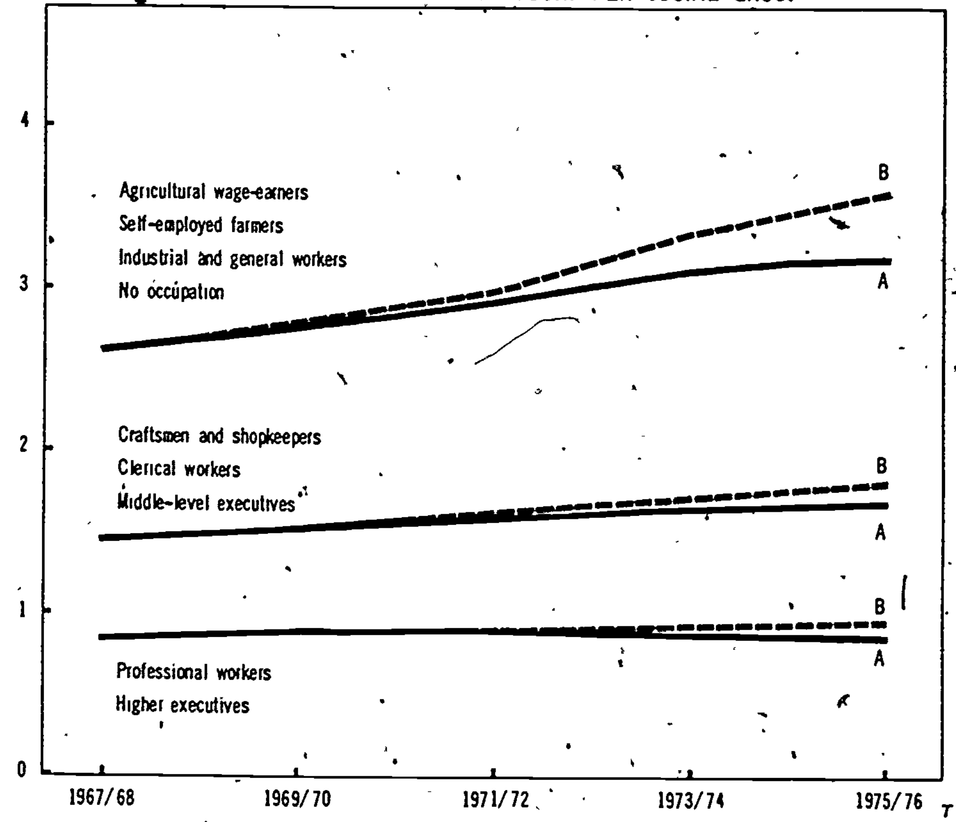
This observation leads us to view with caution the reduction in the disparities of representation that emerged from our study when the reform is carried into effect.

Furthermore, the breakdown of current costs by social group emphasises that group 1 is not only under-represented, but obtains a lower overall share of resources.

The limitation of the study's findings and their linear nature stem mainly from a narrow statistical base which has prevented an examination of why CEG's (and to a lesser degree CES's) are a barrier to access to "2e" classes. The advantage in using this model is mainly that it quantifies reactions that are to a large extent already foreseeable.

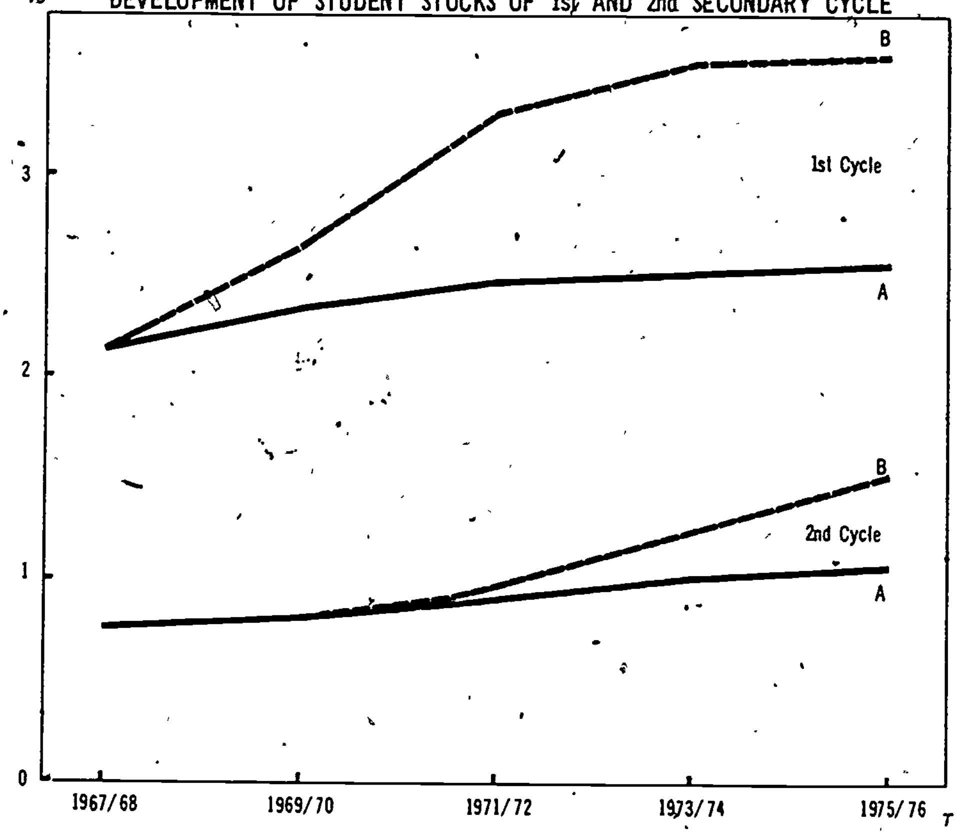
Graph 1

DEVELOPMENT OF STUDENT STOCKS PER SOCIAL GROUP



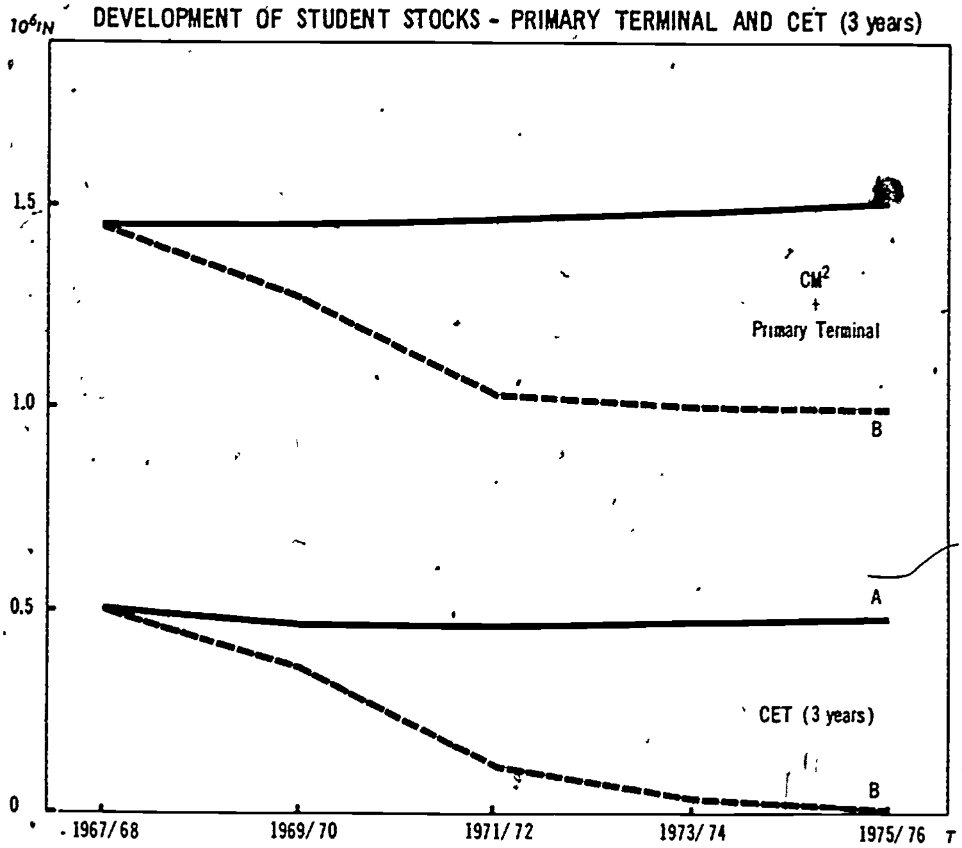
Graph 2

DEVELOPMENT OF STUDENT STOCKS OF 1st AND 2nd SECONDARY CYCLE



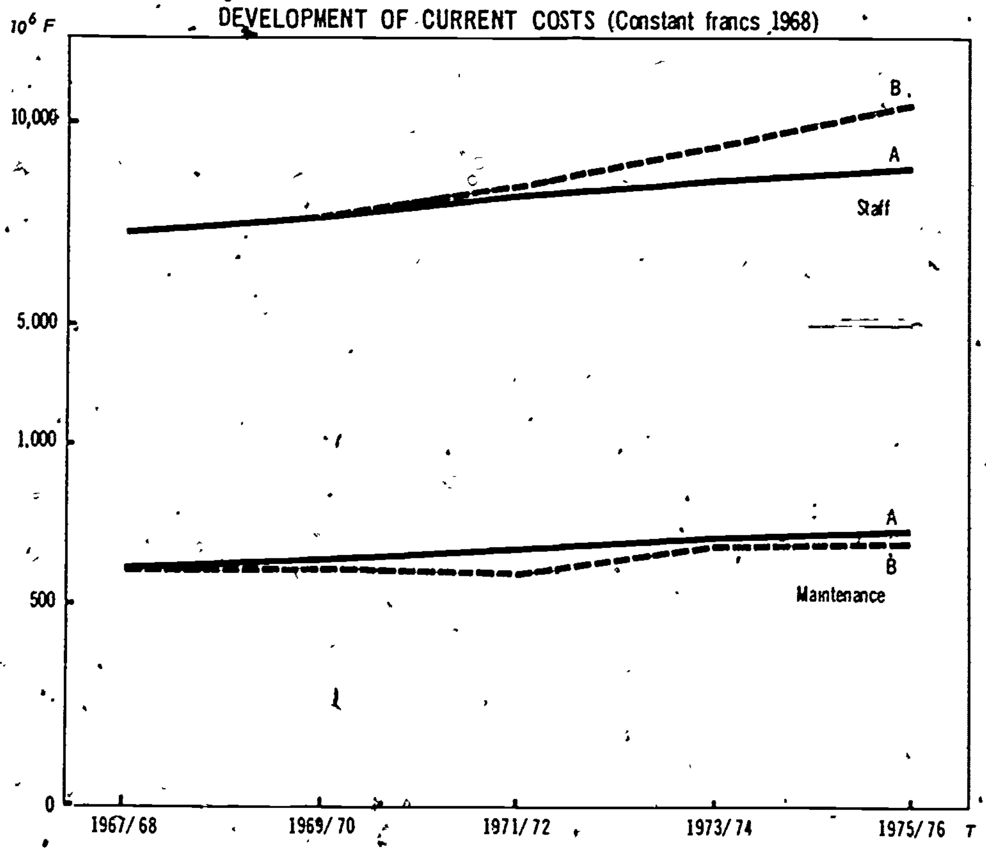
Graph 3

DEVELOPMENT OF STUDENT STOCKS - PRIMARY TERMINAL AND CET (3 years)



Graph 4

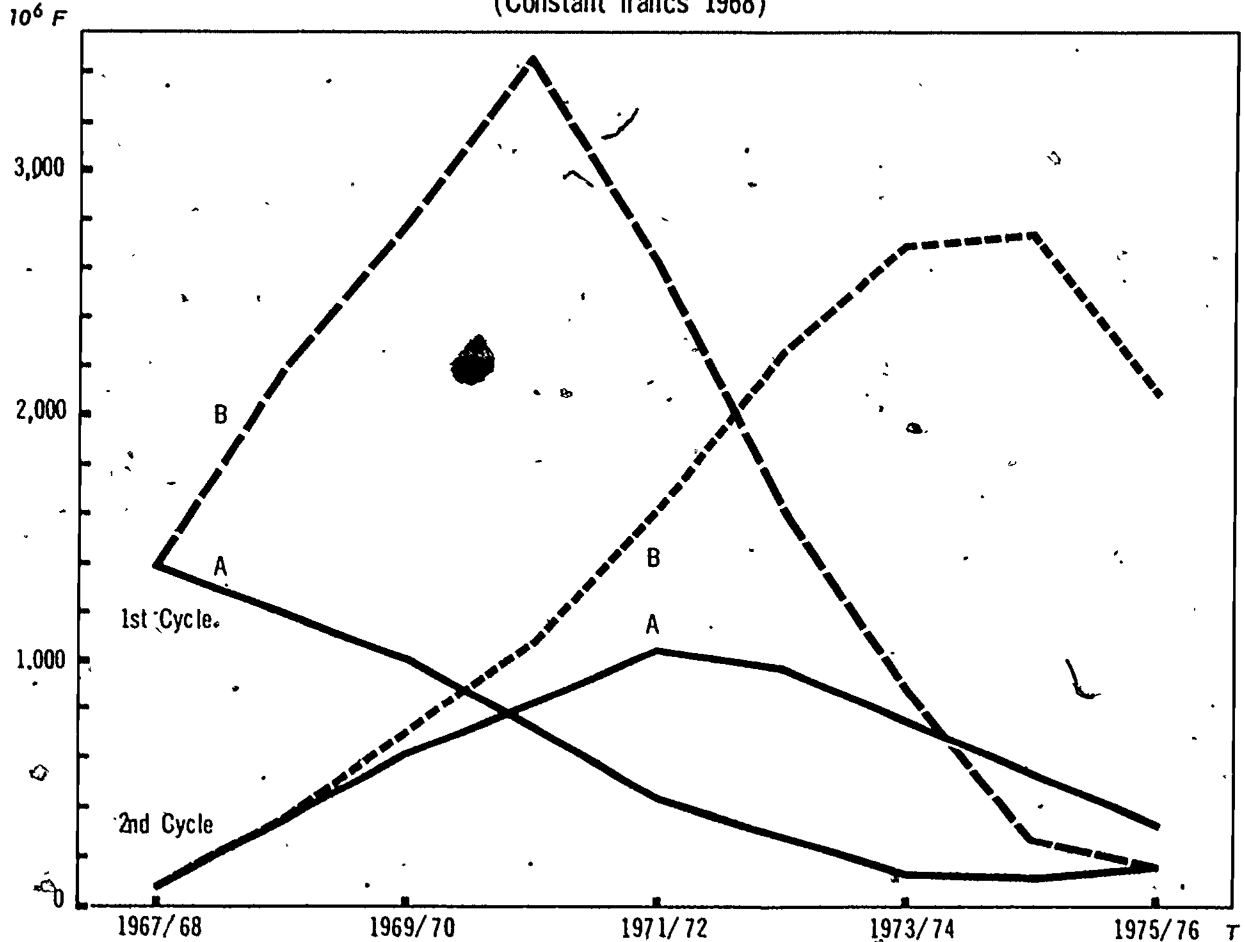
DEVELOPMENT OF CURRENT COSTS (Constant francs 1968)



Graph 5

YEARLY REQUIRED INVESTMENTS - SECONDARY

(Constant francs 1968)



1. Development of student stocks per branch of education (thousands)

Year		67/68	69/70	71/72	73/74	75/76
CM2 Primary Terminal	A	1446.4	1453.3	1465.8	1479.8	1500
	B	1446.4	1268.8	1036	994.2	992.6
3-year CET	A	503	474.6	464.3	472.9	477.6
	B	503	362	118.7	9.6	0
Lycée, CES, CEG 1st cycle	A	2103.9	2352	2477.9	2518.9	2549.1
	B	2103.9	2652.9	3309.8	3569.5	3615.2
Lycée 2nd cycle	A	767.4	818	924.3	1020.5	1068.7
	B	767.4	822.3	972.9	1248	1515.7
2-year CET *	A	93.1	111.1	131.4	149.8	156.1
	B	93.1	113.4	142.4	190	225
Total	A	4913.8	5209	5463.7	5641.9	5751.5
	B	4913.8	5219.4	5579.8	6011.3	6348.5

2. Development of student stocks per class Reference alternative A (thousands)

Class	Unit	67/68	69/70	71/72	73/74	75/76
CM2	1	949.7	962.3	968.1	978.7	991.8
F.E.1	2	220.1	230.0	232.1	233.4	238.1
F.E.2	3	276.6	261.0	265.6	267.7	270.1
CET 1	4	201.8	183.4	188.3	190.8	192.3
CET 2	5	157.5	148.0	144.9	148.0	149.4
CET 3	6	143.7	143.2	131.1	134.1	135.9
6e	7	645.3	674.1	680.5	684.7	698.4
5e	8	574.5	647.9	664.4	669.4	675.7
4e	9	485.6	563.5	603.9	613.7	617.9
3e	10	398.5	466.5	529.1	551.1	557.1
2e	11	295.8	330.5	378.2	405.7	414.7
1e	12	245.5	256.8	294.7	329.1	343.7
T	13	226.1	230.7	251.4	285.7	310.3
CET*1	14	55.1	62.0	73.8	81.9	84.1
CET*2	15	38.0	49.1	57.6	67.9	72.0

3. Development of student stocks per class
Structural change alternative B (thousands)

Class	Unit	67/68	69/70	71/72	73/74	75/76
CM2	1	949.7	962.3	968.1	978.7	991.8
F.E.1	2	220.1	97.6	14.6	0.4	0
F.E.2	3	276.6	208.9	53.3	15.1	0.8
CET 1	4	201.8	100.4	13.3	0	0
CET 2	5	157.5	119.8	34.2	0.3	0
CET 3	6	143.7	141.8	71.2	9.3	0
6e	7	645.3	822.7	922.9	938.8	958.4
5e	8	574.5	749.4	923.7	913.1	916.0
4e	9	485.6	595.6	808.2	891.0	891.4
3e	10	398.5	485.2	655.0	826.6	849.4
2e	11	295.8	334.8	415.0	548.3	623.0
1ère	12	245.5	256.8	304.5	393.1	494.2
T	13	226.1	230.7	253.4	306.6	398.5
CET*1	14	55.1	64.3	81.6	108.4	122.2
CET*2	15	38.0	49.1	60.8	81.6	102.8

Unit	Year / Sol.	67/68			69/70			71/72			73/74			75/76		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	A	61.1	27.4	11.5	61.2	27.5	11.3	61.1	27.4	11.5	61.2	27.5	11.3	61.2	27.5	11.3
	B	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
2	A	69.8	21.1	9.1	70.9	21.2	7.9	71.0	21.2	7.8	71.0	21.2	7.8	71.0	21.3	7.7
	B	"	"	"	66.7	23.8	9.5	39.0	36.3	24.7	50.0	25.0	25.0			
3	A	72.9	22.9	4.2	68.0	23.2	8.8	68.3	23.4	8.3	68.3	24.5	8.2	68.4	23.4	8.2
	B	"	"	"	66.8	24.6	8.6	57.4	30.4	12.2	48.3	31.8	19.9			
4	A	68.7	22.5	8.8	63.2	24.6	12.2	63.8	24.7	11.5	64.0	24.8	11.2	64.0	24.8	11.2
	B	"	"	"	65.8	23.3	10.9	73.7	20.3	6.0						
5	A	72.3	27.1	0.6	65.5	23.6	10.9	62.8	24.7	12.5	63.4	24.7	11.9	63.4	24.8	11.8
	B	"	"	"	66.4	23.1	10.5	73.7	19.0	7.3						
6	A	71.5	27.9	0.6	67.2	23.8	9.0	61.5	25.4	13.1	62.0	25.6	12.4	62.2	25.7	12.1
	B	"	"	"	67.2	23.7	9.1	64.2	24.2	11.6	74.2	20.4	5.4			
7	A	51.2	30.3	18.6	53.4	30.6	16.0	53.6	30.6	15.8	53.6	30.6	15.8	53.6	30.6	15.8
	B	"	"	"	57.5	28.6	13.9	59.2	27.7	13.1	59.3	27.7	13.0	59.2	27.7	13.2
8	A	44.4	34.5	21.1	52.3	30.9	16.8	53.0	30.9	16.1	53.0	31.0	16.0	53.0	31.0	16.0
	B	"	"	"	55.0	29.4	15.6	59.1	27.6	13.3	58.9	27.8	13.3	59.1	27.7	13.2
9	A	44.5	32.7	22.8	49.5	31.8	18.7	53.0	30.7	16.3	53.2	30.8	16.0	53.3	30.8	15.9
	B	"	"	"	49.7	31.3	19.0	56.2	28.7	15.1	58.2	27.8	14.0	58.3	27.7	14.0
10	A	42.9	32.3	24.8	43.6	33.5	22.9	50.6	30.9	18.5	52.2	30.6	17.2	52.4	30.6	17.0
	B	"	"	"	43.0	34.1	22.9	51.0	30.8	18.2	55.9	28.9	15.2	56.5	28.7	14.8
11	A	37.6	32.2	30.2	37.2	32.4	30.4	41.1	32.6	26.3	45.5	31.7	22.8	46.3	31.8	22.0
	B	"	"	"	37.2	32.6	30.2	40.6	33.1	26.3	47.6	31.0	21.4	50.4	30.1	19.5
12	A	39.8	32.2	28.0	35.0	33.5	31.5	35.5	34.5	30.0	41.3	33.4	25.3	43.7	33.1	23.1
	B	"	"	"	35.0	33.5	31.5	35.1	34.9	30.0	41.8	33.3	24.9	47.1	31.8	21.1
13	A	40.5	30.7	28.9	37.2	31.9	30.9	35.2	32.6	32.2	37.7	33.2	29.1	42.4	32.3	25.1
	B	"	"	"	37.2	31.9	30.9	35.2	32.7	32.1	37.3	33.6	29.1	43.9	32.0	24.1
14	A	63.7	34.7	1.6	63.2	35.2	1.6	64.9	32.8	2.3	67.3	30.6	2.1	67.5	30.4	2.1
	B	"	"	"	63.3	35.1	1.6	64.3	33.4	2.3	69.4	29.4	1.2	70.9	28.1	1.0
15	A	71.8	20.6	7.6	63.6	35.0	1.4	62.5	35.2	2.3	66.6	31.4	2.0	67.5	30.5	2.0
	B	"	"	"	63.5	35.0	1.5	61.8	35.7	2.5	67.2	31.2	1.6	70.7	28.3	1.0
Total	A	53.4	29.5	17.1	53.6	29.5	16.9	54.3	29.4	16.3	55.1	29.3	15.6	55.5	29.3	15.2
	B	"	"	"	"	"	"	54.6	29.3	16.1	55.9	28.9	15.2	56.7	28.6	14.7

4 – Participation rates by social group (per cent) – Alternatives A and B

5. Disparity index per type of education and for the whole system

Type of education \ Year		67/68	71/72	75/76
CM2 Primary Terminal	A	.032	.023	.023
	B	.032	.076	.0
CET 3-year	A	.057	.003	.003
	B	.057	.051	
1st cycle Secondary	A	.155	.046	.040
	B	.155	.018	.005
2nd cycle Secondary	A	.239	.283	.139
	B	.239	.287	.100
CET 2-year	A	.034	.026	.026
	B	.034	.028	.040
E	[illegible]	.517	.381	.231
	B	.517	.460	.145

6. <u>Development of teacher requirements (thousands)</u>

Type of education	Year	67/68	69/70	71/72	73/74	75/76
CM2 Terminal	A	41,326	41,522	41,880	42,281	42,857
	B.	41,326	36,252	29,600	28,405	28,360
Short Vocational CET	A	26,192	25,734	26,175	27,361	27,845
	B	26,192	20,889	11,472	8,770	9,886
Secondary 1st Cycle	A	91,754	102,768	108,490	110,347	111,652
	B	91,754	115,541	144,682	156,681	158,692
Secondary 2nd Cycle	A	38,806	41,352	46,721	51,595	54,040
	B	38,806	41,567	49,162	63,048	76,612
Total	A	198,080	211,318	223,266	231,582	236,394
	B	198,080	214,247	234,916	256,904	273,550

7. Yearly required investments (Francs in millions)

		67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76
CM2 Primary Terminal	A					3	13	39	52	19
	B									
Short Vocational CET	A	340					282	209	127	76
	B	340								
1st cycle	A	1393	1291	1013	753	445	249	139	121	152
	B	1393	2181	2783	3442	2656	1638	873	274	146
2nd cycle	A	88	278	629	872	1041	971	766	537	334
	B	88	278	705	1082	1625	2250	2698	2749	2084
Total	A	1821	1569	1642	1625	1489	1515	1153	837	581
	B	1821	2469	3488	4524	4281	3888	3571	3023	2230

PART II

S.O.M. AND CONTROL THEORY

by

Paul ALPER

TABLE OF CONTENTS

I. INTRODUCTION

The purpose of this paper is to look at the Simulation Option Model (3), or SOM, of the OECD from the point of view of control theory both in order to discuss SOM and to suggest certain possible expansions of the model which might be quite fruitful. In order to avoid ambiguity about what is meant by control theory, the following definition will be used:

> "Control theory is that body of knowledge concerned with actively bringing a system from one state of nature to another (possibly the same) with a performance criterion either explicitly stated or tacitly understood."

Notice that the above definition makes no mention of just what type of mathematics is involved but rather it stresses the word "actively" because the real distinguishing feature of control theory as opposed to, let us say, astronomy, is the conscious desire on the part of the analyst to do something such that the system behaves better in light of the explicit or tacit criterion.

However, not only does control theory have a good bit to say about influencing the behaviour of a system but it can materially add to the description of the system as well. In fact, much of what is now referred to as "Modern Control Theory", loosely speaking, can be broken down into two categories, (1) analysis and (2) optimization; the former is concerned primarily with the types of mathematical representations which are most suited for explaining, describing and presenting the data, the system and the results, while the latter focuses attention on what can be done both theoretically and in practice using these representations to produce the best results.

Some recent papers (10,12) have used some optimization techniques taken from control theory and have applied them to educational planning; too often the misleading impression is obtained that only this facet of control theory, optimization, is relevant to fields such as economics, education or the social sciences in general. As a by-product, it is hoped that by concentrating on SOM, this paper can be useful in indicating how other aspects of control theory can be profitably exploited both for SOM in particular and educational planning models in general.

II. GRAPHS AND TABLES

When engineers look at research done in educational planning models, there is often a sense of disorientation brought about due to the overwhelming number of tables in a typical report and the almost total lack of graphs. Referring to the usual type of educational planning report, Evans (6) notes that:

Figures in brackets refer to References p. 94.

"These plans quickly immerse the reader in extensive tables of numbers - population data, school enrolment 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."

Moreover:

"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 are typically sketchy or even completely absent. Such data severely limit the accuracy of calculations based on them and argue 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?"

Why not, indeed? And it was very refreshing to see that the authors of SOM chose to display prominently - and in round numbers - the graphical unfolding of enrolment and expenditure versus time, leaving the tables at the very back of the report. However, as Evans also suggests, they could go still further and display on one graph, "Supply of Teachers vs. Time" and "Demand for Teachers vs. Time" in order to show clearly how different policies relating, for example, class size, teaching load, rate of success and rate of choice, will produce different types of results - for example, too many teachers, not enough teachers, just enough, too many one year and then a shortage the next and so on.

Furthermore, it might be of some use to plot one variable versus time. For example, for specific policies, a decision-maker might wish to see such things as (1) "Resource Expenditure vs. Class Size", (2) "Teacher Supply vs. Number of Students" or (3) "Medical Students vs. Total Population" in order to get a quick picture of how the educational sphere is developing with respect to itself and to the rest of society. One of the main motivating factors behind the production of mathematical models in educational planning was to give the decision-maker a tool which would reduce the huge amount of interconnected and confusing data so that he would be able to see immediately what should be done. The further use of graphs as opposed to tables would go a long way in providing such a service and the possibility of providing such graphs as suggested here for SOM should be looked into.

III. "WHAT IF" AND FEEDBACK

One of the most important features of SOM which distinguishes it from most previous mathematical models in educational planning is that instead of giving one projection, SOM can calculate one projection for each of the various assumptions. As the report put it:

> "The SOM is 'neutral' with regard to priorities between educational objectives, since it merely simulates the development of the system on the basis of various assumptions or estimates of such factors as transition coefficients, demographic developments, restricted entry or other resource restrictions, relationships between physical and financial resources, etc. It can thus be seen as a kind of 'what-if' model, in which the effects of considered changes are traced through the educational system. It is, for instance, designed so as to be able to answer such questions as: 'What consequences concerning the educational outflow and educational resource requirements will we get if this transition coefficient increases over time in this way, or if class size is changed so and so much?'"

Philosophically and practically speaking, this "what-if" viewpoint is very important but not without certain unanticipated hazards. In his review of the book, Decision Models for Educational Planning(1), Vaizey(13) makes the following devastating comment concerning the book's advocacy of the radical position that not only should alternatives be shown but is in fact the most useful way of presenting the results:

> "This, it must be said, has not been my own experience. I tried very hard on the National Advisory Council for the Supply and Training of Teachers to have a range of figures put up which would be explicitly based on various hypotheses but it was most strongly pointed out by the officials concerned that inevitably the Treasury would fasten on the lowest. It was presumably for this sort of reason that the Robbins report put forward one single series of figures rather than the ranges that they undoubtedly considered."

In other words, SOM is absolutely correct in getting away from the false and restrictive notion that there is only one course that society and education will follow and SOM is completely right in trying to be as explicit as possible about its assumptions. According to "Alternative Educational Futures and Educational Policy Planning"(2), a minimum requirement for Second Generation Educational Planning, SGEP, is that the model have the following aspect:

> "Tracing through the future consequences of current and foreseeable decisions. This amounts to an attempt to determine alternative educational futures resulting from past and current policy decisions. It can be labelled a 'forward running' or 'exploratory' approach."

But as Vaizey indicates, the decision-maker may not be sophisticated enough to know what to do with his tool. Perhaps in parallel with providing better analytic instruments for the decision-maker, CERI should undertake considerable effort to educate the decision-maker in how to utilize his instrument properly. For example, in keeping with the spirit of Vaizey's comments, even such a modest proposal as graphs instead of tables would be to no avail if the decision-maker were so poorly versed in mathematics as to prefer tables over graphs because tables give exact, 6-digit information while graphs give him a headache. Rather than as Vaizey put it, "Let us hope that somebody, somewhere can understand them," a conscious effort should instead be made to ensure that the decision-maker comprehends what SOM and other educational models are telling him.

However, the "What if" approach has a weakness besides that of the decision-maker's possible inability to comprehend what he is being informed of. The "what if" approach is indeed "forward running" in the sense meant by control engineers. That is, SOM as presently set up is feedforward or open-loop only and contains no feedback with respect to the control variables or the transition proportions.

The way SOM is presently constituted, the transition proportions are considered as exogenous variables and for every configuration of the transition matrix, in conjunction with preselected or pre-programmed values of the control or decision variables (which are, for example, class size, teaching load, rate of choice, rate of success and size of the bottlenecks in the sectors of restricted entry), there is then an unfolding of the future. For a different set of exogenous transition proportions and/or different values of the control variables there is a different unfolding of the future.

As Fig. 1, a very simplified block diagram of SOM, reveals, the entire SOM model is open-loop with no feedback coupling between the results - students, teachers, money spent - and the transition proportions or the control variables. In other words, the vector of control variables, $\underline{u}$, and the transition proportions, p_{ij} are functions of time only:

$$\underline{u} = \underline{u}(t) \qquad (1)$$

$$p_{ij} = p_{ij}(t) \qquad (2)$$

This assumption, as embodied in Eqs. (1) and (2), is very difficult to defend. Transition proportions don't have lives of their own quite independent of the number of students and teachers in the various sectors; the control or decision variables in the real world are not merely pre-programmed but rather are related in a feedback way to how the future is developing.

In a sense, SOM, by not taking into account the feedback nature of the situation, is vulnerable to the criticism by Frisch(7) and later by Edding and Naumann(5) made with reference to models which completely suppressed the influential nature of decisions:

> "On the one hand, one still retains the onlooker viewpoint, and tries to make projections on this basis (growth models of the current types). And on the other hand one will afterwards try to use such projections as a basis for decisions. How can it be possible to make a projection

without knowing the decisions that will basically influence the course of affairs? It is as if the policy-maker would say to the economic expert: 'Now you expert try to guess what I am going to do, and make your estimates accordingly. On the basis of the factual information thus received I will then decide what to do.'"

"... scientists in attempting to provide information for policy decisions had to anticipate exactly those political decisions for which their findings were supposed to provide the basis of information."

Obviously, the decisions and the transition proportions must be related to the states of the system and it could be highly misleading if policies and social demands were presented as being entirely unaffected by the states of the system. As the Secretariat of the OECD put it,(2)

"... more attention will need to be paid to feedback mechanisms. There will, therefore be a growing need for applications of adaptive control theory to educational policy-planning problems."*

In Section V, the archetypal model of control theory will be introduced and it will be shown how Eqs. (1) and (2) could be modified in order to exhibit this feedback property and consequently avoid the pitfalls mentioned by Frisch and Edding and Naumann.

IV. CRITERIA: EXPLICIT AND IMPLICIT

Once again, according to the OECD Secretariat(2), a necessary requirement for SGEP is the inclusion in the model of "multidimensional goal assessment" or in other words, a criterion. SOM of course does not have an explicit performance index. This is not so severe a limitation as it seems at first. According to the definition of control theory given above, criteria may be either explicit or implicit. It is well known that it is exceedingly difficult and perhaps even impossible to formulate an explicit criterion in education which would be universally accepted as correct and meaningful. Two recent documents prepared for the OECD (9,14) deal at great length with the fact that society has become increasingly fragmented with respect to the beliefs and values held by the various groups regarding education and thus deciding on an index of performance agreeable to all concerned is very hard to imagine.

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* It is beyond the scope of this paper to discuss properly what is meant by adaptive control. In the late 50's and early 60's, much attention was paid to this area by controls people but it has not proved to be nearly so fruitful as was envisaged at first. Although the property of adaptivity certainly sounds desirable, building in such a feature is often impossible in practice. Moreover, whether a control system has the property of being adaptive or not often depends on the subjective views of the designer and not upon any strict, universally agreed-upon definition.

Much of what is now called "Introductory Control Theory" had criteria which were implicit and qualitative and therefore hard to use analytically: fast rise time, good phase margin, not too much overshoot and so on. But within this limitation, a good deal of important, useful work has been accomplished.*

SOM's index of performance seems to be implicitly given by the graphs and tables for the different alternatives. Presumably, the decision-maker would scan or study all the carefully laid-out graphs and tables and via some internal computer of his own mind he would select that policy vector which optimizes some inner objective function of personal feelings. If this is so and will be so for quite some time to come due to the inherent difficulties of making criteria explicit, then it becomes vitally important to present the alternative results in the clearest possible way so that an educated, knowledgeable decision-maker can properly use his experience.

As has been suggested, one way to give insight is to display the results in the form of graphs. Another possibility, is to display in addition to the computer flow diagram, a block diagram such as Fig.1 in order to show essentially and without excessive detail how the submodels fit together and what, if any, feedback mechanisms are present. If it is argued that decision-makers do not understand block diagrams, then it is necessary to instruct them in the use of block diagrams. After all, it makes very little sense to expend so much effort to improve our models from what CERI refers to as "First Generation Educational Planning" to "Second Generation Educational Planning" if the decision-maker remains at the zeroeth generation.

Continuing in this vein, because SOM's criterion is implicit, it becomes necessary to use even more "esoteric" notions than graphs and block diagrams. Most of SOM's flow model as discussed in the report could be viewed as a linear discrete system whose coefficients are constant or time-varying; non-linearity enters into the picture due to the sectors of restricted entry. Although non-linearity detracts greatly from the tractability of the analysis, it would be conceptually possible to linearize this type of non-linearity (which control theorists refer to as a "soft limiter") by finding a linear equivalent(8).

This linear equivalent, even though possibly time-varying, could be employed so that such useful control concepts as eigenvalues, modes of vibrations, impulse response, fundamental matrix and so on can be discussed.** In this way, the level of discussion can be lifted up markedly. Although Section II of this paper has proposed the superiority of graphs over tables for data reduction purposes, graphs of outcomes are really not very basic to the understanding of the system. Because SOM has very many states, graphs of every student and teacher sector

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* For a discussion of how some implicit criteria may be made explicit, see Chapter 8 of Schultz and Melsa(11) which is a very well written book on some aspects of "Modern Control Theory".

** Strictly speaking, some of these concepts are not defined for time-varying systems and either approximations have to be made or the concept has to be generalized; usually resulting in more difficult computation.

for every conceivable control policy, immigration pattern and transition matrix would still offer the decision-maker an unenviable task in data reduction.

However, control theory has been concerned with exactly that (analogous) type of large multi-variable system and the problems of analysis and data reduction which confront educational decision-makers. Inasmuch as the above mentioned notions of eigenvalues, etc., have proved useful for control systems, it would be expected that they would do likewise in education. But once again, a training programme might have to be implemented with regard to educating the decision-maker.

V. ARCHETYPAL CONTROL MODEL

Control theorists have found that from an analytic, computational and philosophical point of view, the best way to frame a discrete control problem is to

$$\text{Extremize with respect to } \underline{u} : J \qquad (3)$$

with the dynamics put in the form of

$$\underline{x}(k+1) = \text{function of } \underline{x}(k), \underline{u}(k), k \qquad (4)$$

where J is a functional of $\underline{x}(k), \underline{u}(k), k$.

$\underline{x}$ is the vector of the states.

$\underline{u}$ is the vector of the controls.

k is discrete time.

When the system is linear, then Eq.(4) becomes

$$\underline{x}(k+1) = A\,\underline{x}(k) + B\,\underline{u}(k) \qquad (5)$$

where A and B are matrices.

Given this framework, control theorists attempt to find the <u>control law</u>

$$\underline{u} = \underline{u}(\underline{x}) \qquad (6)$$

which will extremize the functional, J. Notice that $\underline{u}$ depends upon the states of the system or in other words, Eq.(6) is a feedback relation between the states and the controls and stands in marked contrast to Eq.(1).

With regard to the transition proportions, if it is felt that a particular p_{ij} depends on such things as students, teachers or resources, then p_{ij} is one of the states of the system and Eq.(4) (or if linear, Eq.(5)) applies so that

$$p_{ij}(k+1) = p_{ij}(\underline{x}(k),\underline{u}(k),k) \qquad (7)$$

Again, this is in marked contrast to Eq.(2).

But a heavy price is extorted for incorporating reality. Not only do the computations get more difficult because additional states are included, but also the feedback relationships between the states and the control variables must be determined. Unfortunately, not very much is presently known about the closed-loop feedback relationship given by Eq.(4), Yet, we can't conveniently assume it away by requiring the model to be open-loop or feedforward only, if indeed there are feedback mechanisms operating in the system.

This is, of course, the dilemma of many social science models: "How to trade off mathematical convenience against the real world's complexities." Unless educational planning models face up to this situation whereby decisions are coupled in a closed-loop feedback manner with the states of the system, progress will be minimal.

VI. SUBMODELS - CONTROLLABILITY AND OBSERVABILITY

Basic to the philosophy of SOM is the concept of optionality embodied in the combining and discarding of submodels to suit the situation; for example, both the Teacher Supply Submodel and the Resource Submodel can be utilized or not as the data and the decision-maker demand. Intuitively, there is much to be said in a positive way with respect to increased flexibility and comprehensiveness regarding the combining of submodels; there also exist some dangers which are not immediately obvious at first and some care is needed when putting submodels together.

Much of "Modern Control Theory" is motivated by complicated multivariable systems and these have led to a thorough re-examination by control theorists of intuitive concepts which were handed down from the study of much simpler systems. It has been found that when combining subsystems or submodels, special attention must be paid to the resulting system's (1) "controllability" and (2) "observability"; it turns out that subsystems which may be each controllable and observable when combined may result in an overall system which is neither controllable nor observable.*

Loosely speaking, in an educational planning context, controllability would refer to the ability of the decision-maker to steer the system from any state to any other in a finite time while observability would refer to the decision-maker's ability to ascertain the behaviour of the states from the measurement of the system's outputs. Since the steering of the overall system and the ascertaining of its behaviour are fundamental to the desires of the decision-maker, it becomes apparent that very great heed must be taken regarding the controllability and observability of

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* It goes without saying that subsystems which may be each stable, when combined may result in a system which is unstable.

the overall system. Because subsystems which are each controllable and observable may produce a non-controllable and non-observable overall system, particular care is required in the combining of these subsystems. Without such care, the decision-maker may find himself unable either to influence certain states or determine their behaviour.

VII. DETERMINISTIC VS. STOCHASTIC MODELS

SOM as presently constituted is deterministic only. For each constellation of transition proportions, decision variables, inputs, etc., there is one and only one set of results. That is, once the constellation has been agreed upon, the results take the form of knife-edge forecasts. For example, when discussing the raising of the school-leaving age, SOM tries to avoid introducing non-deterministic effects by assuming in all cases but 4A* that those who were forced to stay on will "adopt the continuation pattern of those who continue voluntarily"; in case 4A*, those who were forced to stay on will "leave school as soon as possible". So-called second-order effects which intuitively are probabilistic in nature are ignored in the presentation of the results although the report does mention them in passing:

- "On the other hand, certain pupils who earlier stayed on after the age of 15 may stay on even longer because of the reform, in order to keep their 'educational differential'".

As Armitage (1) has pointed out, such probabilistic effects may be quite crucial in just this situation where behaviour patterns may change due to policy changes. Unfortunately, a model which is stochastic or a basically deterministic model which includes stochastic elements is usually much more difficult to handle. Again, we are in the situation where we have to balance off our desire to model fully the system against the increase in mathematical intractability of the model. Furthermore, with respect to the example in SOM, if we could introduce the necessary probabilities in order to calculate a range of answers for each policy, then each of the curves pictured, instead of being hairline or knife-edge, would be some sort of cone spreading out into the future and possibly, therefore, overlapping. As Ziegler(14) put it,

> "The point is that the longer the time perspective, the more uncertain are the assumptions on which linear projections rest, and the greater is the 'spread' between the maximum and minimum parameters of the functions extrapolated. The reliability of these assumptions decreases because we are less certain both about our expectations and our intentions."

On the other hand, Coleman(4) points out, "there is an ever-present danger with probabilistic models that we will use them to say little or nothing - but to say it elegantly - about the behavior at hand." He further adds that in reality, deterministic models, because they are simpler may indeed be better because "simpler mathematics may allow investigation of problems which remain completely closed so long as the extra burden of the total distribution is carried along, for the basic model may be made more complex without reaching unmanageable mathematics. And the argument that the stochastic process is more 'fundamental' is not a valid argument at all." As a final note he lethally observes that, "some probabilistic models do little more than formalize our ignorance."

Thus it is seen that SOM's non-stochastic nature is not necessarily the handicap which it seemed at first. With particular reference to the raising of the school-leaving age, however, the omission of the probabilistic effects which can cause spreading of the forecasts, may result in presenting the decision-maker with very misleading advice due to the dubious precision of the graphs.

Despite the above quotations selected from Coleman's book, it should be noted that Coleman is very much in favour of using stochastic models when applicable and relevant; note that he himself devotes seven chapters, or approximately 200 pages to stochastic models.* Part of the conceptual, as opposed to the purely computational, difficulties of stochastic models is that they often call for parameters or variables which are exceedingly hard to measure even in principle and whose very existence is questionable and thus Coleman's acid comment concerning formalizing ignorance.

For example, when Armitage treats the raising of the school-leaving age by means of <u>a priori</u> probabilities which the decision-maker has of student behaviour, this brings up the problem of "subjective probability", a concept that has caused marked disagreement among statisticians; some statisticians insist it doesn't exist while others, equally insistent, claim it is pivotal. But if probabilistic effects are important and relevant, stochastic models would point the way to the measurement of various quantities for which no one had previously bothered (or perhaps dared) to gather the necessary data.

Whether or not the model is deterministic or stochastic, the decision-maker is still interested in controlling and observing the system. Control engineers have now built up a considerable body of knowledge, both theoretical and practical, concerning both types of models and how much extra difficulty may be involved conceptually and computationally when a deterministic model is widened to include stochastic elements(10). With some very clever utilization of a high-speed computer, some of Coleman's criticism regarding intractability can be overcome - some, but by no means all and perhaps nowhere near enough.

But steering a chemical plant whose parameters are partially known with noisy inputs and noisy outputs so that some reasonable (if not fully explicit) index of performance is made "good", if not best, is certainly roughly analogous to the situation in educational planning. In educational planning, a decision-maker on the basis of very noisy data and an incompletely known educational plant tries to make the system perform acceptably. Consequently, it wouldn't be entirely surprising that if SOM should ever incorporate probabilistic features, much frustration could be avoided and efficiency gained if the massive literature of control theory were investigated.

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* In addition, several other chapters have stochastic models but their main attention is focused on the deterministic approximations.

VIII. SUMMARY AND CONCLUSIONS

This paper has attempted, without resorting to too much mathematics, to consider SOM from a control theory point of view in order to offer possible paths of investigation which might be profitably exploited for educational planning models in general. Certain key concepts in control theory have been mentioned; among them are feedback, controllability, observability, block diagrams, index of performance and so on. The archetypal control framework for the deterministic case was sketched and contrasted with the present form of SOM. Discussion was also made, using the perspective of control theory, regarding the use of more refined tools for presenting the results to the decision-maker and the need for him to be able to understand these tools. Some comments were given regarding stochastic and deterministic models with reference to the fact that both need to be properly steered, and that control engineers have a considerable body of expertise in this area.

Because this paper has stressed the positive contributions of a control point of view, perhaps a caveat is needed in closing. Consider the driving of a car as illustrated in Fig. 2a, 2b and 2c.* One way to drive the car is, as shown in Fig.2a, to look in the rear-view mirror and steer in the hope that the road will continue on as it has in the past. Another way, as shown in Fig.2b, is to drill a hole in the floorboards, straddle the center line and look down and steer according to the center line beneath the feet.

Naturally, a better procedure, and one which embodies good control principles, is look at the road which lies a reasonable distance ahead and steer accordingly, Fig.2c. But while this model of steering a car is seemingly proper for exhibiting the usual type of control problems, is it relevant for educational planning?

For example, perhaps instead of a road, that is to say, a well-defined path, there is a broad plateau whose surface is not homogeneously smooth. Instead of a car, we have a bus and all the passengers have a steering wheel and an accelerator with most of the steering wheels and accelerators unconnected to the wheels of the bus. Furthermore, let us add a bit of fog, non-uniformly distributed so that some passengers have a better view - or at least <u>think</u> that they have a better view. We can quickly see that if educational planning falls into this situation as represented in Fig.2d, then we have a vastly different type of problem and one in which control theory may not have too much to contribute.

In spite of this caveat, we need not be too gloomy. Educational planning, while not containing all the pleasant properties of simple control systems, nevertheless is not so chaotic as the situation depicted in Fig.2d is. The very fact that we feel that planning should be and can be done implies that there exist certain rationally thought-out decisions which will produce better results. Therefore, it is hoped that some of the ideas from control theory as presented here can aid substantially in actively determining these correct decisions.

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* Figure 2 is taken from discussions with Professor J.G. Balchen of The Division of Automatic Control in Trondheim who originally proposed this idea. In a loose way, Fig.2a, 2b and 2c correspond to Ziegler's "future as an extrapolation of the present", "future as the present" and "single, alternative future", respectively.

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13. Vaizey, J., "Models of Education", New Society, January 22, 1970.

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Figure 1

VERY SIMPLIFIED BLOCK DIAGRAM OF SOM

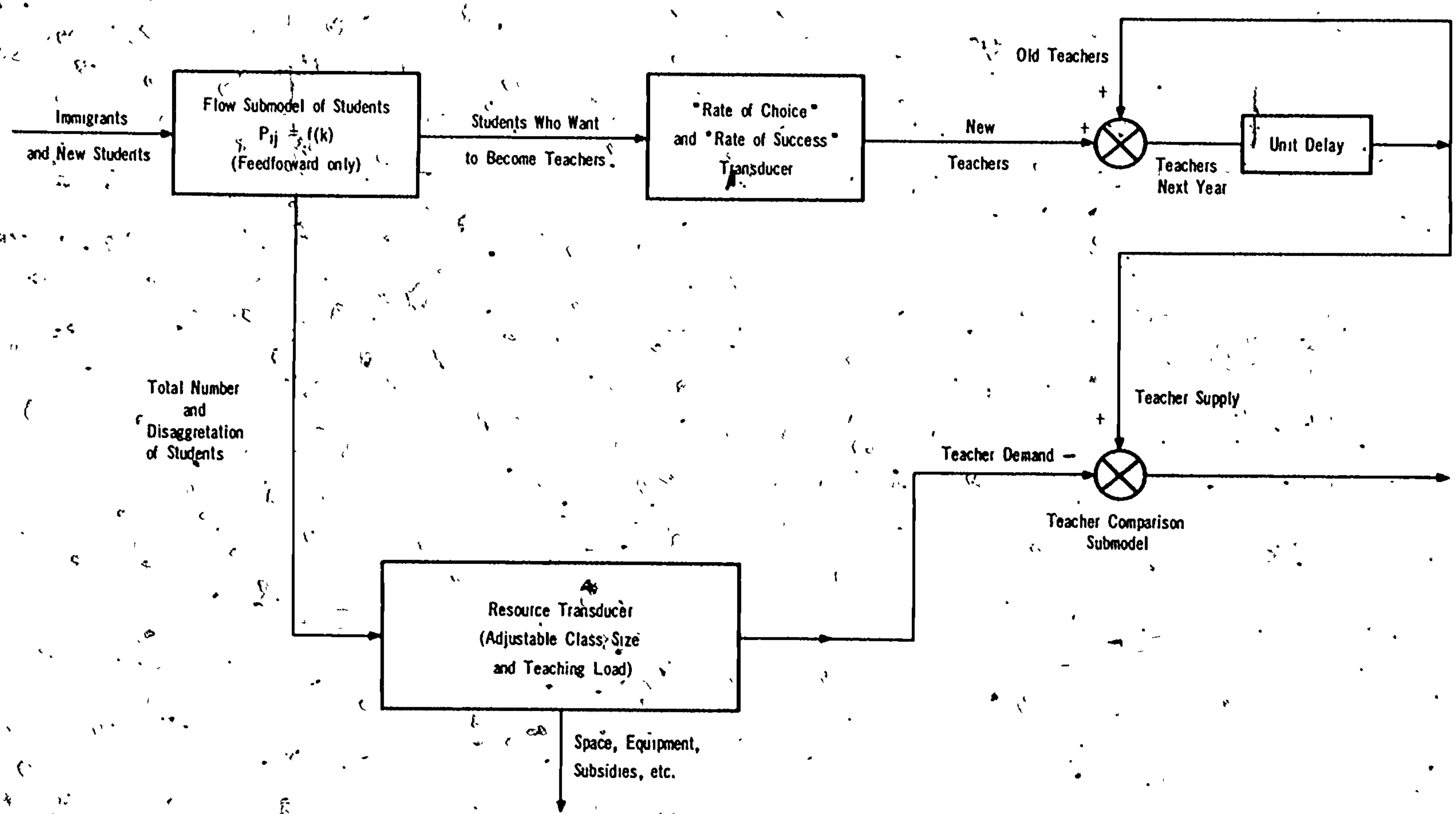
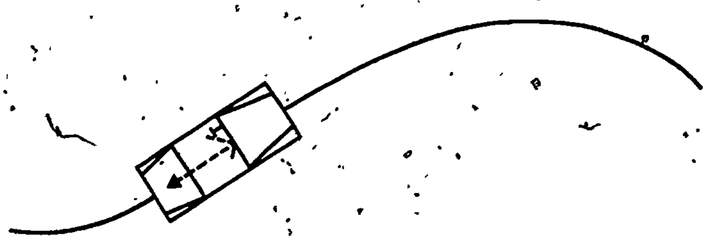
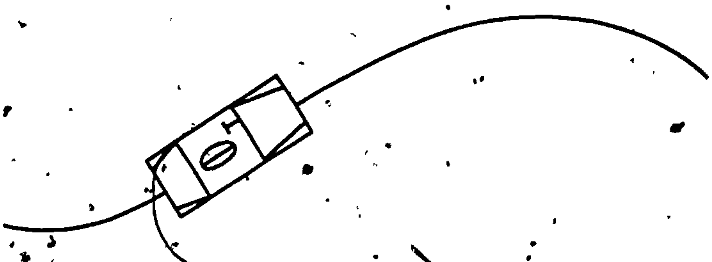


Figure 2

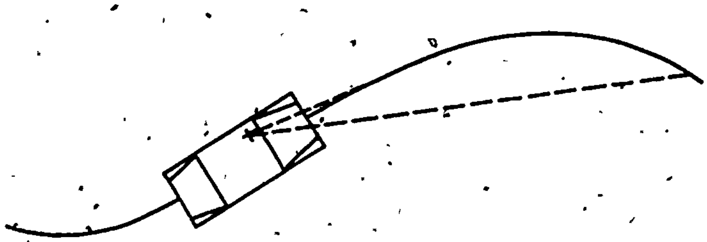
SOME POSSIBLE ANALOGOUS MODELS FOR EDUCATIONEL PLANNING



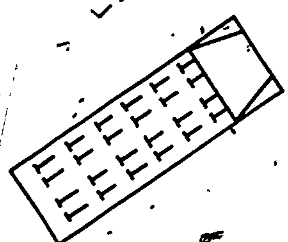
a) Stearing a Car Using Rear-Wiew Mirror Only.



b) Stearing a Car Using a Hole in the Floorboards.



c) Stearing a Car Using Reasonable Amount of the Road Ahead - Good Control Theory Strategy.



d) A Bus on a Foggy (Roadless) Plateau With Many Would-Be Drivers.

SOME PROBLEMS AND POTENTIALS OF SIMULATION MODELS FOR EDUCATIONAL PLANNING: A COMMENTARY BASED ON OECD's "SIMULATION OPTION MODEL" (SOM)

by

Richard DURSTINE

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I. INTRODUCTION

1. The request made by OECD for this paper implied a desire for evaluative comments about roles and applications for models of the educational system; more particularly simulation models; and especially the Simulation Option Model (SOM) recently published by OECD. I infer from this an invitation to examine and evaluate SOM in some detail. Since that examination will involve some apparently critical remarks, it is important to make clear at the outset my general impressions of SOM, so that the later parts of this paper can be seen in the context of my overall reaction to the work that SOM represents.

2. Firstly, it is difficult to evaluate comprehensively a model with which one has not worked closely and extensively. To read about a thing as complex as SOM without seeing it in action, let alone being on first-hand terms with its inner workings, makes possible only a speculative examination. For that reason, anything said here about SOM must be recognised as the reactions to it of a relative stranger.

3. Secondly, my reaction on the whole to the intent, focus and design of SOM is favourable. It seems to me a sensible step in the evolution of models designed for the service of educational planning and management. The failings of SOM are those of not going far enough; an understandable shortcoming in work of this sort.

4. I like the emphasis on SOM as a tool for simulation and experiment, rather than as a direct means to planning or decision. It is important to keep models of this sort at one remove from the decision process, in concept as well as in fact.

5. The need for tools like SOM is for small ones of flexible application, accessible and attractive to working administrators. How well SOM meets these last criteria is a point about which I should like to know more. SOM clearly makes a move toward flexibility by allowing certain of its parts to be used separately from the others.

6. The literature on models for educational planning is a fairly new one, particularly the literature relating to educational, as compared to economic models, to use the language of the OECD Technical Report on SOM. The earliest such models were fairly small, and usually operated by hand (i.e. with the aid of a desk calculator, or perhaps a slide rule). Later there came a tendency towards rather large-scale computerised models, encompassing a great many considerations, but expensive to operate and complicated to comprehend. SOM is, I believe, representative of a third stage in the evolution of educational planning models, one which combines the technical advances of the second stage with the simplicity and accessibility of the earlier and simpler models. But I believe that we still have quite a way to go in that direction.

7. If models are to contribute meaningfully to the central problems of educational planning and management, they must be both intellectually and operationally respectable. Here also, SOM seems to be satisfactory, though further acquaintance with it would be needed for a firm judgement on this score.

8. The remainder of this paper consists of three parts: firstly, a discussion of the technical requirements to which a model like SOM should measure up, and how well SOM fares in that regard; secondly, some comments on the requirements and possibilities for application of a model such as this one; and finally, some more detailed and specific criticism of the Technical Report, and of the model itself. This final part has the nature of an appendix, and is a by-product of preparation of the more general parts of this paper.

II. EVALUATIVE COMMENTS ON SOM

9. I choose to preface this commentary with a review of my attitudes about the general qualities a model such as SOM should have. This review will serve two purposes: firstly, to serve as background for the evaluation; and secondly, to put these remarks in context through revealing the prejudices of their maker.

10. Any model is an approximation of reality. Models made or dealt with by technicians in an organisation like OECD are almost always designed to reveal certain chosen aspects of reality, and to promote understanding of them. Depending on the kind and level of understanding desired, a greater or lesser degree of approximation will be used in design of the model. Since models are costly to make and to use, it is as wrong to be too elaborate and precise as it is to be overly approximate. In short, there exists an <u>economics of models</u> which relates their cost and their usefulness; though to my knowledge no one has yet discussed or studied that economics in a serious way.

11. A corollary to the approximateness of models is that they are essentially arbitrary in their design. One who makes models is free to do as he pleases, to design his model as he perceives its uses and its cost. So models often cannot be compared directly in terms of one being "better" than another. Such a judgement depends on uses and resources, and any evaluation of models should take this into account. Much of any evaluation of a model must be of the circumstances of its use. In summary, a model is a <u>tool</u>, and like any tool needs to be selected and used properly and carefully.

12. The real value of a model lies in fact in its approximateness and arbitrariness. It is through these qualities that we are able to carry out investigations with models which we would never dare to undertake with real systems. We can probe, experiment, and even attempt outrageous things with the aid of a model, to get an idea how these actions would work out in reality, without paying the penalty that would often be exacted in reality. A model, therefore, is a safe and flexible ground for experimentation, and therein is its principal usefulness.

13. In addition to the general qualifications set forth above, there are a number of more specific qualities desirable in a model such as

SOM. The selection of such qualities is to a large extent a matter of personal judgement; and so they are presented below without comment in a list, to which the reader may add or delete, depending on his own preferences. In addition, some of these qualities conflict with one another. In practice a model must be designed to provide a suitable balance among them, depending on its intended use. Here is the list:

1) The model should be accessible to its users, preferably those with some power to take decisions, and it should provide responses prompt enough for their use in real decisions.

2) It should be flexibly enough designed to be applicable to a variety of situations, and should be expressed in terms of a variety of operational dimensions.

3) It should be sufficiently faithful to the process it represents that needed conclusions can be safely drawn from it, and be clear enough in its own operation that its potentials and limitations are readily perceived by its users.

4) It should in some way take account of the non-quantifiable aspects of the process it represents.

5) It should provide suitable links to related exogenous variables so that it can be examined in the light of their variations.

6) Its design should strive for economy of operation, within the limits of other demands placed on it.

7) It should be of such a scale that the economy, flexibility, and accessibility mentioned above can be achieved in a variety of instances of its use.

The last point in the above list reflects a strong feeling on my part - that the purposes of educational planning will be well served if we move from large centralised models to smaller ones more frequently applied over time and over a range of situations.

i. A Look at the Technical Qualities of SOM

14. With the above comments in mind, let us review SOM in terms of its major features of structure and operation. SOM represents operation of the educational system in te s of four kinds of components: students, teachers, other inputs, and funds, all of which are divided into subcategories as appropriate. It deals with these components in terms of projections of numbers of students, and of the need for teachers, supplies, facilities and funds, both operating and capital. In doing this, it makes some recognition of the need for satisfaction of constraints on the system; and for balance among its parts. There is also provision to deal with stocks and depreciation of capital equipment, though just how and to what extent this is done by SOM is not clear from the Technical Report.

15. The general areas I see as lacking from the above hasty outline of SOM are: consideration of the efficiency of the system, and how that efficiency affects both its own operation and its service to the public; consideration of future commitments induced by present actions; fuller consideration of alternatives in curriculum, staffing, enrolment and use of facilities. It is also not clear how the model generates and makes use of information about changes in its structure and inputs.

16. The makers of SOM have produced a neutral, "what-if" model that can examine the operation of an educational system through both "forward running" and "backward running" modes. It can deal with considerable disaggregations of kinds of students - by sex, by grade level and by background, and to a lesser extent with different kinds of teachers and facilities. All these features contribute favourably to its flexibility of operation, as does the provision for time-variable transition co-efficients. These features also contribute to the model's ability to represent reality faithfully; but they must be applied sparingly because of their contribution to the negative aspects of cost and complexity.

17. SOM's operational qualities will be examined further here by means of a list of questions. These reflect my concerns both about the model itself, and with the way it is presented in the Technical Report. They are thus meant not only as questions, but also as bases for further discussion of this and similar models.

1) What has been the cost of operation of SOM, as a function of the kind of system considered, and of the number of the model's ~~options that were used~~? ~~It~~ would be interesting to ~~know these~~ costs in terms of time, skills, and money. Is it possible to estimate costs of a run of the model before beginning? What about capital costs of past development and of future improvements to the model?

2) From operational experience so far, what is the relative importance of the several technical features of the model, for example, the restricted unit calculation?

3) Can SOM deal with the total stock of graduates, dropouts and leavers from the educational system (i.e. with the total stock of these persons available to contribute to the economic system)? If so, what provisions are made for measuring initial stock, and for its attrition through death, retirement, and migration?

4) How are inventories and depreciation of physical goods handled, and what has been the experience in gathering data for this purpose?

5) Can SOM take into account, with regard to capital investments, their acquisition time, the commitments they imply, and the effect of interest and discount rates?

6) Has provision been made to consider alternatives to purchase - for example, rental, repair, or expansion of existing facilities; or just making do? It is valuable for a model such as SOM to take into ~~account~~ such variations, since they could play an important role in action decisions.

7) Who has made use of SOM so far, and who are expected to be its future clients, particularly in terms of the level of decision-making responsibility of these users? In all likelihood it is still too early to answer this question, but it should be taken into account in the future development and use of this model.

Some of the items above go well beyond the present status of SOM, into issues of its further development and application. For that reason they are included here as questions rather than as items of evaluation.

2. Some Further Technical Issues

18. This evaluative commentary concludes with brief consideration of some more specific issues. The first of these is the possibility of satisfying demand for teachers, at least temporarily, by use of teachers with an "incorrect" level of qualification. This point seems to be covered by the Technical Report, but that is not made clear. Alternatives of teacher supply, like the alternatives to capital investment mentioned earlier, are important as stimulants to expansion of the number of kinds of alternatives considered by decision-makers. The more the model can suggest and reveal the impact of these alternatives, the more useful will it be to actual decisions.

19. A second technical point regards the submodel for indirect resource requirements. The synthetic and constructive nature of this submodel is attractive as a tool for examining the effect of changes in the resource structure. Representation of such a model by a "tree" structure might further facilitate the understanding of such effects.*

20. Another issue here is the handling of the "restricted units" of the system. The attempt made by SOM to deal with this issue is valiant, but needs further scrutiny, particularly with regard to marginal and underutilised restricted units. As the calculations stand, it looks as though some units might be either restricted or unrestricted depending on the sequence in which the calculations are carried out. Also regarding the restricted units, is it indeed realistic to distribute places in them proportionately to the number of students in the several "k-groups" that the model recognises? This may be an attractive policy from an egalitarian viewpoint, but I wonder how well it is carried out in practice. If inequities exist on this score (and they surely do in some cases) the model should be made to identify them.

21. Finally, the variable structure available to describe the system in terms of its units, levels and branches, is attractive from the viewpoint of the flexibility it affords the model's user, as is the option to use or abandon the several submodels.

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* Such a model and its operation are described in "Marginal Costs for Marginal Decision: The Case of Team Teaching in Barbados", by Richard M. Durstine and Barclay M. Hudson, an unpublished draft prepared for the International Institute for Educational Planning, IIEP/RP/1-CS, May, 1969.

III. THE USES OF MODELS OF THE EDUCATIONAL SYSTEM

22. A model like SOM, if it is not applied, is nothing more than a costly intellectual and computational exercise. Likewise, if it is insufficiently used, or applied at the wrong decision-level, its value will be less than it might be. There are two kinds of things that might stand in the way of effective use of SOM or of any similar model. These may be roughly classified as features of the model itself, and those of the environment in which it functions. The most effective models, of course, are likely to be those in which there is a "good fit" between these two sets of characteristics.

23. The features that the model needs in order to be minimally equipped for successful operation have already been suggested in the evaluative comments earlier in this paper. If the model adequately meets the conditions listed there, it may gain the acceptance of operational people. Without that, it can have little role in the operation, control and future revision of the educational system it was designed to represent and to benefit. Further, the complexity of the situations the model represents, and of the results it produces, emphasises the importance of clear displays of those results, and of the use of graphical and pictorial forms of presentation whenever possible.

24. The other side of the story is the opportunities the environment offers the model for successful operation. This is a complex and variable issue. It will be reviewed below in terms of: the availability and nature of data; administrative acceptance and use (or rather lack of it); and the cost of creating and operating the model.

25. The British Case Study presented by the Technical Report, illustrates the extent of problems arising from shortage of statistical data. The shortcuts, estimates and other compromises explained there were necessary and appropriate; approximate treatment being far better than none. But if this sort of problem with data exists in the United Kingdom, what form must it take in countries where the educational system is less well established? What are the minimal conditions on data if a model such as SOM is to be of value? What can be done to satisfy these minimal conditions, and what will be the cost?

26. It is also interesting in the British Case Study that 1966-67 was the most recent feasible base year for the calculations. Further, the development of transition coefficients and units costs is very tricky in practice, and requires a high level of accountancy to avoid results that are deluding. The Technical Report mentions briefly the patching together of ill-fitting categories of data. That is another intriguing technical issue. How does it work out in practice?

27. The above are my guesses as to the statistical issues. I should like to hear from the users of SOM what problems they have in fact discovered in their experience with gathering input data - its availability, currency, accuracy, and what kinds of surrogates it was possible to find in its absence. What attempt was made to estimate or borrow difficult-to-obtain data from related situations?

28. All in all, therefore, this application of an altogether simple model, which SOM in fact is, illustrates well how complicated is the

situation which it models, even when limited to purely quantitative considerations.

29. The use of this kind of model by administrators is a topic on which I have little experience or knowledge. My guess in general is that it will be difficult to get administrators to use it, for two reasons. Firstly, they are likely to be suspicious of a tool they do not understand, especially when it is meant to influence them in decisions which they themselves must later defend. Secondly, they are likely to be too busy to use it fully. The first restriction might be overcome through education of administrators, though promotion of technical tools to a non-technical audience can be a lengthy job. The second difficulty will likely always be with us, but might be relieved by better communication between technician and administrator.

30. The problems with regard to administration are well illustrated by the United States, where there are upwards of ten thousand "ministries of education", each doing its own planning within some very general constraints set by the state and federal governments. If models of the educational system are to be fully useful here, they must reach from the national and state levels to these smaller decision-making units. This implies a need for models that are simple, small of scale, clearly presented and easy to understand, and which offer inexpensive results. The programming and computation might be done at some central point, but the models need to be of a kind that can be used conveniently at the local level. Perhaps this is a problem peculiar to the United States. But I think its resolution might be useful in other contexts as well.

31. A final comment on application relates to cost. More needs to be known about the expenditure of time, skills and money needed to create, test and put into operation a model like SOM. This again suggests the need for models of moderate size, so that cost will be sufficiently commensurate with usefulness that educational decision-makers will be encouraged to use these models. SOM takes a step in this direction, by allowing many of its parts to be bypassed or condensed. But surely much remains to be done in the direction of economy.

. 1. Some Possibilities for Application

32. Once the somewhat mechanical problems introduced above are resolved, uses for models of the educational system come readily to mind. Many of these uses are suggested by the Technical Report, such as estimates and projections of the need for school places, teachers, supplies and equipment, and funds for operation and investment. A somewhat hopeful look into the future of simulation models suggests they might also aid our overall understanding of the educational system, in terms of its performance and its costs. If we could relate curriculum and other measures of instructional quality to transition coefficients (and to other measures of raw output), we might be led to useful insights. Up to now it has not been possible to comprehend at one time the full scope of the educational system - from classrom to curriculum to budget. These things are as yet very little understood, despite all the attention that has recently been paid them. Simulation models alone are not going to provide that understanding. But they might be the experimental tool that will enable us to explore the problem.

IV. MORE SPECIFIC COMMENTS

33. The hopeful speculations of the previous pages can only come to pass if specific models are developed, tested, applied and improved upon. That means a great deal of detailed and painstaking work, of which SOM is one example. It is thus appropriate to conclude with some critical comments on the details of SOM itself. These will be of two kinds: (i) relating to the Technical Report itself; and (ii) relating to the model as it is reflected in the Technical Report.

1. Critique of the Technical Report

34. The report as a whole states its case clearly, though somewhat sketchily because of limitations of space. In parts, however, particularly in the appendices, it shows strong evidence of multiple authorship, so that the reader is forced to adapt himself to changes in notation as he goes from appendix to appendix.

35. The descriptive material of the first pages, in attempting to be brief, is often also confusing. An example is the description of structure of the modelled system (pp.9-11), which could surely be improved both in clarity and correctness.

36. In parts, for example the bottom lines of page 34, there are inconsistencies that suggest the authors did not put on paper precisely what they meant to say. I interpret these flaws as being in the presentation, not in the model, but it is not possible to be sure of this.

37. The flow charts would be more valuable if they were more detailed. It would be helpful to have three glossaries of terminology: (i) Fortran names; (ii) subprogramme names with brief identifying descriptions; and (iii) names and brief descriptions of the available outprints.

38. In discussion of investment costs on page 103, more attention should be paid to the cumulative costs through time, since it is these that will be meaningful for comparison among alternative investment programmes.

2. Some Technical Points Relating to the SOM Model

a) On page 26 and elsewhere, "smoothness" is given as a criterion. How does one measure "smoothness"? Similarly, on page 32, how in line is "in line"?

b) Page 39, are repeaters in the restricted unit included in the demand for places in it?

c) It is unclear how the case of increased restricted unit capacity is in fact handled.

d) Perhaps it is not important to the results, but the treatment of marginal restricted units troubles me. By this I mean those units which are restricted only after overflow from other restricted units starts coming in to them. It would then seem to matter in which order the restricted units are considered.

e) Vicinity of page 52, when dealing with investment in space and large scale equipment for an individual school, the induced cost may be so "lumpy" with respect to the number of pupils served that a linear relationship is not adequate. A related issue is utilization of existing space, and variations and limitations on room sizes. Has anything been done to allow for these annoying practicalities?

f) Page 55, development of unit costs like CURSP in an effective and concise manner can be a tricky business.

g) Pages 96 and 102 (bottom paragraph in each case), here is the "lumpiness" problem again. On page 102, for example, under-utilisation will indeed diminish as the school-leaving age is raised; for a while. But after a point, new teachers and space will be needed. This point needs to be identified and taken into account.

h) Page 96, I have trouble understanding so large a discrepancy between observed and computed teacher stock.

i) Page 100, why do only the upper three forms undergo changes due to trends in the transition coefficients? I should think they all would.

A CRITICAL EVALUATION OF SOM AND COMMENTS ON FUTURE DEVELOPMENTS WITH EDUCATIONAL MODELS

by

Peter ARMITAGE

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I. INTRODUCTION

There have been numerous attempts to produce highly flexible educational models in terms of computer programmes. As one suspects that many of these attempts have been abortive, we must begin by congratulating the team responsible for SOM on their achievement. The pursuit of generality in educational models does not present very formidable theoretical problems but we know from experience that the task is arduous and exacting.

The main virtue of SOM is that it consolidates and improves upon earlier work. Previously the ground covered by SOM has been treated in stages rather than in one connected sequence. Five years ago, the emphasis was heavily on models of the stocks and flows of students and teachers through the system. Since then it has become the practice to assess the cost implications, if not the full resource consequences, of (at least) those projections which were deemed to be of interest. For a long time too, it has been the practice to assess the implications for the demand and supply of teachers of any new projections of student numbers. There should be a gain in having these previously separate calculations connected up in the same computer run: apart from the convenience of having the calculations done together, the link-up will encourage a broader view and discourage the former piecemeal approach. The second main feature of SOM which I find virtuous, is that it contains a treatment of bottlenecks (i.e. restricted units). At one time there appeared to be a conspiracy either to deny that bottlenecks existed or to ignore them because of the mathematical complications which they introduced. Although the treatment here can fairly be described as rudimentary, it is another welcome step forward that bottlenecks are confronted and not avoided in SOM. The third main virtue of SOM lies in the facility with which alternatives can be examined, not only in separate computer runs but to some extent within the same calculations.

II. POSSIBLE APPLICATIONS

The breadth and generality of SOM is such that it can and should be widely used in diverse contexts. The present rate of change in most educational systems is so great that the exploration of possible developments could be phrased in innumerable models. This is certainly true in Britain (or more precisely, England and Wales), as can readily be seen by looking at just one sector, secondary education. Already the process of the reorganisation of secondary education is well advanced. Only 2 per cent of secondary schools were comprehensive in 1960 whereas they now comprise 15 per cent and are still increasing rapidly. Though less visible, there is also much curriculum development and a tendency towards later specialisation which may be accelerated in two years time when the school leaving age is raised to 16. There is the more distant prospect of a reform of the examination system though the form of the new system has not yet been decided. The repercussions which could follow from these and other envisaged developments raise a host of questions that could be explored in a variety of appropriate models. Given time, it would seem possible to devise an atlas of possible applications of the SOM model in the British context, and, no doubt, this is true of all the other Member countries of OECD. However, I am confident enough of the usefulness of SOM to feel that this is an unnecessary and rather academic task. Without the motivation of purpose, only illustrative and superficial models are likely to be devised (see Chapter 2 of reference 2): with motivation, it is not an easy task to devise models which the builder feels are 'meaningful' or satisfactory in terms of his purpose. I propose only to develop one sub-model, partly for use in later criticisms and the discussion on future uses of models.

This is a flow sub-model which as in SOM could be linked to resource, teacher supply and teacher comparison sub-models. It is drawn from our recent work which has been concentrated on the secondary school system, that is the point at which students are free to leave the education system but some proceed to higher education.

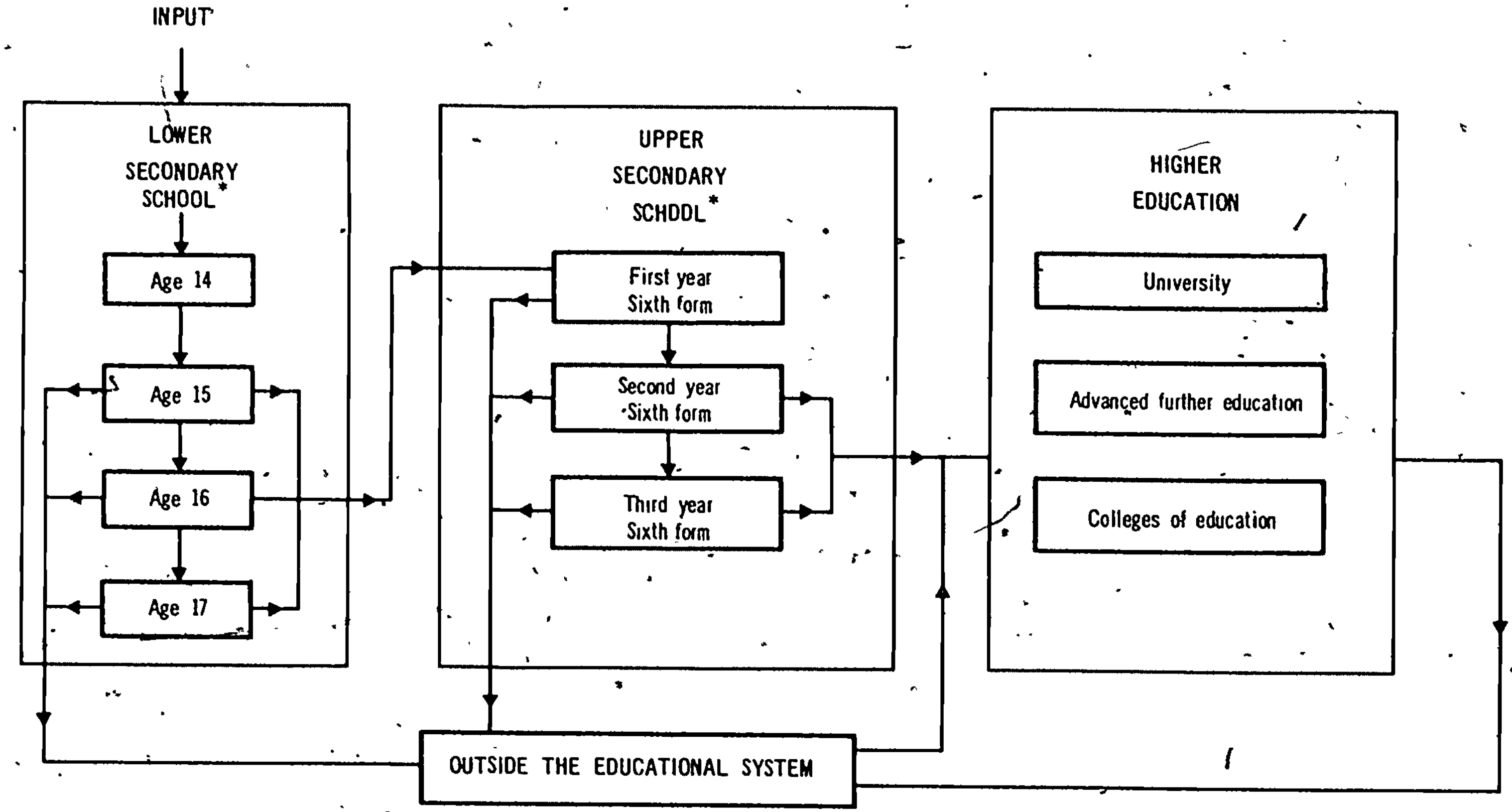
Various aspects of the flow sub-model are described in Figures 1, 2 and 3. Some further comment is necessary. In the past our model descriptions have mainly been in terms of age, though progress through the system is not simply determined by age. From the educational point of view, further progress is dependent upon the level of achievement so far, so that the 16-year-old who has taken his 'O' level examination behaves differently from the 16-year-old who has not. Numbers of passes in the ordinary ('O') and in the advanced ('A') level examinations are necessary for entry to the sixth form and to higher education respectively. This is the basis of Figure 2 and it will be noted that we are no longer concerned with age once the 'O' level 'cohort' has been formed. Since there is much concern with the implications for the provision of faculty places in higher education and, later, for qualified manpower, of such phenomena as 'swings' away from science in the sixth form, the third aspect of subject choice has been introduced as in Figure 3. The possibilities of more detailed sub-models along these lines are suggested by references 3 and 4. For some purposes, the greater detail introduced into the secondary school sub-model would need to be matched by a comparable degree of detail in a tertiary education sub-model, e.g. in the form of university faculties, etc.

III. WARNINGS

SOM is a computer programme package ready for use by anyone who takes the trouble to assimilate its specifications. Providing that the model-builder does this properly, he will find that much of the solid work needed to get a model running has been done for him. However, this does not mean that his task has been rendered simple and easy. Two of the most difficult aspects of model construction are not stressed in the report. These are not so much criticisms of SOM as warnings to potential model-builders. Anyone who has had a little experience of model-building will be aware of these difficulties and these warnings will be unnecessary. They are most important for anyone embarking on model applications for the first time.

Figure 1

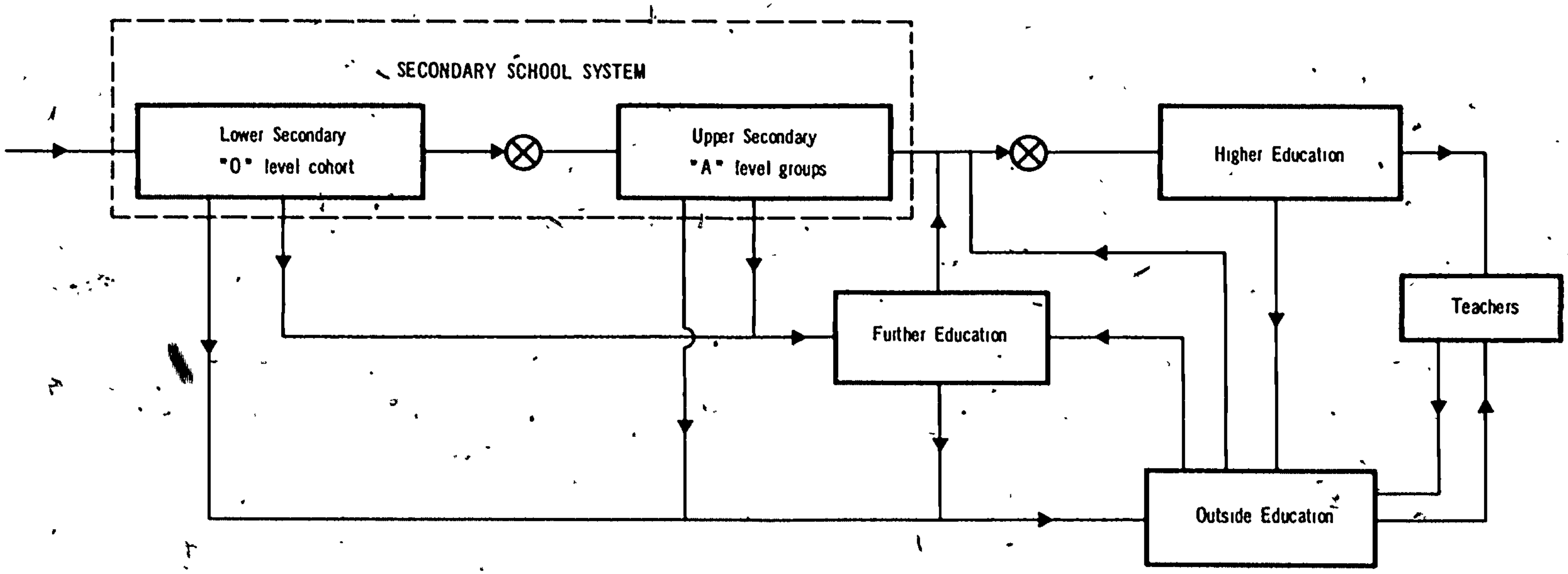
"INSTITUTIONAL" VIEW OF FLOW SUB-MODEL



* In the lower secondary school, this structure is repeated for five types of secondary school: (1) grammar and technical; (2) comprehensive; (3) modern; (4) other maintained; and (5) direct grant and independent. In the upper secondary school, the structure is repeated for three types of secondary school (with 2, 3 and 4 above amalgamated into one type) and three subject groups, see Figure 3.

Figure 2

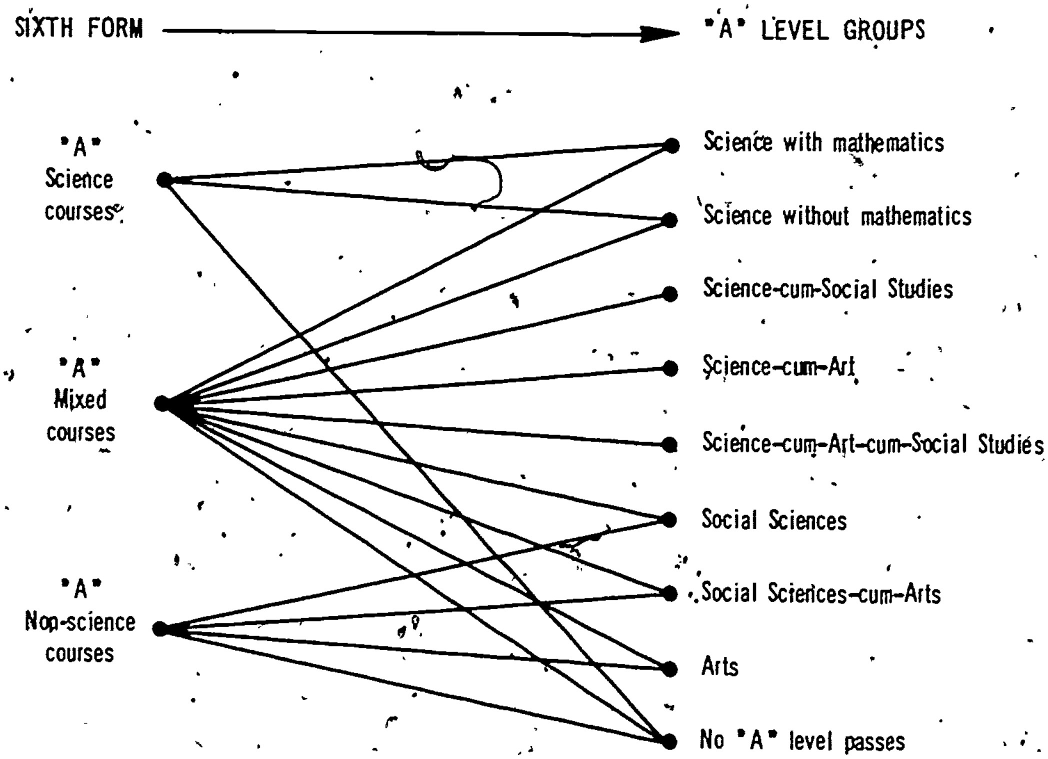
RELATIONS OF SECONDARY SCHOOL SUB-MODELS TO THE REST OF THE EDUCATIONAL SYSTEM



⊗ Points where entry standards applied.

Figure 3

SUBJECT VIEW OF THE FLOW SUB-MODEL



The first of these problems concerns the structure of the model. The starting point of SOM is that you have already decided on a description of the educational system as a number of 'boxes' or 'units' with interconnections. The problem of making this description, which precedes pressing the SOM button, is by no means trivial for structures do not remain fixed. At the present time in Britain, we are beginning to get the appearance of sixth form colleges and, with the raising of the school leaving age, the way will be open to the evolution of junior and senior secondary schools or other forms of reorganisation. The situation is similar in tertiary education with a debate in progress on the changing functions of the universities, the polytechnics and other further education establishments and there is talk of new hybrids such as 'polyversities'. In both areas there is the prospect of institutional transformation which, clearly, should be allowed for in the construction of any model. It is a mistake, I think, to conceive of the model in terms of rigid structures where change is entirely produced by changing transition proportions between unchanging types of institutions. In so far as existing institutions disappear, as may be the case with secondary modern and maintained grammar schools, if the process of total comprehensivisation is carried out, this may be achieved by making appropriate sets of transition proportions tend to zero over time. If new structural forms are expected to appear, the specification of the model must pre-state when this will happen and provide values of any new transition proportions introduced into the system. As a time-step simulation model of some generality, SOM should be able to cope with structural change assuming the user has a sound conception of the nature of his model at the outset.

The second warning concerns the values of the transition proportions. The innocent procedure is to look at past values of the proportions and extrapolate them into the future. For example in the sub-model described above, the time series for the transition proportion of 14-year-old boys staying on to age 15 in grammar and technical schools has been:

1964	1965	1966	1967	1968
0.948	0.955	0.936	0.896	0.928

It is not unusual to find disturbances in such series due to elementary changes in regulations or even the statistical classification, and though our feelings might be violated by the fluctuation and slightly downward trend towards staying on, this particular series would not appear to be too suspect. Although disappointed by the absence of a coherent pattern in the past values, the determined empiricist might proceed by assuming that the future value of this proportion should be set at some fixed value between 0.9 and 0.95 or that from the 1968 base value of 0.928 it would fall each year by, say, 0.01. In interpreting past data, however, we need to be highly sensitive and to make use of any other knowledge of the education system that we possess. Almost certainly this particular transition proportion has been depressed over time because the statistics do not reveal the transfers out of grammar and technical schools due to comprehensive reorganisation. It is possible to make a crude 'correction' by arguing that when grammar schools are absorbed into comprehensive schemes, all the children in those schools, whatever their age, are affected. Since they are below school leaving age, the transition proportions for 13-year-olds staying on to age 14 in grammar and technical schools should be unity, whereas they have been:

1964	1965	1966	1967	1968
0.990	0.990	0.969	0.927	0.956

By scaling these proportions up to unity to get a correction factor for each year and by using these factors on the other age groups, the 'corrected' time series for the 14-year-old boys staying on to age 15 in grammar and technical schools becomes:

1964	1965	1966	1967	1968
0.958	0.964	0.966	0.967	0.971

It may be that the smoothness of this corrected series is spurious, but it is definitely more appealing. Though it cannot be confirmed for want of precise information, it would appear to provide a better basis for assuming future values of the proportion.

The point of this warning is that we do not always have the statistics that we would wish and that we have to make do with statistics which should not be trusted too much on their face value. Even where a relatively long time series is available, the statistics can be undermined by disturbances in the system which may be difficult to detect. When they can be detected, we are often left with very short 'valid' series. Assumptions about future values of the transition proportions should not be made mechanically but call for great vigilance and judgement.

IV. COMMENT AND CRITICISMS

In this section I would like to make a few separate comments on SOM. Further criticisms, perhaps more significant, will be implied by the discussion on the future use of educational models in the final section.

1. The demand and supply of teachers

It would seem from the description that this part of the exercise bears considerable similarity with the teacher demand and supply calculations that have been carried out in England and Wales for a number of years(5),(6). The criticisms(7),(8), made of these calculations are probably applicable in the case of SOM. I would particularly draw attention to the observation that the demand for teachers is not measured in the economist's sense. What is measured is the supply needed on certain assumptions of staffing ratios and class sizes. In Britain, pupil-teacher ratios were adopted which were intended to diminue the number of classes of over-40 in primary schools and over-30 in secondary schools. In practice it has been found that additional teachers have not always been used to reduce class size and recent experience 'has thrown doubt on... the practicability of equating any particular pupil-teacher ratio with a particular limit of class size'(6).

The teacher comparison sub-model strikes a simple balance between 'demand' and supply. In more sophisticated applications, it may be necessary to permit the changing state of teacher supply to have feedback effects on the transition proportions determining students progress and, in particular, their aspirations to become teachers.

If a full manpower planning model(9),(10) is required, it will be necessary to up-date teacher age distributions and this has not been done in SOM. I wonder if it would be difficult to adapt SOM for this purpose?

2. Restricted entry in the flow sub-model

It seems to me that assumption (a) (page 13) is too severe and that it is a dangerous misconception to think that units cease to be restricted if the supply sometimes exceeds the demand. It is surely not an acceptable assumption that there are points in the system where we must be permanently reconciled to an excess of demand over supply. A proper definition of a restricted entry unit seems to me to be any entry point at which the number of places is subject to constraint. It may be that sometimes there will be a shortage of places and that at other times places will be unfilled. Part of the measure of good planning will be the extent to which demand is refused and the extent to which resources are not utilised.

Assumptions (d) and (e) (page 13) may also need to be relaxed. Clearly they are primarily made for computational convenience, though, in both cases, it could be argued that the assumptions were reasonable first approximations. It would appear desirable that further developments of SOM should:

(i) take account of the fact that rejected students may not be a representative sample of students from unit J and should not be redistributed in proportion to the original transition coefficients to the remaining open units (e.g. students rejected for university places may show a greater inclination to be repeaters in the last year of secondary school);

(ii) permit discrimination between competing source units where there is a shortage of places.

3. The application study

This example serves its purpose in demonstrating the use of SOM. However it is worth making some critical comments which do not undermine its illustrative function.

As is stated in the conclusions (page 31) the future school population may have been overestimated by assuming that students 'forced' to stay on behave like those who previously stayed on voluntarily, and underestimated by assuming that those who stay on voluntarily are subject only to present trends and do not have further reaction 'in order to keep up their "educational differential"'. Again we are in a situation where the assumptions made are those which can most readily be accommodated by the model, but are not necessarily satisfactory. It is possible to attempt compensating effects in both cases as we have done elsewhere(2) (in another purely illustrative example). For example, the transition proportion for the 'forced' students aged 16 not staying on to 17 could lie (there being no past evidence) anywhere in the range from zero to the value of the comparable transition proportion for the 'voluntary' students. We can, of course, assume a value which is some fraction, k $(0 \leq k \leq 1)$ along this range and it would be of considerable interest to investigate how the decision on timing the raising of the school-leaving age would be affected by taking different values of k. This approach, however, is also unlikely to be satisfactory because we do not expect the decision to stay on to depend solely on age. This was one of the reasons for the sub-model described in section 2 above, and a quite different treatment of raising the school-leaving age is possible in this case. The Robbins Report pointed out that raising the school-leaving age to 16 would mean that all pupils would stay at school until the year when 'O' levels are normally taken and that: 'The extra effort required in order to obtain a useful qualification would thus be reduced. It is in any case likely that a raising of the school-leaving age will have a considerable upward effect on the trend to stay on into the sixth form'(11). In this model, we would have to decide how the extra year's schooling could affect the size of the 'O' level cohort and make provision for it to have an 'epidemic' effect on the desire to stay on to the sixth form. It would be necessary to make assumptions about the proportion who will now attempt 'O' levels who would not previously have done so; about the proportion of these students who are capable of reaching the standard required for sixth form entry; and about the proportion of students who, though eligible for the sixth form, would previously have decided to leave school but now, in the changed circumstances, behave differently. It seems to me that this formulation is more amenable to the theories of educationalists and teachers and more responsive to the thinking which lies behind the raising of the school-leaving age.

Several changes would have to be made for this example to be elevated to a practical case study. I do not think the study could be limited to the demand side and other parts of the educational system would have to be included. The opinion (page 27) that the adaptation of further education is irrelevant to the timing and method of raising the school-leaving age seems to me to be unrealistic. I doubt whether cases B and C which raise the school-leaving age in steps over two or three years would be acceptable to educational administrators and such a view might have to be accepted as a diktat or constraint. I do not think that 'the incidence of the changing structure of secondary education' (page 93) can be avoided. Accepting that the school-leaving age is being raised as part of a transformation that is already taking place makes the problem much more difficult but there is nothing to be gained by pretending that only one variable is changing at a time as in some classical experiment. For this example to be raised to successful practice, one further thing is necessary: an objective or criterion.

Some interesting remarks are made (page 26) on the criterion of choice. A smooth development is thought desirable but 'smoothness' is not a sufficient criterion for speed of implementation is also involved, and, in the end, no precise criterion is defined. As the conclusions (pages 31-32) show, no amount of reasonable rhetoric can conceal the impotence induced by the want of an objective.

V. FUTURE DEVELOPMENTS

This final section is concerned with where do we go from here?

Apart from the difficulty of dealing with structural change already mentioned, I believe that one of the outstanding problems is parameter reduction. In making descriptions of any system, we are inclined to be profligate in the introduction of parameters. While models which have few parameters because they grossly oversimplify the system will only be of limited value, the fewer the parameters and variables the more penetrating any study of the possible behaviour of the system is likely to be.

For example, in considering the raising of the school leaving age, a model might be constructed in which the transition proportions were age specific and defined for each type of secondary school. If there were five relevant age groups and five types of school, this would mean 25 transition proportions with assumptions necessary in each case. Apart from the fact that there must be some relativity built into these assumptions, it would seem to make educational sense to argue that students who had not reached the standard suitable for sixth form entry had a general propensity to stay on which was amplified (or dampened) by a factor specific to the type of school. It could also be argued that pupils who reached the sixth form entry standard could be expected to behave similarly whatever their age and whatever type of school they attend. If the model could be set up in these terms, there would only be seven parameters of which two could be regarded as key. The reduction from 25 to seven parameters could greatly aid the tractability of the model. It seems to me that a ruthless attack on redundant parameters would pay off if the contraction was made on the basis of a true understanding of the nature of the educational process.

We need to do more than make technical improvements. If educational model-building is to progress as I believe it must, we will have to revise our outlook. For example, the Technical Report points out that SOM has the property of being 'forward' or 'backward' running. I feel that this claim is a hangover from the days when model-builders were trying rather desperately to ingratiate themselves to manpower planners. In the early, crude, deterministic models, this reversibility was simply achieved by matrix inversion on the assumption that all transition proportions and inputs could be pre-stated for the entire period of interest. In the case of more complex models, it is also necessary to pre-state the number of places to be provided at every restricted entry unit, and reversibility may no longer be possible. It seems to me that it is fatuous to calculate the present displacement from the position compatible with a particular pattern of provision and given targets. With the present state of the system known, it makes more sense to attempt to determine a pattern of provision which reaches given targets. Furthermore, even if models can be made to retain the property of reversibility, I doubt whether we should proclaim it to attract would-be manpower planners: the days are past when we need to stimulate sectarian approaches.

In the same vein, I feel that we need to be a little more honest with ourselves when we claim 'computerised models make it possible to examine many alternatives and to test the sensitivity of results to uncertainties in input data' and 'priorities in the statistical data collecting work can be established'. Though the first claim is true, it is rare that more than a few alternatives are examined and, in displaying alternatives to administrators, I have yet to see a report which suggests that the uncertainty is such that these alternatives are indistinguishable. Most of the mentions of sensitivity analysis in the literature are incantations intended to exorcise the spectre of uncertainty. Again, it is true that formulating a model helps to clarify data needs but must we always make it sound as if they will do this even if they do nothing else? Knowing what information is needed is, of course, of paramount importance: nonetheless I think it would do no harm to play the information gain down for a while and to regard it more as a fringe benefit.

I am sure that the team who created SOM are aware of these points and, in view of their just claim that 'it can be of real use in a first exploration of the consequences and implications of alternative educational strategies', that they are aware of the naivété of the whole conception of 'what-if' models. Attempting to answer 'what will happen if this?', 'what will happen if that?' (and a qualification of the type 'other things being equal' should be added) is a sterile exercise in fantasy. The hypothetical tone poses the existence neither of any problems nor of any objectives. 'What-if' models are not so much 'neutral' as 'oblivious'. The most that can be claimed for them is that they have insight value like toys for management games.

This is, of course, only another way of saying that we must search out the real problems and rigorously define them. There is a strong temptation to phrase problems in familiar terms similar to textbook examples and case studies of practical applications in industrial and business situations, even though a little reflection will reveal significant differences from the real educational system. However we are unlikely to get very far by pretending that we have deterministic, linear systems with linear, or even quadratic, objectives when, in fact, we have a stochastic, non-linear system and a complex, not to say confused, objective. Solving imaginary problems is at best a hollow success: great care in defining the real problems is always worthwhile.

Inevitably this leads to the difficult, but vital question of the objectives of the system. We must overcome our dismay that there is no clear, agreed, single objective and reconcile ourselves to the fact that one is unlikely to emerge. I think that we must accept and attempt to live with the plurality of objectives. An attempt to sketch how this might be done is set out in Figure 4 where the objective is shown, not as a function to be optimised, but as a collection of performance criteria to be examined. Manpower, private and social demand, investment and cost criteria have been discussed at some length in the literature. We have added further sets of criteria (or constraints) to cover political and administrative aspects and it may well be that we have overlooked other important dimensions of the regulatory process. At present we wish to adopt the open-minded position of wanting to represent all the demands placed upon the educational system (whether they be economic, social, political or educational) in the box marked "objectives" in Figure 4. To begin with there will only be batteries of statements under each head. These could take such forms as:

manpower	-	desired numbers of doctors, teachers, scientists, technologists ... required at different times, i.e. time-profiles for various forms of qualified manpower;
costs	-	budgetary constraints, e.g. educational expenditure must not exceed x per cent of gross national product, ceilings for allocations on building costs, teachers salaries, etc.;
private and social demand	-	desired percentages of the age cohort entering higher education, graduating etc.;
investment	-	rates of return for various forms of qualified manpower;
political	-	equality of opportunity for both sexes and all social classes;
institutional	-	restrictions determined by the present forms of administration and the potential maximum capacity of existing institutions.

We do not anticipate that any one of these aspects will be reducible to an equation which can be maximised or that additivity can be established between different aspects. We would stress also that not all the statements made will be quantitative and we will not ignore qualitative statements. For example, the power of the Universities Grants Council and the Vice-Chancellors Committee in relations between the Department of Education and the universities and the power of the Local Education Authorities between the D.E.S. and the schools may not be measurable but it is nonetheless tangible. Again, in the raising of the school-leaving age example, we are told as a starting point in the SOM report that 'the reform has been found desirable' and this suggests a political statement of the kind that the leaving age must be raised to 16 before year t. Without such a statement, none of the other criteria will necessarily ensure that such an action is ever executed.

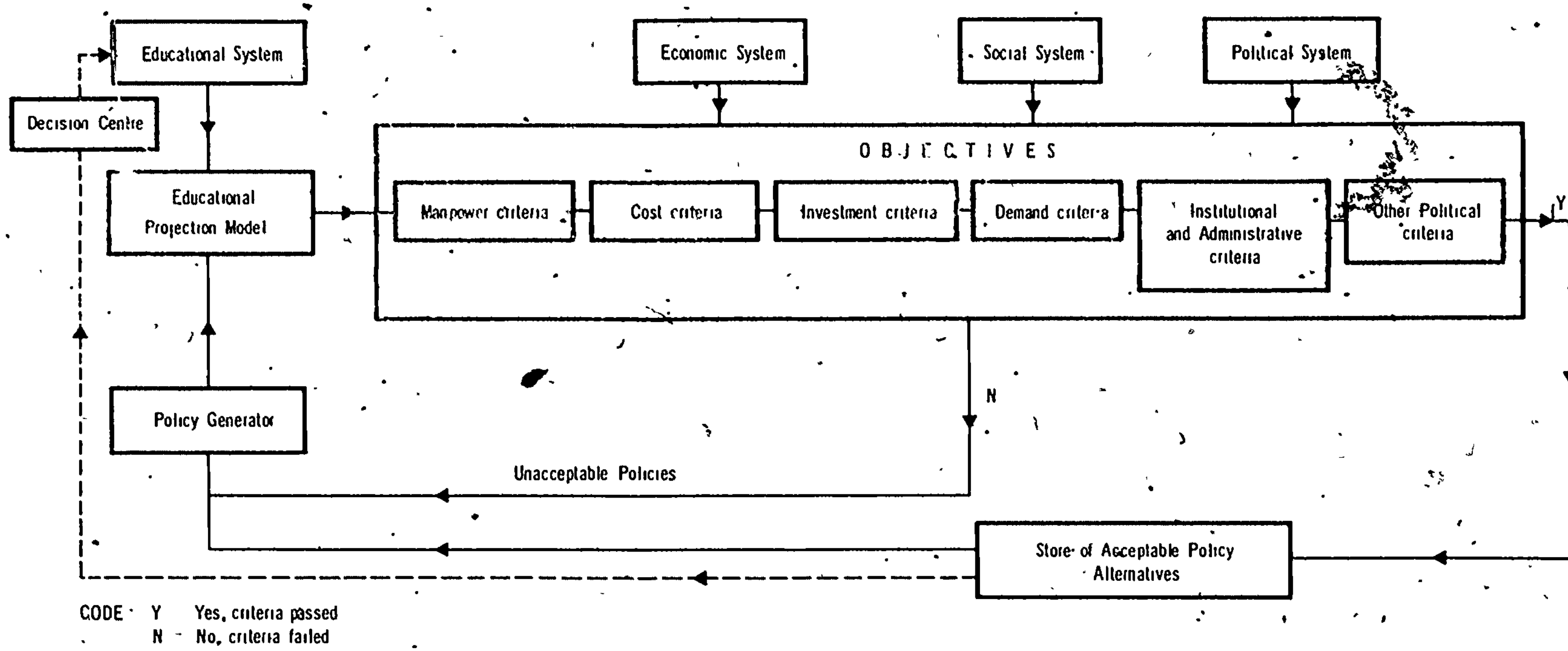
It is envisaged that the mesh of statements would constitute a series of filters which could lead to the rejection of a policy, or, if all the filters are passed, to the recognition of an acceptable policy. Of course, it could happen that no policy was found which satisfied all statements but this would be of great interest and would indicate which criteria were the most important. It might then be possible to redefine statements more precisely and to put them into 'hard' and 'soft' categories such as 'must not be violated', 'may be violated but not desirable', and possibly to arrange them into hierarchies according to their constrictive power.

In Figure 4, arrows have been omitted within the "objectives" box to avoid suggesting that criteria can be placed in a priority order; we do not mean to suggest that manpower criteria are foremost, that cost criteria come next with political criteria least important. (Indeed it is not always obvious under which heading a criteria should be placed). However, if any discriminatory power of statements can be established, this different kind of priority may allow us to search through a much increased number of alternative strategies. We have already commented that, although many alternatives can, in principle, be scrutinised, the number actually examined [illegible] severely limited. If we want to make a full, or at least a sub[illegible]xploration of alternative policies, then we will need to d[illegible] unsatisfactory alternatives at the earliest possible stage by applying strong criteria at the first convenient opportunity. This will require that the model integrates the objective criteria and the projection mechanism rather than the present implied practice of completing the full projection before submitting the policy to tests. This will lead us away from the SOM approach where the resource and teacher supply models are 'essentially supplementary' and will mean sacrificing the attractive prospect of regarding the sub-models as optional facilities.

Finally it is hardly necessary to point out that this scheme possesses some of the features of a control system but lacks others. The scheme possesses a projection mechanism which enables possible future states of the system to be estimated, and a variety of possible actions are presumed in the "policy generator". However the fact that the "objectives" are not resolved prevents the determination of a best course of action. At this stage, the scheme will only lead to the identification of a number of "acceptable" policies with no means of choosing between them. For the present the best that we can do is to display these alternatives to educational administrators and to learn from their comments. It may be that hidden criteria will be revealed or that criteria already taken into account to some extent can be made more explicit and sharpened. Perhaps, if we can persist with this learning procedure of refining criteria, we will eventually be able to build up what might be called a calculus of objectives.

Figure 4

A SCHEME FOR INVESTIGATING POLICY ALTERNATIVES



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SOME PROBLEMS OF SOM(e) MODELS

by

B.A. THOOLEN

TABLE OF CONTENTS

INTRODUCTION[1]

This report gives an evaluation of "SOM. A Simulation Option Model of the Educational System" (OECD, 1970). This evaluation is carried out by way of a comparison with a Dutch educational model, which is partly based upon the concept of student flows.

The first chapter gives a short formal description in mathematical form of the Dutch educational model. In this stage only technical problems of model-building are dealt with. The comparison with SOM in Chapter II is likewise restricted to a technical evaluation.

Another, and more important, problem of model-building is connected with the question of the possibilities and limitations of a model. Chapter III is devoted to this aspect and contains a criticism of both SOM and the Dutch educational model. This evaluation provides some suggestions for further developments in model-building.

(1) I wish to thank R. Ruiter for his valuable and stimulating suggestions and comments.

I. A SHORT- AND MEDIUM-TERM MODEL FOR THE DUTCH EDUCATIONAL SYSTEM

At the Dutch Central Planning Bureau forecasts in the field of education are made for inputs (teachers, expenditures), throughputs (students) and outputs (skilled manpower). Accordingly three groups of models can be distinguished: student models, resource models and manpower models.

A further distinction can be made according to the time span of the forecasts. Detailed forecasts are made for the short-term, while forecasts using more global methods are preferred for the long-term. The three submodels presented here can in principle be used for any time span. The main purpose of the models, however, is to produce forecasts for the short- and medium-term. The complete model consists of the following equations:

(1.1) $d_t = R_t \cdot p_{t-1}$

(1.2) $p_t = O_t \cdot p_{t-1} + Q_t \cdot d_t + E_t \cdot c_t$ — student flow model

(1.3) $n_t = S_t \cdot p_{t-1} + U_t \cdot d_t$

(1.4) $z_t = V_t \cdot p_{t-1}$

(2.1) $l_t = LPR_t \cdot p_t$

(2.2) $x^l_t = W^l_t \cdot l_t$

(2.3) $x^m_t = W^m_t \cdot p_t$ — resource model

(2.4) $x^{inv}_t = W^{inv}_t \, (l_t - l_{t-1}) + ex^{inv}_t$

(2.5) $x_t = x^l_t + x^m_t + x^{inv}_t$

$$(3.1)\ A_t = V'_t . A_{t-1} + C^n_t . N_t + I_t$$

manpower supply model

$$(3.2)\ B_t = F_t . A_t$$

In the following a formal description is given for each of the submodels, together with the definitions of the various variables and coefficients. The way in which forecasts come about is described in Chapter III.

1.1 The student flow model

The model has been built on the basis of the education matrix (or student flow table) which gives a systematic survey, by type of school and grade, of student stocks and of all inflows, throughflows and outflows of students in the educational system.

Statistical information on student flows is collected by the Dutch Central Bureau of Statistics(1). For some important flows (e.g. to university education) statistical series have been published since 1930. Education matrices, containing flows by type of school (but not by grade) are available from 1961 on. Beginning in 1967 the student flows are specified by grade for nearly all types of schools. For the first six years estimates have been made of various flows by grade so that time series of flow coefficients are coming into existence.

In the education matrix and the model the two sexes are treated separately. For every year of the forecasting period all elements of the education matrix are calculated and added up to student stocks. Further the model estimates the numbers of school leavers by educational level, which are an input for the manpower supply model.

The basic equation of the model is extremely simple(2):

$$(1.1')\ p_t = O_t . p_{t-1} + \hat{E}_t . c_t$$

in which: p = a vector of student stocks by type of school and grade (1 .. j)

O = a matrix of transition coefficients (j x j), representing repetition, transfer from other

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(1) See e.g. "Overgangen binnen het onderwijs en intrede in de maatschappij, 1936, 1956 en 1961-1966", Centraal Bureau voor de Statistiek, The Hague, 1967, and "A modern system of educational statistics: the matrix-method", J. de Bruyn, The Hague, 1969.

(2) For the sake of convenience the matrices presented here are the transposed form of the original education matrix.

grades of the same type of school and transfer from other types of school

c = a vector of age cohorts, to which new entrants can belong (1 .. h)

E = a matrix of entrance coefficients (j x h)

The first term stands for the flows within the educational system. Each student stock by type of school and grade in the preceding year (t - 1) is multiplied by the corresponding transition coefficients in order to calculate the inflow into each grade in year t. To this is added the numbers of new entrants into the educational system (including immigration, restarting of studies, etc.) which for every grade are calculated as a fraction of one or more age-cohorts.

A second group of results the model produces is the numbers of school leavers to educational level who finish their education and may join the labour force:

$$(1.2') \quad n_t = S_t \cdot p_{t-1}$$

in which: n = a vector of school leavers by educational level (1 .. g)

S = a matrix of leaving coefficients, translating output per grade into output per educational level (g x j)

Finally, the outflow resulting from death and emigration is calculated by:

$$(1.3') \quad z_t = V_t \cdot p_{t-1}$$

in which: z_t = a vector of students died or emigrated between t-1 and t, by grade (1 .. j)

V = a diagonal matrix with death and emigration coefficients by grade (j x j)

This last equation has the function of a check upon the consistency of the model, because now all possible flows from p_{t-1}, the old student stock, have been summed up. Consequently the total of all flow coefficients from a certain grade i should equal unity (see equation 1.5).

Graduation

Transfer from one type of school to another is generally speaking only possible when a diploma of the lower type of school has been obtained. Accordingly there are substantial differences in the outflow patterns and the changes in it over time for students with or without diploma. Moreover within one type of school more than one type of diploma can be obtained with diverging flow patterns.

In order to take all this into account the model can be rewritten as follows:

(1.1) $d_t = R_t \cdot p_{t-1}$

(1.2) $p_t = O_t \cdot p_{t-1} + Q_t \cdot d_t + E_t \cdot c_t$

(1.3) $n_t = S_t \cdot p_{t-1} + U_t \cdot d_t$

(1.4) $z_t = V_t \cdot p_{t-1}$

in which: d = a vector with the numbers of diplomas obtained (1 .. k)

R = a matrix of graduation coefficients, showing the fraction of students per grade obtaining a diploma (k x j)

Q = a matrix of transfer coefficients to grade i per diploma (j x k)

U = a matrix of leaving coefficients per diploma by educational level (g x k)

In graph 1 a schematic presentation is given of the matrices appearing in the above model. The dimensions have been taken from the application of the model to the whole educational system, in which we distinguish 38 different types of schools with altogether 163 grades (j = 163) and 41 kinds of diplomas (k = 41). In equation 2 the age cohorts are shown (h = 20) and in equation 3 the output is specified by educational level (g = 25). From the diagram it will become clear that a very detailed specification of grades and flows is obtainable within this system.

In the model only the inflows into the categories d_t, p_t, n_t, and z_t are described. An essential aspect however is that all outflows from p_{t-1} and from d_t are taken into account. Therefore, for every grade i resp. for every diploma f the following equality should hold:

Graph 1

STUDENT FLOW MODEL

1. GRADUATION

$d_t = R_t \cdot p_{t-1}$

$$\begin{bmatrix} d_1 \\ \vdots \\ d_k \end{bmatrix} = \begin{bmatrix} r_{11} & \cdots & r_{j1} \\ \vdots & \ddots & \vdots \\ r_{1k} & \cdots & r_{jk} \end{bmatrix} \cdot \begin{bmatrix} p_1 \\ \vdots \\ p_j \end{bmatrix}$$

2. STUDENT STOCKS

$p_t = O_t \cdot p_{t-1} + Q_t \cdot d_t + E_t \cdot c_t$

$$\begin{bmatrix} p_1 \\ \vdots \\ p_j \end{bmatrix} = \begin{bmatrix} o_{11} & \cdots & o_{j1} \\ \vdots & & \vdots \\ o_{1j} & \cdots & o_{jj} \end{bmatrix} \cdot \begin{bmatrix} p_1 \\ \vdots \\ p_j \end{bmatrix} + \begin{bmatrix} q_{11} & \cdots & q_{k1} \\ \vdots & & \vdots \\ q_{1j} & \cdots & q_{kj} \end{bmatrix} \cdot \begin{bmatrix} d_1 \\ \vdots \\ d_k \end{bmatrix} + \begin{bmatrix} e_{11} & \cdots & e_{h1} \\ \vdots & & \vdots \\ e_{1j} & \cdots & e_{hj} \end{bmatrix} \cdot \begin{bmatrix} c_1 \\ \vdots \\ c_h \end{bmatrix}$$

3. OUTPUT

$n_t = S_t \cdot p_{t-1} + U_t \cdot d_t$

$$\begin{bmatrix} n_1 \\ \vdots \\ n_g \end{bmatrix} = \begin{bmatrix} s_{11} & \cdots & s_{j1} \\ \vdots & & \vdots \\ s_{1g} & \cdots & s_{jg} \end{bmatrix} \cdot \begin{bmatrix} p_1 \\ \vdots \\ p_j \end{bmatrix} + \begin{bmatrix} u_{11} & \cdots & u_{k1} \\ \vdots & & \vdots \\ u_{1g} & \cdots & u_{kg} \end{bmatrix} \cdot \begin{bmatrix} d_1 \\ \vdots \\ d_k \end{bmatrix}$$

4. DEATH, EMIGRATION

$z_t = V_t \cdot p_{t-1}$

$$\begin{bmatrix} z_1 \\ \vdots \\ z_j \end{bmatrix} = \begin{bmatrix} v_1 & & \\ & \ddots & \\ & & v_j \end{bmatrix} \cdot \begin{bmatrix} p_1 \\ \vdots \\ p_j \end{bmatrix}$$

$$(1.5)\quad \underset{\text{(transfer)}}{(o_{i1} + \ldots o_{ij})} + \underset{\text{(graduation)}}{(r_{i1} + \ldots r_{ik})} + \underset{\text{(leaving)}}{(s_{i1} + \ldots s_{ig})} + \underset{\text{(death)}}{V_i} = 1$$

$$(1.6)\quad \underset{\text{(transfer)}}{(q_{f1} + \ldots q_{fj})} + \underset{\text{(leaving)}}{(u_{f1} + \ldots u_{fg})} = 1$$

In other words, looking at graph 1, the four columns containing outflow coefficients from grade i, namely in matrices R,O,S and V, should add up to unity. The same applies to the two columns containing outflow coefficients from diploma f, namely in matrices Q and U. With this a complete description is given of the model when constant coefficients are used.

Changing coefficients

Most of the coefficients however show a certain development in time. This phenomenon should be taken into account when forecasts or simulation exercises are made. The most simple hypothesis is that of a linear development. In that case for every coefficient matrix the following calculation is made:

$$O_t = O_{t-1} + dO$$

Instead of constructing every year a new matrix O_t, only two matrices have to be estimated, namely one for the base year and one - constant - matrix with yearly changes in coefficients. In the same way the matrices E_t, Q_t, R_t, S_t, U_t and V_t are calculated year by year.

The advantage of this procedure is that the condition, stipulated in equations (1.5) and (1.6) can very easily be fulfilled. For this it is sufficient that the total of the corresponding changes in the coefficients equals zero.

In this way justice is explicitly done to the necessity that a change in one coefficient always implies a corresponding change in one or more other coefficients.

The changes in coefficients (do_i etc.) need not necessarily be constant in time. Apart from this linear development of coefficients other time paths can be built in, such as an exponential development or an expected irregular variation of coefficients in time. Further, an upper or lower boundary can be indicated. These complications do not affect the essential features of the model.

1.2 The resource model

Although the resource model presented here is used for forecasting educational expenditures on the short- and middle-term, the degree of specification is rather crude. The underlying reason is the paucity of statistical material. Statistical information per type of school is only given with a breakdown to:

- personnel expenditures,
- other current ("material") expenditures, and
- capital expenditures.

Therefore the model has been kept as simple as possible, using at the same time the maximum quantity of available statistical information.

(2.1) $l_t = LPR_t \cdot p_t$

(2.2) $x_t^l = W_t^l \cdot l_t$

(2.3) $x_t^m = W_t^m \cdot p_t$

(2.4) $x_t^{inv} = W_t^{inv} (l_t - l_{t-1}) + ex_t^{inv}$

(2.5) $x_t = x_t^l + x_t^m + x_t^{inv}$

in which: l = a vector of teachers, including auxiliary personnel, by type of school, expressed in full-time equivalents (1 . . j)

LPR = a diagonal matrix with teacher-pupil ratios per type of school (j x j)

x^l, x^m, x^{inv}, x = vectors of expenditures for education; resp. personnel, material, capital and total expenditures by type of school (1 . . j)

W^l, W^m, W^{inv} = matrices of unit costs, per type of school (j x j)

ex^{inv} = a vector of exogeneously determined (replacement) investments by type of school (1 . . j)

Personnel expenditures

Starting point of the model is the estimate of student numbers made by the student flow model, which are added up for the two sexes and the grades to total numbers per type of school. The coefficient LPR is the reciproke of the expected mean pupil-teacher ratio which depends on three factors: class size, the number of teaching hours per class and the number of working hours per full-time teacher devoted to pure teaching. Ideally the model would treat these factors more explicitly as at the background of each lie a host of other variables. In as far as information on these factors is available it is used here as random information for an exogeneous estimate of LPR and the trend in this coefficient.

It should be noted that LPR represents the expected ratio, which means that i.a. class size can be sub-optimal when a shortage of teachers is expected. This can be concluded from a comparison between supply of and demand for skilled manpower.

The number of teachers, l, are not specified by the teachers' educational background, though salaries are dependent on this factor too. If sufficient reliable information would be available, it would be possible to fill in this information in equations (2.1) and (2.2). Then l, LPR, and W^l would become matrices of the order (g x j), specifying both educational level and type of school.

Other current expenditures

Under this heading come so-called material expenditures, representing inputs from other sectors of the economy, other than investments, such as normal upkeep of buildings; equipment and furniture; gas, electricity and water; cleaning; administration; libraries; etc. Here a simple relation with the numbers of students is used where W^m presents unit costs per student.

Capital expenditures

Investments in educational buildings are divided into two groups:

a. expansion in order to create places for the growing numbers of students and to make possible the execution of policy measures which require additional school capacity (i.a. a lowering of the pupil-teacher ratio);

b. replacement of obsolete capacity, including the improvement of the quality of existing schools.

An additional category is regional replacement in connection with the drift of families from the old towns to the new suburbs. This means that idle capacity arises in the old towns, so that total capacity is not expanded. In equation (2.4) $(l_t - l_{t-1})$ gives an approximation for the first category, while replacement is determined exogeneously; W^{inv} stands for capital expenditures per additional teacher.

1.3 The manpower supply model

Education can be considered to produce various types of benefits. From an economic point of view the output of the educational system consists of the training individuals have undergone and which they can utilize in their professional life.

In the student flow model the output n_t was estimated for both sexes by educational level. The entry into the labour force and the resulting total stock of trained manpower is calculated for male and female separately, as follows: (1)

$$(3.1)\quad A_t = V'_t \cdot A_{t-1} + C^n_t \cdot N_t + I_t$$

$$(3.2)\quad B_t = F_t \cdot A_t$$

in which:

- A = a matrix with numbers of educated individuals by age (1 . . h) and educational level (1 . . g)
- V' = a sub-diagonal matrix of survival rates (h x h)
- N = a diagonal matrix of school-leavers (g x g)
- C^n = a matrix containing the age distribution (1 . . h) of school leavers by educational level (h x g)
- I = a matrix of net immigration by age and educational level (h x g)
- B = a matrix of the labour force by age and educational level (h x g)
- F = a diagonal matrix of participation rates by age (h x h).

The first term of equation (3.1) calculates what numbers of last years stock of educated will survive and will be available this year. Differences in survival rates between educational levels seem to be negligible so that the mathematically more attractive approach of one set of survival rates is not too unrealistic. In making this calculation it is at the same time taken into account that everybody is going to belong to the next higher age group. This is done by the special way in which matrix V' is built up: except for the sub-diagonal, containing the coefficients $v'_{2,1}, v'_{3,2}, \ldots, v'_{h,h-1}$, all elements are zero. In a schematic form the procedure runs as follows:

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(1) In practice the effects of part-time education are included by an extension of equation (3.1).

$$\begin{bmatrix} 0 & 0 & 0 & 0 \\ v'_1 & 0 & 0 & 0 \\ 0 & v'_2 & 0 & 0 \\ 0 & 0 & v'_3 & 0 \end{bmatrix} \times \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \\ A_{h1} & A_{h2} & A_{h3} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \\ A_{h1} & A_{h2} & A_{h3} \end{bmatrix}$$

The oldest age group (A_{h1} - A_{h3}) passes the age-limit and disappears after multiplication with zeros. The youngest age group (A_{11} - A_{13}) becomes the next-youngest and is filled in on the second row. The first row will be filled by part of the newcomers (n).

In the second term this output of the educational system is given an age distribution by educational level after which it is added to the existing stock.

Lastly net immigration is treated as an exogeneous variable which is supposed to be known by age and educational level. This approach is preferred to a direct relation with the existing stock for various reasons. The most important reason is that in the Netherlands immigration of manpower with a relatively low educational level is an instrument of manpower policy.

In a complete forecasting model net immigration could at least partly be made endogeneous, namely by relating it to the outcome of a comparison between supply and demand by educational level.

The coefficients in matrices V' and C^n are supposed to vary over time. Changes of these coefficients will, however, be extremely small, so that this problem only exists in longer term forecasts.

Equation (3.2) is an extension of the manpower supply equation appearing in the general model of the Central Planning Bureau. In this presentation the same participation rates are indicated for each educational level. In fact, however, especially for women, these rates are highest for the highest educational levels. In practice therefore matrix F is constructed with participation rates by age and educational level (h x g) and matrices F and A are multiplied element by element. It will be clear that the total stock B per age group should correspond with the outcome of the general economic model.

1.4 Technical aspects of the model

A final remark can be made about the manner in which the computations are organised. It will be clear that an application of the model, and especially of the student flow model with its large numbers of coefficients would nearly be impossible without the aid of a computer. Even when a computer is available problems may arise from limited memory capacity if one wishes to distinguish too many types of schools and grades.

The computer currently used for this model is a Philips Electrologica X-8, with a maximum capacity of 17,500 numbers. Thus it was not possible to programme a direct matrix multiplication as indicated in equation (1.2) with an (0) matrix of 163 x 163 elements. Of these nearly 27,000 elements only about 1,000 are non-zero. Therefore the solution had to be sought in an efficient use of the large number of zero elements. In the computer programme a "boolean" matrix is read in for each of the matrices of the model, indicating on what places of the original matrix non-zero elements appear(1).

By this procedure only a minimal use is made of computer memory space. A 163 x 163 matrix with 1,000 non-zero elements needs the memory space of only 1,500 numbers (1,000 coefficients plus 500 numbers for the boolean matrix).

In this way computer capacity is no real bottleneck for the application of a student flow model, however detailed one may wish to make it.

II. A COMPARISON OF SOM WITH THE DUTCH EDUCATIONAL MODEL

The following paragraphs are more specifically devoted to the OECD technical report "SOM A Simulation Model of the Educational System". This is mainly done by comparing the submodels of SOM with those of the Dutch model. Further some remarks will be made about specific attributes of SOM.

2.1 The flow submodel

In line with the Dutch model the flow submodel could be reduced to one equation, namely:

$$(4.1)\quad p_t = O_t : p_{t-1} + E_t . c_t .$$

In SOM this simple piece of arithmetic is complicated in various ways:

a. First the educational system has been broken down to 5 levels. Within a level there may be a flow from each unit to any of the other units. Further if there is a flow from any unit to a unit in a higher level, this unit is repeated when calculations for the higher level are made. This complication is not made for theoretical or efficiency reasons, but on technical grounds only.

b. The same applies to the maximum set to the number of units within one level. For the Dutch educational matrix with its 163 grades, a maximum of 5 levels with 40 units

(1) This idea originates from and has been worked out by A.A. van der Giessen, mathematician at the Central Planning Bureau.

each would mean much pinch and scrape to press it into this framework.

c. The number of students within one level must not exceed 20,000. In a small country like the Netherlands, in more than 20 out of 163 grades this number is surpassed, which means that many coefficients have to be raised or reduced by a factor 10 or 100. Thus the very useful consistency check of equation (1.5) can hardly be applied here.

These remarks do not contain any criticism of the programming work done for SOM, because much inventiveness is shown.

In general, however, limited computer memory space cannot be a justification for restrictions to the application of a model. In the first place more elegant solutions are possible. An example has been given in paragraph 1.4 where it was shown that by using a boolean matrix nearly all memory space needed for zero elements can be saved. In the second place it is no longer necessary nowadays to work with too small computers. In this connection it may be mentioned that the (Dutch) Central Planning Bureau is going to make use of a giant Univac computer, situated in London, with which it is connected by a terminal. Keeping this technical possibility in mind it seems rather absurd that for the application of SOM to the United Kingdom a limited capacity computer was used.

Turning to the model itself, a main difference is that <u>graduation</u> is not explicitly dealt with. There are however essential differences in the flow patterns of graduated and non-graduated students. When coefficients are kept constant in time the two approaches are the same. With changing coefficients, however, problems may arise from diverging developments of the two categories. Therefore preference should be given to the splitting-up of equation (1.1') into the two equations (1.1) and (1.2) as presented in paragraph 1.1.

A further difference with the Dutch model is the way in which <u>school leavers</u> are defined. In SOM everybody leaving the educational system is put together under this heading. No distinction is made between those who finish their education and can be expected to join the labour force (n) on the one hand, and death and emigration (z) on the other hand. Thus:

$$(4.3) \quad (n + z)_t = s_t \cdot p_{t-1}.$$

In this way a direct link with a manpower supply model is hard to make, as first the component parts n and z have to be separated. In fact, in the teacher supply submodel part of the student flow submodel had to be repeated in order to find the output (n).

One of the good features of SOM is the inclusion of <u>restricted entry</u>. This possibility is not dealt with in the Dutch model, as it is not an acute problem in the Netherlands. (In any case entry is not openly restricted). Still some remarks could be made on the assumptions d) and e) on page 39. Proportionality of redistribution of those not admitted (d) and proportionality of admittance (e) are not very realistic assumptions, which make the model less general than desirable.

2.2 The resource submodel

The resource submodel has been constructed in order to produce forecasts of cost implications of educational development. This goal can be considered a rather narrow one in comparison with that of the Dutch model, with which forecasts of expenditures are made. In every country budgetary (and manpower) constraints are responsible for the existence of a gap between what is desirable (requirements) and what is attainable (expenditures). Therefore an expenditure forecast has more realistic value than a resource requirements forecast, which does not indicate what will really happen.

For example at first sight it is not clear why current costs for teachers are determined in the model by the numbers of teachers needed; and not by the numbers of teachers calculated in the teacher comparison submodel. This is, however, acceptable in a resource requirements model, though one may wonder what the salary costs are of teachers who are not available.

In the following some critical remarks will be made on the submodel given the existing goal. Suggestions for the extension of the model into an expenditure model will be given in Chapter III.

In general the model gives a good description of the factors that determine the need for resources in education. The distinction made between direct and indirect requirements is theoretically sound, but not too useful in practice, because the distinction will always be vague.

Another question concerns investment requirements. No mention is made of replacement investments, so it is not clear how this category is calculated in the model.

A large amount of statistical information is needed to produce resource requirements forecasts as described in the model. It is an advantage of the model that more simple approaches are made possible too, so that the model even can be used in cases where statistical information is scarce.

2.3 The teacher supply submodel

For an evaluation of the teacher supply submodel a comparison could be made with the Dutch manpower supply model, which can be used for estimating teacher supply also.

A first remark can be made on the calculation of the inflow of new graduates. In paragraph 2.1 it was pointed out that the treatment of school leavers in SOM is too crude, so that part of the student flow model has to be repeated here.

Another important difference between the two models is that in SOM only <u>marginal changes</u> in the teacher stock are estimated. This approach has some disadvantages in comparison with the integral approach of the Dutch model, where the total stock of potential teachers - "A" - is the basic element of the estimates. In the marginal approach of SOM it will especially be difficult to make an assessment of the inflow from and the outflow to other occupations and the non-active population. The outflow could possibly be estimated in relation with the existing stock of professional teachers, but estimates of the inflow can only be made on the basis of information on the reserve-stock, consisting of people with the required training currently working in other occupations and of non-active teachers (mostly women). For the last category it is essential to have information on the age-distribution as participation rates vary strongly between age-groups.

A yearly assessment of the total stock of potential teachers would further open the possibility to introduce more alternatives on the supply side in the Teacher Comparison Submodel.

A more specific remark could be made on the sense of isolated variations in the "<u>rate of choice</u>" for new graduates. If these variations are supposed to be induced by global policy measures one should expect corresponding variations in the flows to or from other occupations and the reserve-stock. An isolated variation in the rate of choice can thus only follow from specific, graduate-oriented measures.

2.4 <u>The teacher comparison submodel</u>

This model has been designed to produce conditional forecasts of balancing procedures. In fact, however, only one combination of variations can be produced by the model, namely with class size as a general balancing measure and weekly hours of teaching plus supply of new graduates as specific measures. Thus the model is far less general than the other submodels: other - and probably more realistic - balancing measures cannot be simulated with the model. The model can therefore only be valued as a starting-point for a field in which still much work has to be done.

2.5 <u>General aspects of SOM</u>

The most striking aspect of the publication on SOM is the large amount of attention given to calculation procedures. The impression is given that the organisation of calculations is a more important aspect of educational forecasting than the problem of how to make estimates of parameter values. Moreover the calculation procedures are unnecessarily complicated.

It is possible that this technical bias is responsible for the weak points in the model which can be summarised by saying that the assumptions are too specific for a generally applicable model and that too much is forecast outside the model. Ideally a model like SOM which is designed for general use should contain all statistically significant relationships existing within the educational system and between the educational system and society. For every relationship or group of relationships it should then indicate possible short-cuts which can be used in cases where the required detailed information is not available. The Resource Requirements Submodel goes somewhat into this direction. In fact, the Dutch educational model which has been designed for one specific country, is more general than SOM.

The second remark refers to the problem of what part of the forecasting job is included in the model and what part is treated exogeneously. Both SOM and the Dutch educational model leave all parameter estimation outside their scope. The problems arising from this division of work between a calculation model and outside estimation will be discussed in Chapter III.

In the introduction to SOM a general discussion is presented on the model concept and the role of mathematical models. (In passing it may be observed that a presentation of the model in mathematical form would have made reading easier). It is stated that in a model "the choice of characteristics taken into account, as well as the degree of accuracy aimed at depend on the types of problems for which the model has been designed." In other words: a theoretical conception has to underlie a model. This general rule has, however, hardly been applied to SOM. For example, a justification for the choice of a calculation model and for the use of a flow model is hardly given.

Further, on page 3 of the publication it is stated that SOM is meant as a tool for <u>conditional</u> predictions of the development of the educational system. In this connection two questions can be raised:

a. What is the use of conditional forecasts?

b. Why has SOM been designed to produce conditional forecasts?

Neither of these two questions have been answered in the publication.

III. A CRITICAL EVALUATION OF BOTH MODELS

3.1 Forecasting and simulation models

The distinction often made between pure forecasting models and simulation models is interesting from an analytic point of view, but in practice it can easily become a source of misunderstanding. Simulation is expected to give an answer to the question "what-if"? In order to compare the outcome of a simulation (the "what") and to judge the variant which is simulated (the "if"), an estimate of the most probable situation has to be made beforehand. For example when a future lowering of the pupil-teacher ratio is simulated, the most probable number of pupils has to be known before the outcome of the simulation can be evaluated. Moreover a forecast of expected total educational expenditures is needed in order to know whether there is a point in thinking of lowering the pupil-teacher ratio.

As stated before, the parameters of both SOM and the Dutch model have to be estimated exogeneously. This means that the model by itself cannot produce realistic forecasts, i.e. forecasts which have any reasonable probability of being fulfilled. Special attention should therefore be given to the estimation of coefficients.

Apart from the need for a realistic forecast as a basis for simulation exercises two additional requirements should be made. The first one pertains to the magnitude of variation. Here, an insight is needed beforehand of the boundaries between which the simulated assumption or estimate may lie. Otherwise simulation may become a useless game that can only create misunderstanding by those who have to work with the results (i.e. educational policy-makers. Here again additional analysis and estimation is needed outside the model.

Lastly, a simulation has to be consistent. If no prior analysis of the interdependencies with other elements of the system has taken place, simulation gives wrong answers. For example, if in a student flow model the inflow into grammar schools is doubled by simulation, the outcome of the above models will be that the number of pupils will double too and after some time one will see a doubling of the numbers of university students. Whether this is realistic or not is however an open question: other types of students will enter grammar schools, the quality of education in grammar schools may be lowered, and the transfer to university education will not be unaffected.

The danger of simulating isolated variations is especially present when a too technical approach is used. This means that calculation models like SOM and the Dutch model have to be supplemented with other models (implicit or explicit) which describe the interdependencies within the system.

The following paragraphs contain some suggestions and experiences on the way in which the shortcomings of both models can be met.

3.2 The need for a realistic forecast

SOM and the Dutch educational model have one thing in common: they are just technical descriptions, which are valuable as bookkeeping procedures but form a poor description of reality. Compared with economic forecasting the student flow model resembles most the technique used for the application of an input-output system which has to be supplemented by an econometric model (containing behavioural equations) in order to produce realistic forecasts. In fact in the Netherlands the econometric model produces the forecasts which are systematically worked out with the aid of input-output analysis. In the following a description is given of the way in which forecasts of the coefficients could be made.

The student flow model

Here, four groups of coefficients have to be estimated: entrance coefficients (E), transition coefficients (O,R and Q), leaving coefficients (S and U) and death and emigration coefficients (V). For each of them a thorough analysis has to be made of the factors that determine their development in time(1).

For example the transition coefficients are influenced by the level of income per capita (GNP/B), social stratification (B^g), scholarships (Sch) and autonomous factors (au). Moreover repetition and transfer is influenced by the "educational history" of students: the number of classes repeated, etc. (O_{t-1}, O_{t-2},...), thus:

$$O_t = (GNP/B_t, B_t^g, Sch_t, O_{t-1}, O_{t-2}, \ldots, au).$$

A practical example of the problems arising when coefficients are estimated will be given on the basis of an application of the student flow model to Grammar Schools. From cross-section and time-series analysis it appeared that a strong correlation exists between the admission to Grammar Schools and income per capita. This relation has been used for the assessment of entrance coefficients (E_t). The estimated growing transfer to Grammar Schools implies a decline in the transfer to other types of secondary education. The consequences and plausibility of this have been tested in an application of the model to the whole educational system(2).

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(1) See for example: R. Ruiter, "The past and future inflow of students into the upper levels of education in the Netherlands", OECD, 1967.

(2) See e.g. B.A. Thoolen and R. Ruiter: "The long-term development of education in the Netherlands", OECD, 1969.

In estimating the future development of transition coefficients only an approximation could be reached of the methodology outlined above. The main reason is that in 1968 a major reform of the structure of secondary education was established. This means that autonomous factors play an overwhelming role. Here information could be used from the experience of experimental schools which started many years ago with the new structure.

The transformation of the old structure into the new one will evolve gradually. It turned out that the student flow system is a very efficient tool for the description of this gradual introduction of the new structure with a corresponding disappearance of the old one. Main advantages of this system are the built-in consistency of simultaneous flows and the fact that all flows can be described explicitly.

A summary of the most important coefficients used in this application of the student flow model is presented in Table 1. The coefficients for the years 1967 and 1980 are given as fractions of student stocks at the beginning of the school year.

Table 1

Key coefficients for Grammar Schools, males, 1967 and 1980

	lowest grade		highest grade	
	1967	1980	1967	1980
repetition	.160	.105	.100	.050
passing, resp. graduation	.722	.825	.870	.925
transfer to other education	.105	.065	.004	.005
school-leaving	.012	.004	.024	.018
death, emigration	.001	.001	.002	.002
	1.000	1.000	1.000	1.000

Source: 1967 Central Bureau of Statistics

1980 Estimate, central alternative

The table shows a decline of the repetion rate which is expected to result from the intended tackling of the repetition problem by educational authorities. The decline of the school-leaving rate is caused by the general tendency to stay longer at school. Consequently, the passing rate will go up. Taken together the flows add up to 100 per cent of student stocks at the beginning of the school year.

The resource model

Starting with personnel expenditures two groups of coefficients have to be estimated: the teacher-pupil ratio (LPR) and mean salaries per teacher (W^1). For LPR starting point of the estimate is the desired ratio: LPR^d, which is dependent on the desired class-size, the number of teaching hours per class and the number of working hours per full-time teacher devoted to pure teaching. Then equation (2.1) becomes for the desired numbers of teachers l^d (in full-time equivalents):

$$l_t^d = LPR_t^d \cdot p_t.$$

Next an estimate has to be made of teacher supply (l^s) which is dependent on the numbers of persons with an adequate educational background (A^1), and autonomous factors:

$$l_t^s = f(A_t^1, au).$$

(See also equation 3.2 of the manpower supply model).

Balance between supply and demand is reached by relative teacher remunerations and other mostly autonomous factors, including policy decisions at the demand side:

$$l_t = f(l_t^d, l_t^s, {W^1}/{W_t}, au).$$

The development of mean salary per full-time teacher cannot be estimated without information from a general economic model. For example the medium term economic model of the C.P.B. contains the following wage equation(1):

$$w_t = 0.220\ (pc_t + pc_{t-1} + pc_{t-2}) + 0.400\ (h_t + h_{t-1}) - 0.045\ (w_t + w_{t-1}) + 0.086.$$

Here the wage level depends on the change in consumption price (p_c), the change in labour productivity (h), and unemployment (w), including effects from earlier years.

The development in time of teachers' salaries depends on three factors:

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(1) See: C.A. van den Beld: "Dynamiek der ontwikkeling op middellange termijn", Rotterdam, 1967.

a. general price rise due to inflation;

b. general increase in real wages; and

c. specific increase in teachers' salaries.

From an analysis of the period 1950-1966(1) it followed that for all educational levels taken together the rise of mean salaries was explained for 55 per cent by the first factor, for 40 per cent by the second, and for only 6 per cent by specific factors. A forecast of the first two factors has to be derived from a general wage equation. The last factor is mainly dependent upon the supply/demand situation for teachers. The importance of the salary factor is stressed by the fact that nearly 75 per cent of the increase in personnel expenditures in the above period was caused by the increase in salary per teacher.

Material expenditures for one type of school vary with the numbers of students, classes or teachers and schools. Moreover there is a variation in time because of price increases and because of specific increases which can partly be explained by policy measures, but have above all an autonomous character. Thus:

$$x_t^m = f(p_t, l_t, \text{schools, prices, GNP/B, au}).$$

The addition of (GNP/B), income per capita, to the above function can be explained by the fact that the specific increase is strongly related with the rising standard of living which has its implications for "living" at school. The main cause is the rising quality (and thus price) of already existing materials, and the purchase of newly invented educational facilities.

This factor exercises an important and thereby disturbing influence on an analysis, because it overwhelms largely the other factors. In the period 1950-1966 the more or less autonomous increase can be estimated to explain nearly 50 per cent of the total increase of material expenditures per student.

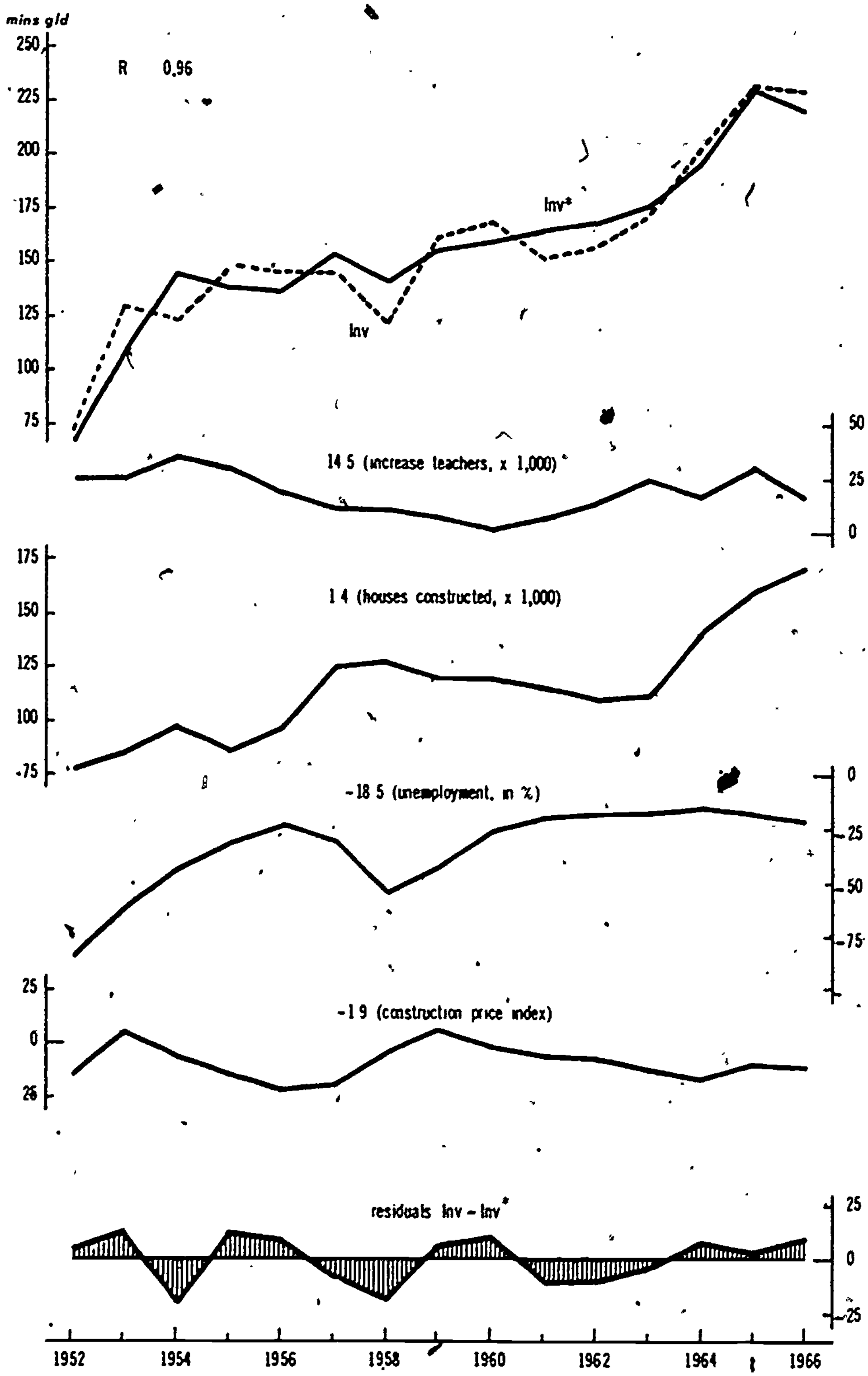
Capital expenditures were presented in equation 2.4 as a function of needed capacity expansion and exogeneous factors. In SOM only investments needed are calculated. In fact, however, the exogeneous factors are more important than the desired capacity expansion. From an analysis of investments in primary and pre-primary education, the following relation was found (see also graph 2):

$$\text{inv.}_t = 14.5\,(l_t - l_{t-1}) + 1.4\,\text{hc} - 18.5\,w_t - 1.9\,\text{p.inv.}_t + 67.0$$

(1) See: J. Passenier and R. Ruiter: "Expenditures on education in the Netherlands", OECD, 1969.

Graph 2

INVESTMENT IN PRE-PRIMARY AND PRIMARY EDUCATION
(in millions of guilders, 1966 prices) 1952-1966



The number of houses constructed (hc) is used as an indicator for regional replacement as houses are mainly built in the new suburbs, while unemployment (w) and the price rise (p.inv.) are economic factors that explain fluctuations. From Graph 2 it will become clear that the growth in the number of teachers explains only a marginal share of the variations. This means that a purely technical (or SOM) approach does not work in forecasting capital expenditures.

Total resources were found by adding up the three component parts. However, even if more realistic estimates as indicated above are made for the component parts, one cannot be sure that a realistic estimate for the total of expenditures is obtained. The estimates are very detailed so that a cumulation of estimating errors can result. Therefore a global check is needed in order to judge whether the total amount is acceptable from a macro-economic point of view. This is done by relating total educational expenditures to Gross National Product. This relation was investigated for the years 1900-1966(1). Four different periods can be distinguished, characterised by different elasticities. When the crisis period 1930-1938 is left out, a declining elasticity can be noticed, viz. 3.75 for 1900-1915; 2.63 for 1915-1930, and 2.09 for 1950-1966. An extrapolation of this trend produces a useful global check for more detailed expenditures forecasts.

The result of a comparison between the two forecasts may be that the more detailed estimates have to be checked, e.g. on inconsistencies. It is possible then that the two outcomes remain different. Without further analysis it is not possible to judge which one is the most realistic.

The manpower supply model

In paragraph 1.3 something has been said already about the necessity of a link with a general economic model. For example participation rates partly depend on the general economic situation:

$$dB_t = -0.500\,(dw_t + dw_{t-1}) + d\,B_{au.t},$$

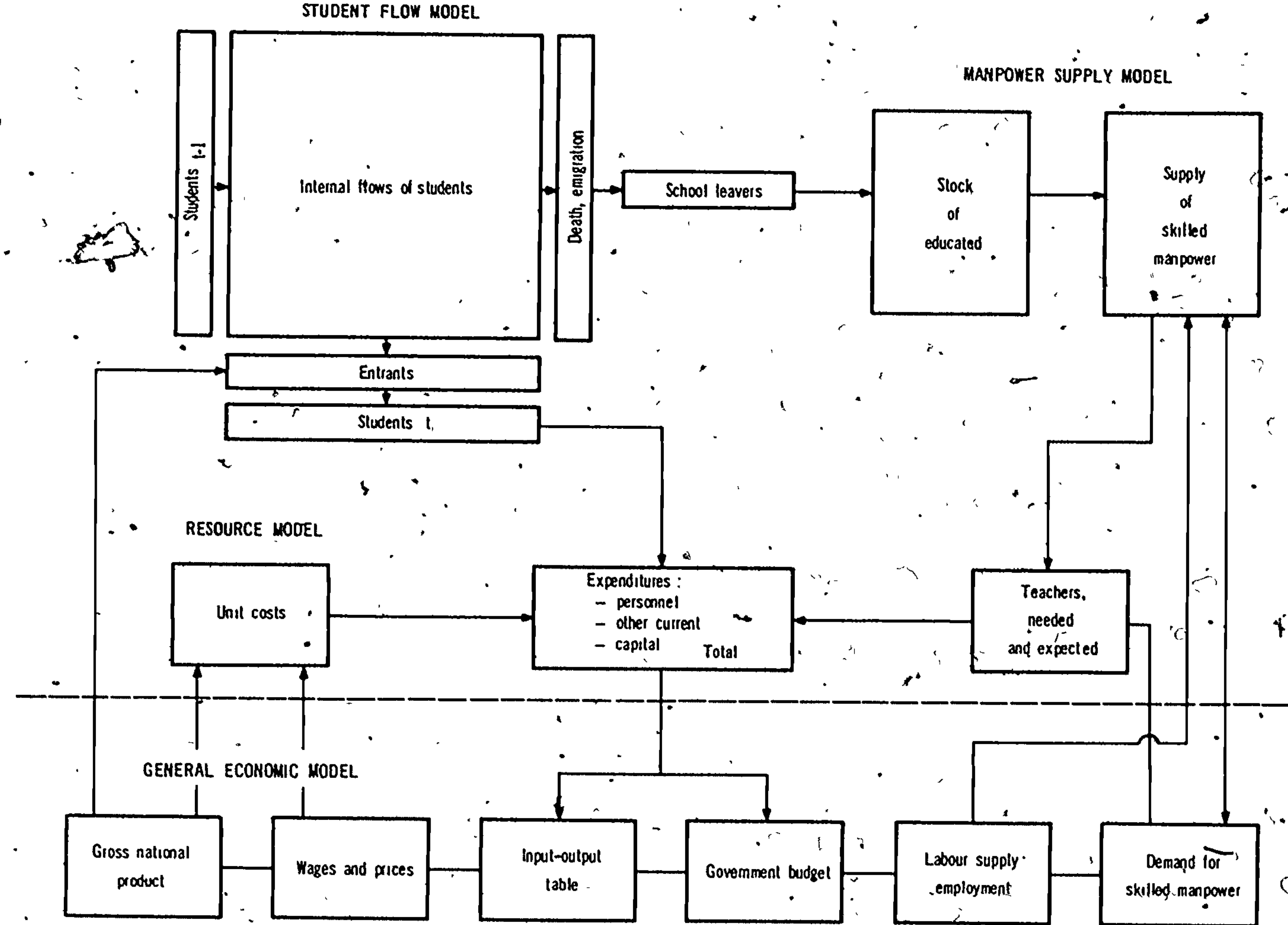
which means that the increase of labour supply (dB) is smaller than the autonomous increase (dB_{au}) when unemployment (w) is rising. On the other hand the general economic model needs information from the educational model on the participation in education of age groups above the compulsory age, which can either study or work.

The outcome of the educational model, the supply of manpower by educational level, can then be compared with the demand for skilled manpower following from the general economic model. An example of this was included in the latest medium-term plan of

(1) Passenier and Ruiter, op.cit.

Graph 3

STRUCTURE OF THE EDUCATIONAL MODEL.



the Central Planning Bureau: "The Dutch Economy in 1973". Estimates were made of global econometric relations between the demand for educated manpower (by five levels) and some general economic indicators. After comparison of demand and supply (estimated with the aid of the model presented here), a picture arose of possible shortages and surpluses by educational level. The outcome was checked, i.e. with expert-opinion in this field.

There are still some shortcomings, especially in the field of available statistics from which these kinds of relations can be estimated. In any case it is a new step in a field where still much work has to be done.

Conclusion

In the foregoing a deeper insight is given in the way in which forecasts are made (or should be made) of coefficients appearing in the educational model presented in this paper. In Graph 3 a summary is given of the many links within the educational model and with the general economic model. From this survey a broad pattern arises of flows of information each of which has to be based on prior analysis.

It is clearly a too simple idea that the design of a formalised model is a sufficient condition for educational forecasting. On the contrary, it is not even a necessary condition. The analysis of relations existing within the educational system and with other systems is at least as important as a model. Both SOM and the Dutch educational model presented in Chapter I are nothing more than sets of definitional equations for which all pure forecasting has to be made outside the model. The extension of the Dutch model presented here means that the original model is maintained and that a set of behavioural equations is added. Apart from a purely technical description of the operation of the educational system (e.g. transfer to higher types of schools), the model thus obtained gives a description of the way in which the operation of this system is influenced by the reaction of people (e.g. the influence of rising income on the transfer to higher types of schools).

Only in this way the model becomes: "a theoretical description of certain aspects of a real life process or system"(1), with the aid of which realistic forecasts can be made. Moreover, only in this way the model produces the advantages that it gives "a deeper insight in what (statistical) data are the most important ones for obtaining information relevant to educational planning policies"(1).

3.3 The need for realistic simulation

After the foregoing discussion not much has to be said about the way in which a realistic magnitude of variation, to be simulated by the model, has to be chosen. From the analysis two

(1) Quote from: "SOM", OECD, 1970.

categories of variation problems appear.

First, estimates of coefficients are always accompanied by estimating errors which give an amount of uncertainty to the outcomes. Thus on statistical grounds a certain deviation from the estimated values is possible. Here simulation is desirable because it gives an insight into the upper and under boundaries between which the most probable outcomes may lie. Especially for policy-makers it is important to know to what extent they can trust the so-called "central alternative" which is produced by the pure forecast.

A second category of problems for which simulation is desirable is the uncertainty about the assumptions made. Here a distinction can be made between autonomous factors on which policy-makers have little or no influence, and instruments which form part of educational policy. Policy-makers may be expected to have a special interest in the way their instruments work and in the extent to which they can exercise influence with their instruments.

Examples can be taken from the application of the student flow model to Grammar Schools.

An example of the first category of variation problems is formed by the unexplained residuals in entrance rates in the analysed period. As a consequence one should take into account a certain extent of variation for the forecasting period.

A problem belonging to the second category is the uncertainty about the extent to which educational authorities will succeed in reducing the repetition rate. In the central alternative a very gradual reduction of repetition was assumed. It is however possible that a quicker reduction will result. Therefore it has been tested with the model what is the influence of variations of the repetition rate on the numbers of pupils and diplomas. A striking result was the small effect of this coefficient.

The repetition rate was looked upon here as a variable on which educational policy-makers can assert influence with the aid of their instruments. One can question, however, the extent to which such instruments can be used in practice. This question refers in fact to many of the instruments policy-makers are supposed to have at their disposal. The result is that the influence of government policy can easily be overestimated. For example in the report by Passenier and Ruiter, cited before, the conclusion was reached that "post-war policy-makers in education can only be praised (or blamed) for about 10 per cent of the increase in the educational budget". The same kind of conclusion was reached by Ruiter in his report: "Education and Manpower Forecasts"(1). From an analysis of three important categories of instruments it followed that "in all probability these instruments are not very effective in achieving the objectives in view".

The same phenomenon can be observed in another field, viz. income policy. In the Netherlands government has many instruments, but rather ineffective ones, at its disposal. Compensating powers

(1) In: "Planning and development in the Netherlands", vol.III, No.1/2. The Hague, 1969.

in society make that income policy does not work adequately as can be shown by multiple regression analysis.

The conclusion is that simulation should be preceded by careful analysis of the extent to which variations can be expected and instruments can be used.

3.4 The need for consistency in simulating

From the examples given above a second conclusion can be drawn. When isolated variations are simulated compensating (or cumulating) factors are not taken into consideration so that wrong answers are found.

Especially in the student flow model a variation in one of the coefficients has implications for many other coefficients, not only in the same year, but also in future years. This has been expressed in paragraph 3.2 by:

$$O_t = f(\ldots\ldots, O_{t-1}, O_{t-2}, \ldots\ldots).$$

In a purely technical (or SOM) approach these inter-dependencies are not taken into account so that one cannot expect to find correct answers. This is proved in the SOM report by the Application Study. Here the transition coefficients found in the base year for the whole student stock are extrapolated and applied to a certain marginal group of students. This marginal group would have left school if the school-leaving age had not been raised. This means that these students show in any case <u>not</u> the same flow pattern as those who stay at school voluntarily. (Moreover the question can be raised whether a student flow model is the best one for the study of these kinds of problems; cohort analysis seems to offer a far more efficient approach).

For a proper use of a student flow model for simulation purposes each simulation problem requires another specification of students, for example:

- to social group, i.e. democratization;
- to region, i.e. removal of regional disparities;
- to educational history, i.e. tackling of repetition problem;
- to second-best choice, i.e. redistribution in case of restricted entry;
- to age-group, i.e. raising the school-leaving age, etc.

From a technical point of view a detailed specification can easily be handled by a student flow model.

Only seldomly will the statistical material for these specifications be available. But a guess based for example on enquiries will produce better results than a bold application of general coefficients to a marginal group.

The inter-dependencies between variations of the coefficients are automatically implied if the right specification is chosen for a simulation problem. For that a painstaking analysis may be necessary. Simulation of a student flow model without prior analysis of the inter-dependencies is nothing more than the managing of a sophisticated system of bookkeeping by a junior clerk.

IV. SUMMARY AND CONCLUSIONS

A comparison between SOM, the OECD Simulation Option Model, and a Dutch educational model which is partly based on the concept of student flows, shows that apart from some technical differences, a large extent of similarity exists. This is hardly surprising where both models only describe technical relationships within the educational system. The student flow model, for example, has only one exogeneous variable, namely population, and describes education as a completely closed system.

Partly on the basis of experience with the application of the Dutch model an attempt has been made to investigate the possibilities and limitations of both models for the purpose of educational forecasting and simulation. It appeared that this type of model does not produce by itself realistic forecasts or simulations that give correct answers.

This means that calculation models like SOM and the Dutch model have to be supplemented with sets of behavioural equations which describe the relationships between education and the whole economic and social system.

The most important conclusion is that analysis is at least as important as a model and that the design of a model without prior analysis only means a first, experimental stage in model building.