DOCUMENT RESUME

ED 139 062 EA 008 9?2

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TITLE The Applicability of Cost-Resource Models to the Planning Requirements of the Education Department of Victoria, Australia. IIEP Occasional Papers No. 39.
INSTITUTION United Nations Educational, Scientific, and Cultural Organization, Paris (France). International Inst. for Educational Planning.
PUB DATE Mar 75
NOTE 40p.; Parts of document may be marginally legible due to print quality of the original
AVAILABLE FROM IIEP Publications, 7-9 rue Eugene-Delacroix, 75016 Paris, France (4.00 francs)

EDRS PRICE MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS Costs; Demography; *Educational Planning; *Models; *Primary Education; *Resource Allocations; *Simulation; Teacher Salaries
IDENTIFIERS *Australia (Victoria); *Simulation Model of the Educational System

ABSTRACT

The type of model this paper is concerned with consists of four parts: a set of variables describing the part of the educational system to be analyzed; a set of relationships among variables, expressed as equations; estimates of the parameters governing the relationships; and solution procedures for the model. In the first section of this paper, four models are examined to illustrate their strengths and weaknesses and a more detailed examination is given to one of these--"SOM--A Simulation Model of the Educational System," developed by the Organization for Economic Cooperation and Development. The second section constructs a model of primary education in Victoria. The main purpose of this exercise is to become aware of the problems involved in model construction. The model has two main features--it is a short-term planning tool, unlike the four models examined earlier; and it incorporates specific features of the system in Victoria in an attempt to provide answers to specific questions likely to be asked within that system. While the paper concentrates on the application of cost-resource models to a specific educational system, many of the problems encountered have general relevance to other systems. (Author/IRT)

IIEP Occasional Papers No. 39

THE APPLICABILITY OF COST-RESOURCE MODELS TO THE PLANNING REQUIREMENTS OF THE EDUCATION DEPARTMENT OF VICTORIA, AUSTRALIA

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Unesco: International Institute for
Educational Planning

IIEP Occasional Papers

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Printed in France by the
International Institute for Educational Planning
7-9 rue Eugène-Delacroix, 75016 Paris
March 1975

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INTRODUCTION

Models of the education system are severely limited in the contribution they can make to educational planning. These limitations will become increasingly clear in the course of this paper. What they can provide is basic information in a form which enables decision-makers to see the quantitative results of alternative policies.

The term 'model' tends to be ambiguous because of its use in many different senses. Its meaning in the context of the present study is best defined by reference to the characteristics of the models examined. From a practical viewpoint, the type of model with which we are concerned consists of four parts:

- A set of variables describing the part of the education system to be analysed.
- A set of relationships among variables, expressed as equations.
- Estimates of the parameters governing the relationships.
- Solution procedures for the model.

These features are also present in mathematical models which require a much more detailed knowledge of the relationships between variables than can be expected in the education system. For this reason, many of the models developed in education have incorporated the technique of simulation which is particularly appropriate in complex systems where the relationships between variables are not well understood.

The paper is divided into two distinct sections. Section I consists of a fairly detailed examination of four models, with the purpose of illustrating the strengths and weaknesses of this type of model. By comparing the four models it is sometimes possible to find approaches in one model which overcome the weaknesses found in the others. This overview is followed by a more detailed look at SOM - A Simulation Model of the Educational System, developed by OECD. As SOM is a generalized model, the examination concentrates on its applicability to the long-range planning needs of the Victoria Education Department. It is concluded that the model would be of use, but with a number of provisos.

Section II is an attempt to apply what has been learned from the previous examination, by constructing a model of primary education in Victoria. The main purpose is to become aware of the problems involved in model construction, rather than construct a model which could be made immediately operational. Two features of this model should be mentioned.

1. It is designed as a short-term planning tool. The four models considered in Section I are essentially for long-range planning purposes. The decision to concentrate on the construction of a short-term model made it possible to consider whether this type of model was suitable for short-term planning purposes. The general conclusion is that the limitations of a model are more pronounced

in short-term applications and that techniques which provide a range of optimum solutions could be more useful.

2. The model incorporates specific features of the system in Victoria, and attempts to provide answers to specific questions likely to be asked within that system. This approach tends to highlight the problems that would be involved in using a generalized model.

While the paper concentrates on the application of cost-resource models to a specific education system, many of the problems encountered have general relevance to other education systems contemplating the introduction of such a model.

I. AN EXAMINATION OF FOUR MODELS IN USE WITH EMPHASIS ON THE RESOURCE AND COST SECTIONS OF EACH

The purpose of this section is to look critically at four models which have been developed and applied at the level of national or State education systems. Such an examination will indicate the problems faced in model development and thus can act as a guide in the development of a model specifically for the Education Department of Victoria. In addition, as two of the four are designed as general purpose models applicable to a wide range of education systems, the present examination should indicate whether these generalized models could be applied to the situation in Victoria.

The four models to be examined are:

1. SOM - A simulation model of the educational system. 1/ The model was developed by OECD as a generalized model applicable particularly to situations where data collection is well developed.
2. The Unesco education simulation model (ESM). 2/ This is also a generalized model which has been applied mainly to the education systems of underdeveloped nations.
3. A cost model for Norwegian education, 3/ developed by Olav Magnussen, which covers only primary and lower secondary education.
4. Model showing the effect of demographic growth on the development and cost of first-level enrolment and teacher training. 4/ This model was developed by Ta Ngoc Châu as part of his examination of the influence of population growth on the costs of education.

It is proposed to first examine the four models in terms of a number of aspects related to the stated purposes of the models and the methods used to achieve these purposes. This overview of the four models will be followed by a more detailed examination of the SOM model with emphasis on its applicability to the long-term planning needs of the Education Department of Victoria.

1/ OECD, SOM - A simulation model of the educational system - technical report (Paris, OECD, 1970). Referred to as SOM.

2/ Unesco, The Unesco educational simulation model (ESM) (Paris, Unesco, 1974). Referred to as ESM.

3/ IIEP, Educational cost analysis in action - case studies for planners, Vol. II, pp. 95-130. Referred to as the Norwegian model. (Paris, IIEP, 1972).

4/ Ta Ngoc Châu, Population growth and costs of education in developing countries (Paris, Unesco, 1972), pp. 279-309. Referred to as the demographic model.

The applicability of cost-resource models to the planning requirements of the Education Department of Victoria, Australia

1. Stated purposes

The four models have in common the fact that all claim only to be tools for the computation of the results of alternative resource allocation decisions. 1/ This limited aim is achieved through the solution of a set of equations which describe the assumed relationships between variables. Each model focuses on certain key variables which are considered to be controllable by policy-makers, such as pupil-teacher ratios and class size. By altering these key variables and running the model again, it is possible to assess the system-wide impact of these alternative policy decisions. It is also possible to adopt alternative assumptions as to the future levels of variables such as population growth or retention rates. The model can then be run under these changed assumptions in order to assess the likely impact on the system as a whole. Such repeated solution of the model is normally referred to as simulation. None of the models attempts to produce an optimum solution to the allocation of resources, but merely to spell out the expected results of each alternative allocation. Decisions as to which of these alternatives should be adopted must be made on the basis of educational, social and cultural factors which are difficult, if not impossible, to incorporate in such a model. As part of the simulation aspect, each of the models also provides the facility to measure the sensitivity of the system to changes in policy variables or to changes in one of the exogenous variables such as population growth.

Although the models have much in common, there are also differences in their stated purposes and applications. The Norwegian model, designed as it is for a specific educational system and designed to solve a specific problem, is rather different in approach from models such as ESM and SOM. These differences go beyond alternative methods of calculating variables, (which will be dealt with below) to the 'mental set' of the model designer. The Norwegian model stresses the distinction between policy variables, which are under the control of decision-makers, and exogenous variables, far more than the other models. As Magnussen points out: "Since this model is intended to reveal the cost implications of alternative decisions by the policy-maker, the distinction between policy variables and exogenous variables reflects the extent of his control over the variables." 2/

Another feature of the Norwegian model is the stress placed on the interdependence between variables, which is again a reflection of the purposes for which the model was designed.

ESM has a feature which is missing from all the other models. It rejects alternatives which are not feasible; for example, alternatives calling for an increase in third-level education beyond the possibilities of expansion of the first and second level, or expansion beyond the possibilities of teacher-training institutions to meet the demand. This feature does not make ESM a decision model, but it does eliminate some of the sifting necessary when results are produced. It is interesting that the meeting of experts which critically examined SOM proposed modification of the model to incorporate a similar feature. 3/

1/ SOM, op. cit., p. 5; ESM, op. cit., p. 14; Norwegian model, op. cit., p. 108; demographic model, op. cit., p. 281.

2/ Norwegian model, op. cit., p. 101.

3/ OECD, The use of simulation models in educational planning - a critical evaluation of SOM (Paris, OECD, 1971), p. 8. Referred to as "A critical evaluation of SOM".

An examination of four models in use with emphasis on the resource and cost sections of each

Although in the construction of all models it is necessary to take cognizance of the availability of data, this has been a particularly important factor in the development of ESM. Because it is designed with the needs of underdeveloped nations in mind, this feature is particularly important and has shaped many of the features of the model. For example, although many items of expenditure can be broken down in considerable detail as input to the programme, it will also accept much less detailed data. Even so, in the countries in which the model has been applied, much of the required data was not available in the detail required by the model. 1/

Unlike ESM, which has generally been applied by those who developed the model and has been modified as a result of these applications, documents on SOM stress a wide range of possible applications. The choice of application and modification resulting from this choice, is left to the user. An article by Nuiziere 2/ lists four major areas of application. These cover the use of SOM as

- a forecasting tool
- a programme-budgeting tool
- an exploratory tool, through the use of sensitivity analysis
- a planning tool, through the simulation of alternative strategies.

Although these possible applications are not mutually exclusive, there is a danger that a model which casts its net so widely could produce results which are too detailed for the problem posed by the user. The need for application studies to guide in the modification of SOM was recognized by the meeting of technical experts organized by OECD in 1970, where the following proposal was made. "Efforts should now be concentrated on applications. Modifications to the model should be introduced only in relation to application studies."3/

The problem of disparity between the stated purposes of SOM and the detailed nature of its output is taken up and possible solutions suggested in the section dealing with SOM.

The demographic model, like the others, is used to "... estimate the range of possible costs according to various sets of hypotheses concerning the change of policy variables and of exogenous variables". 4/ But, in addition to this, the model is used "... to isolate the various factors of cost increase and to show their relative share in the increase of total cost". 4/ This is done by comparison of the base year with the horizon year, thus isolating the increase due to each factor.

2. Time horizon

The demographic model, SOM and ESM are specifically designed as long-term planning tools; long term being defined as 10-15 years (ESM), 10-20 years (SOM) and 20 years in the case of the demographic model. The long-term nature of these models determines many of their features. One aspect of this is that variables which are appropriate in the long term would not be satisfactory for

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1/ See for example, Unesco, Application of the Unesco educational simulation model - Philippines - alternative educational strategies, 1970-1985 Technical progress report No. 4. In manuscript.

2/ M. Nuiziere, "Application field of SOM". A critical evaluation of SOM, op. cit., pp. 27-39.

3/ A critical evaluation of SOM, op. cit., p. 9.

4/ Demographic model, op. cit., p. 281.

short-term planning. Pupil-teacher ratio, for example, which is used in both ESM and the demographic model and is implicit in SOM, is quite satisfactory for indicating the total number of teachers required 10 to 20 years in advance. In the short term (3-5 years) decision-makers are concerned with more detailed considerations. An overall pupil-teacher ratio, even if broken down by type of teacher, will rarely indicate how many teachers of that type are actually available to teach. Considerations such as the likely number of teachers on leave, the movement of teachers through promotion, resignation or recruitment and the number of teachers needed for functions other than class teaching are of more concern in the short term.

In the long term also, more variables come under the control of decision-makers. As Magnussen points out: "The policy-maker may have no control over a variable in the short run (for instance the supply of trained teachers), but may be able to affect it in the long run."1/

The use of the simulation technique in a model with comparatively simple variable combinations is particularly appropriate when a wide range of policy variables is available to the decision-maker. The emphasis in both ESM and the demographic model is on the exploration of the effects of alternatives rather than on accurate forecasting. The main application of this type of model is thus correctly seen to be in the area of long-term planning. Of course, there is no reason why the forecasting aspect of the model need be played down even in a long-term model, as is evidenced by SOM. The model does, however, become much more complex and the data needs substantial. Both ESM and the demographic model explicitly aim to provide a model which can be made operational with a minimum of data.

The long-term model is also particularly suitable for simulating the effects of changes in the structure of the education system. Of their nature these structural changes generally take a number of years to work themselves through the system and, in addition, preparation for the changes needs to be made many years in advance. The model can show the impact of the change in each year and alert decision-makers to the level of increased or changed provision in areas such as teacher training and capital expenditure which will be needed in the years before the full impact of the change is felt.

The Norwegian model does not type itself as either short term or long term, but estimates were made up to 1985-1986 in the case described. Many of its features, however, suggest its use also in the short run. An example of this is the loading on teachers salaries to allow for teachers on leave.

3. Flexibility

It is obviously important that a generalized model should be flexible in terms of being applicable to the structures of a number of educational systems. This flexibility is achieved in part in SOM by assuming that education systems consist of a number of 'boxes' and that pupils flow through these boxes, making provision for repetition, drop-out, leaving school and moving to another box. The fitting of an actual school system to this framework is left to the user of the model. A similar framework underlies ESM. Another aspect of both models which contributes to their flexibility is that they allow for varying levels of aggregation when applying the model. Provided the data is available, it

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1/ Norwegian model, op. cit., p. 101.

is possible to provide separate estimates for different regions in a system, for different sex of pupils or teachers, for type of teacher, for type of course and, in the case of SOM, for different socio-economic groups among pupils.

It is also possible, with SOM, to use any combination of the sub-models, without running the full model. After running the full model it would for instance be possible to focus attention on teacher supply and a number of assumptions in this area explored, without again running the full model.

Despite these elements which contribute to the flexibility of generalized models, it is not possible for this type of model to incorporate all relevant features of a particular system. A student flow model for Victoria would, for instance, incorporate flows in and out of the system through overseas and interstate migration, and movements to and from the private school system. Such flows can be incorporated in SOM through the use of 'dummy' units but this appears to be rather cumbersome. Ideally, changes could be made to the model programme to fit it to the needs of a particular education system. This is not possible until computer programmers are familiar with the characteristics of the model and the programme. This would appear to be a major disadvantage of the use of generalized programmes, however flexible in operation they may be.

4. Major variables and equations

The purpose of this section is to indicate how each of the models arrives at key resource and cost values. To do this it is necessary to look at the variables used and the relationships between variables which are expressed in the equations of the model. In order to make clearer the similarities and differences between the models, equations will be expressed in words so as to avoid the confusion caused by the use of different symbols in the four models. This approach is neither as precise nor as elegant as that adopted by the authors of the four models cited. It is used only to highlight the methods of establishing major relationships. Reference to the full description of each model is necessary for a complete understanding of a particular model.

The methods by which the following values are arrived at will be examined:
Teacher numbers: Costs: (a) teacher salary costs; (b) other recurrent costs; (c) capital - places to be built; cost per place.

(i) Calculation of teacher numbers

1. ESM - The number of teachers required is equal to enrolment divided by pupil-teacher ratio. 1/

2. Demographic model - The number of teachers required is equal to enrolment multiplied by teacher-pupil ratio. 2/

1/ All variables are subscripted by type/level of course. Breakdown according to teacher qualifications is achieved by multiplying total teacher numbers by the proportion of teachers holding each type of qualification.

2/ Teachers are broken down according to type of teacher, with each teacher type having a distinct teacher/pupil ratio.

3. SOM - The number of teachers required is equal to the number of class hours to be taught each week, divided by average teachers weekly teaching obligations. The number of class hours to be taught is calculated for each 'activity' 1/ separately and is equal to the proportion of pupils taking the activity divided by the average class size for the activity, multiplied by enrolment and the weekly hours for the activity. 2/

4. Norwegian model - The demand for teachers is equal to the demand for teachers per pupil (teacher-pupil ratio) multiplied by enrolment multiplied by an adjustment coefficient for replacement of teachers on paid leave.

It is clear that ESM and the demographic model use the same method of calculating teacher needs. SOM, if we define 'activity' as the entire primary school curriculum, takes into account average class size and the teaching obligations of teaching staff. The full calculations would, however, be particularly suitable for calculation of secondary school teacher numbers. The Norwegian model, because it is dealing with a specific system, takes into account particular features of the system. Some periods are taken in full classes and some in divided classes and this fact is taken into account in calculating teaching hours per pupil per year. In addition, teachers have set weekly teaching obligations even at the primary level. It then also uses a teacher-pupil ratio, but incorporates a loading to provide additional teachers to replace those on leave. This appears to be a valuable feature of this model and one which could well be incorporated in SOM or other models designed to show total teacher needs. In Victoria, during 1974 at least eight to nine per cent of the total teaching force was on leave at any time during the year. This represents 4,000 teachers to be replaced. Some of these teachers are on short-term leave and can be replaced by emergency teachers, but in the case of long-term leave permanent teachers are needed for replacement. The demand for teachers should therefore incorporate this factor, at least for short-term planning purposes.

(ii) Calculation of costs

Teacher salary costs. (i) ESM - Total teacher salaries are equal to teacher salary costs per pupil multiplied by enrolment. Teacher salary costs per pupil are found by dividing average teacher salary by the pupil-teacher ratio. (ii) Demographic model - Total teacher salaries are equal to the product of yearly teacher salary, enrolment and teacher-pupil ratio. (iii) SOM - Total teacher salaries are equal to the number of teachers multiplied by the yearly teacher salary. (iv) Norwegian model - Total teacher salaries are equal to total school hours per year multiplied by the hourly wage rate and the adjustment coefficient for teachers on leave. Total school hours per year are made up of teaching hours, pedagogical hours and administration hours.

1/ "An 'activity' can be a subject, a group of subjects or the entire curriculum, depending on the aggregation wanted", SOM, op. cit., p. 15.

2/ Chours = Stud x WHC x PERC/CLSZ.
Chours = class hours
Stud = enrolment
WHC = weekly hours for the activity
PERC = proportion of students taking the activity
CLSZ = class size.

An examination of four models in use with emphasis on the resource and cost sections of each

In all cases, average teacher salaries are broken down on the basis of teachers of different types, generally tied to the level or 'activity' in which they teach. The demographic model takes this breakdown a step further by recognizing that teachers of more than one type are likely to teach at each level or in each activity. Primary-level teachers, for example, may be of a number of teacher types, dependent on qualifications or experience, while teachers of science may also be of a number of types. Such variations are implicit in the average salary figures of the other three models, as the average salary will include teachers of all salary types involved at that level or in that activity. This assumes, however, that the salary profile of teachers at a level or activity will remain constant over the planning period. This may not be the case if a specific programme of upgrading teachers qualifications is undertaken. Even without such a specific programme, the salary profile is likely to change because of supply conditions, changes in teacher resignation rates or changed promotion opportunities for teachers.

The demographic model incorporates "... a coefficient which depends upon the qualification profile of the teaching force ... and upon the differences between the average salaries of the various types of teachers ..."1/ Such a coefficient would appear to be useful in the case where a policy of changing the qualification profile or the wage differences between various types of teachers has been announced for the planning period. In the case where these changes are brought about by supply factors, it would seem reasonable to develop the average salary figures with a separate teacher supply model. This approach will be developed in the section on the proposed short-term model for the Victoria system.

Other recurrent costs. Four distinct approaches to the problem of estimating other recurrent costs can be isolated. All four models use costs per pupil for at least some elements of recurrent costs. ESM and the demographic model use only this approach. ESM breaks costs down into a number of categories (e.g. personnel other than teachers, operation and maintenance costs) but the unit in each case is the pupil. A second approach is represented by the Norwegian model, where transport and housing are based on the unit of pupils using the service. Where these items are of importance, this would appear to be a useful refinement. The use of a number of units other than the pupil is the third approach. The Norwegian model uses the 'school hour' as the unit for recurrent costs other than transport, housing, furniture and books. Use of the 'school hour', which includes teaching hours, pedagogical inspection hours and administration hours, has the advantage that it recognizes the different proportion of costs absorbed by pupils at different levels. Such a refinement is probably possible in this form, only in a model designed specifically for a particular system. SOM uses two units other than the pupil. For running costs of buildings, the cost is calculated per square unit for each space type. For major pieces of equipment (e.g. T.V. sets) the unit is the running cost per piece of equipment. While all recurrent costs are related to pupil numbers, some items of recurrent costs are likely to be more directly related to units other than the pupil. The improvement in predictive ability resulting from the incorporation of units other than the pupil is likely to be small in whole system applications of a model. If, however, the model is dealing with smaller sections of the system such as a region or a particular 'activity' (in the SOM sense), then

1/ Demographic model, op. cit., p. 299.

the value of this type of refinement is likely to be much greater. The fourth approach is unique to SOM. This involves the costing of 'indirect resources' such as those for administration and libraries. Here the basis of costing is the 'unit', which could be the administration of a school, or a library. The total personnel, running costs, equipment and space for each unit is calculated separately. The number of 'units' of each type required is based on the number of pupils (or teachers) required to justify the provision of the unit. This will be dealt with in more detail in the section dealing with SOM.

Capital costs. The Norwegian model does not incorporate estimates of capital costs. For the problem to which the model was addressed in the cited reference this may be acceptable, 1/ but in most applications the capital costs involved in each assumption explored will be of importance. ESM and the demographic model both calculate the number of additional places required because of enrolment increases, and the number of places required to replace unsatisfactory accommodation. They differ in the way they break down total capital costs. ESM uses separate values, per pupil place, for site purchase, construction of teaching and common areas, laboratories and workshops, furniture and equipment. The demographic model differentiates between different types of classrooms to be built and attaches to each type of classroom an average building cost per classroom. It then uses estimates of the proportion of each type of classroom to be built, in order to calculate total capital costs. Choice between the two approaches would depend on the extent to which data was broken down by level of education and geographical area. The breakdown of the system would also need to incorporate the element of size of school as it has been shown that smaller schools have higher costs per pupil place than larger schools. 2/ The ESM approach does, however, present formidable data problems in a model which claims to be suitable for application in situations where data is difficult to obtain. 3/

ESM and SOM share a facility for calculating space requirements in the situation where excess capacity exists at some levels or in some areas, at the same time as there is a shortage in other areas or levels. The SOM approach is to divide educational institutions into 'blocks' on the basis of area or type of education offered. It is assumed that investments can be shared within 'blocks' but not between 'blocks'. Thus, if 'blocks' were defined in terms of area, it might be possible to use excess capacity in a primary school to overcome a shortage in a secondary school nearby. The appropriateness of this action would be dependent on factors such as the distance between schools and matching of the types of space in surplus and required. The model could only give a preliminary indication of the possibilities. Further detailed analysis would be necessary to indicate whether the proposed sharing of space was feasible.

1/ See, IIEP, Educational cost analysis in action - case studies for planners, Vol. II, pp. 124-125.

2/ Maureen Woodhall, "The use of cost analysis to improve the efficiency of school building in England and Wales" in IIEP, Educational cost analysis in action - case studies for planners, Vol. III, p. 159.

3/ It should be pointed out that the breakdown listed is only indicative of the possibilities. The model can accept either a smaller or larger number of components. Use of a smaller number of components would however lessen the advantages of the ESM approach.

The approach to estimating space requirements and capital costs is more detailed in SOM than in any of the other models. The room area for each type of space is first calculated using a linear function. AA + BB x class size = room area, where AA and BB are area coefficients. It is thus possible to take into account both area standards for each type of room and, if required, the class size. The number of rooms required takes into account not only the possible number of hours a room can be utilized during a week, but also the average utilization time for that type of room. The total area required is then calculated by multiplying the number of rooms required, by the average room area. Surprisingly, SOM does not incorporate any loading for replacement of unsuitable rooms. This would seem to be a serious omission as such replacement is a cost of any educational system.

5. Features of SOM - a simulation model of the educational system

The major features of the SOM model have been outlined in the previous section, along with those of the other three models. It is proposed here to look more carefully at some features of this model, with the purpose of assessing its possible application to the Victoria Education Department system.

The model is made up of four sub-models:

1. The flow sub-model which calculates pupil flows through the system and incorporates a very useful segment which takes into account the possibility of education units which restrict entry. The model distributes those unable to obtain entry to the restricted units to other units or to school leavers.

2. The resource sub-model which differentiates between direct resources - those directly generated by the teaching function - and indirect resources - those resulting from various auxiliary functions, such as administration and provision of libraries. This sub-model will be dealt with in more detail below.

3. The teacher-supply sub-model incorporates the factility to use the number of different values for policy variables or parameters in the one run of the model, thus enabling the user to explore the teacher supply consequences of a range of assumptions. This would prove particularly important in long-term planning when labour market forces are far less predictable than they are in the shorter term.

4. The teacher comparison sub-model. This calculates the imbalances between supply, as indicated in the supply sub-model, and demand, as calculated for the resource sub-model. The model then considers adjustments possible on both supply and demand.

The resource sub-model of SOM distinguishes between direct and indirect resource requirements which have already been defined. The calculations of direct resources are of four types: (i) physical requirements (teachers, space and equipment); (ii) physical investments (space, equipment); (iii) teacher salaries and other current costs; (iv) capital costs corresponding to the calculated physical investments. 1/

Any or all of these calculations can be carried out, dependent on the purpose of the study. The basic element in calculation of resource requirements is the 'activity'. For the primary school the entire curriculum could be the 'activity', while for secondary schools it could be a group of subjects such as languages. If it is desired to study the upper secondary school in more detail, individual

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1/ SOM, op. cit., p. 50.

subjects can be regarded as the 'activity'. For each 'activity' the following input is required to calculate teacher, space and equipment requirements:

- weekly hours or periods
- class size
- proportion of students taking the 'activity'
- utilization ratio of equipment used in the activity (only major items of equipment are included)
- current cost of operating the equipment
- ratio of the required teaching hours handled by teachers of each category involved in teaching the 'activity'
- weekly teaching obligations
- yearly teacher salary

It is clear that the date requirements are considerable, particularly when estimating the resource requirements for a large number of 'activities', as would be necessary when dealing with secondary education. On the other hand, it is just at this level that the need for detailed information on resources is greatest. Because many resources are usable only in a limited range of 'activities' a model which provides estimates of state-wide resource needs is of limited value and is often misleading. Base data is collected within the Victoria system to provide values for the model, but considerable work is involved in putting this in the form required by the model. The most fruitful approach would appear to be to begin with larger units of 'activities' and to gradually break these down as the data is analysed and the need is seen for information on a particular 'activity'. Care must be taken to see that the model's output is not broken down to such an extent that it becomes too voluminous to analyse adequately.

While the detailed approach adopted in SOM has the advantage of providing decision-makers with a detailed analysis of future resource needs which can readily be translated into policy decisions on teacher training and recruitment or space investments, it has a basic weakness. This is the implicit assumption that the curriculum will remain constant over the planning period, that pupil choice of activities will remain constant and that various teacher characteristics will remain constant. These assumptions become more unrealistic as the time span of the planning period becomes greater. SOM is seen as a long-term (10-20 years) planning tool. Yet, when used at the level of detail possible, its assumptions of constancy make it more relevant over a span of three to five years. Even in the short term, while curriculum changes can be anticipated, pupil choice of 'activities' and teacher characteristics (e.g. weekly teaching obligations) can change rapidly.

To partially overcome this weakness three strategies are possible. When SOM is used as a long-term planning tool, the level of aggregation should be such as to avoid the appearance of excessive precision. It is misleading to suggest that we can estimate the number of Form 6 chemistry teachers of Type A on average salary $X, needed in 1985 or 1995. In the long term, aggregation must be much broader than is appropriate in the short term. Secondly, the use of SOM should not be regarded as a 'once for all' exercise. The model should be applied and a range of values provided, on a regular basis, with the incorporation of new knowledge as to curriculum changes, pupil choices and teacher characteristics. The third strategy involves making full use of the simulation facility when using SOM. By simulating a range of curriculum possibilities, pupil choices and teacher characteristics, it is possible to provide estimates of resource requirements within a band of possibilities. This also involves anticipating changes and building these changes into the simulation. Armitage, in discussing SOM, warns against restricting the number of alternatives explored in a simulation model. "... 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."1/

A related criticism of SOM is that its assumption of a constant structure, consisting of 'boxes' through which pupils flow, is unlikely to be realistic. Similar strategies are necessary to overcome this problem, in particular the anticipation of likely structural changes and their incorporation in the model.

The indirect resources section of the resource sub-model has been briefly dealt with in the section dealing with the four models. It remains only to outline briefly the data required and the output of the sub-model.

For each 'unit' of a particular type of indirect resource (e.g. a library), it is necessary to provide the following input: (i) the area required; (ii) the annual cost, which includes salaries, maintenance costs and costs of non-durable materials; (iii) the capital cost of a new installation. The programme then calculates the total number of installations (based on the pupil numbers required for such an installation) and corresponding space requirements and current costs. By comparing the requirements with the base stock, required investments and capital costs can be calculated.

This approach seems quite valid, in so far as many indirect resources are thought of in this way. A library, for example, is provided for each school of a given size. It would be necessary, however, to subdivide libraries into categories dependent on the size of school for which it is provided. The main question raised by this approach is - What does the model do? The information provided from outside the model is so detailed as to require only some simple arithmetic to provide an answer. This section of the resource sub-model appears only to serve the purpose of completing the picture of resource needs.

A generalized model like SOM has characteristics very similar to a ready-made suit. In choosing either, one should consider not only the quality of the product but also the fit. SOM is a good quality product of its type and represents the most sophisticated generalized model which is readily available. In terms of fit there are a few places where alterations are necessary if it is to fit the Victoria system satisfactorily. In summary, these shortcomings are:

- the cumbersome treatment of migration and transfers from the private sector in the student flow model
- no allowance for teachers on leave
- no allowance for replacement of unsuitable accommodation.

Any alterations can only be carried out by someone conversant with the construction of the model and, with a model and computer programme as complex as SOM, such familiarity cannot be expected until planners and programmers have worked with the model for some time. However, none of these shortcomings is crucial; migration can be incorporated, even though the method is cumbersome; allowances for teachers on leave and replacement of unsuitable accommodation can be calculated manually and added to the estimates. The alternative of a 'tailor-made' model is attractive but expensive to

1/ P. Armitage, "A critical evaluation of SOM and comments on future developments with educational models", in A critical evaluation of SOM, op. cit., p. 125.

develop. In addition, the time taken to make such a model operational is likely to be much greater than that required to bring SOM to this stage.

Any decision on implementation of SOM should also be based on a clear understanding of the limitations of all such models. SOM looks at the education system in isolation from its political, social and cultural background. Some aspects of these influential factors are implicitly incorporated in exogenous variables. Others have to be taken into account by planners and decision-makers when proposing alternatives to be explored in the model and when assessing the resource needs indicated in results. SOM is not a decision model and can only indicate the effects of alternatives proposed by decision-makers. Related to the previous points is the fact that SOM does not take into account qualitative considerations, except to the extent that these are embedded in quantitative alternatives.

What then can SOM do to improve long-term planning in Victoria? It can aid decision-makers by displaying the effects of alternative policy decisions. It can provide not just one deterministic view of the future but can show the range of possibilities for alternative futures through its simulation facility. Secondly, it is designed to operate at both the whole system level of aggregation and also to allow breakdown into smaller units. In Victoria, such breakdown is important at the regional level if regional directorates are to develop in the decision-making area. SOM can also provide estimates of the resource and cost needs of particular programmes. Programmes could be defined at one level of aggregation in terms of the existing departmental divisions (primary, secondary, special services, etc.). With greater breakdown of data the programme could be the teaching of languages in secondary schools or the teaching of a particular subject at secondary level. SOM also have provision for breakdown of data according to the socio-economic status of pupils.

The third major benefit from the implementation of SOM is the indirect influence on data collection and planning within the department. As has been pointed out previously, the data needs of SOM are substantial, but not beyond the resources of the department. The data needs of SOM would provide a framework for data collection and analysis, out of which should develop an integrated information system. The experience of Toronto University is indicative of the possible side effects of the implementation of a cost model. 1/ Introduction of the CAMPUS model led to the need for an integrated information system in order to provide the data required by the model. "Organizational considerations about the means by which the model could be integrated into the budgetary process of the university led to the incorporation of a planning, programming and budgeting system into CAMPUS. Most recently, a fourth component has been added, a master planning system which uses the model as the basic ingredient of the Institution's long-range physical plans."2/

There is every reason to believe that similar developments would flow from the introduction of a model such as SOM in Victoria.

1/ J. Levine, R. Judy, R. Wilson, "Comprehensive analytical methods for planning in university systems - planning a new health sciences education complex", in IIEP, Educational cost analysis in action - case studies for planners, Vol. III (IIEP, Paris, 1972)

2/ Ibid., p. 184.

II. A RESOURCE-COST MODEL OF THE PRIMARY SCHOOL SYSTEM OF THE EDUCATION DEPARTMENT, VICTORIA

1. Purposes of the model

This model is designed as a short-term planning tool, providing estimates of the resource requirements and corresponding costs for alternative resource allocation decisions over a future period of three to five years. It aims to provide answers to the following types of question:

- What will be the extra costs of enrolment changes in the next five years?
- What will be the results, in terms of resource allocation and cost, of population movements, for example, to growth areas being sponsored by the Government?
- What are the likely resource needs and corresponding costs of education in each of the Regional Directorates?
- What would be the extra resource needs if the average class size was reduced from A to B?
- What would be the increased costs of (a specific) change in the number of non-professional support staff?

Such questions are only examples of the type of information the model should be able to provide.

The model identifies three types of variables.

1. Policy variables which are regarded as being within the control of decision-makers during the three to five year period. It is assumed that four factors are controllable: (a) average class size;1/ (b) the staffing schedule which determines the number of staff to be appointed to a school on the basis of the number of pupils in attendance;1/ (c) the number of specialist teachers, with the constraint that these teachers require training; (d) changes in the number of non-teaching ancillary staff, such as typists, teaching aides, nurses. Other factors which could be regarded as policy variables in the long term, such as the distribution of pupils by size of school and the distribution of schools by the number of grades per school, are regarded as non-controllable, in the short term. Salaries are not regarded as policy variables because they are determined by an autonomous wage fixing authority. To the extent that average salaries are dependent on recruitment policies, decision-makers have some control over this factor, but in the short term it is unlikely to be sensitive to policy decisions.

2. Exogenous variables which are estimated outside the model. The major exogenous variables are enrolments, average salary and average cost figures and proportion of teachers on leave.

3. Endogenous variables which are produced by the operation of the model. Examples of this type of variable are the number of classes and class teachers and other teacher categories, the number of schools and the number of classrooms.

1/ (a) and (b) do not necessarily represent the same control factors. An increase in the number of class teachers would reduce the average class size, but a decision to increase the number of scheduled excess teachers, or the number of administrators would not. Specialist teachers are also not included in the staffing schedule.

The applicability of cost-resource models to the planning requirements of the Education Department of Victoria, Australia

The following description of the proposed model begins with a brief outline of the variables included in the model and the level of aggregation of each. This is followed by a description and evaluation of the methods of estimating resource and expenditure needs. Reference to the diagram will clarify the variable breakdown.

2. Variables used in the model

1. The model in its complete form is designed to differentiate between five sizes of school and one type of primary school with post-primary classes. The six categories are:

		Size
1-teacher grade 3 schools	(up to 29 pupils)	1
2-teacher grade 3 schools	(30 to 64 pupils)	2
Grade 2 schools	(65 to 224 pupils)	3
Grade 1 schools	(225 to 499 pupils)	4
Special grade schools	(500+ pupils)	5
Primary schools with post-primary classes		6

In addition, variables are broken down by educational region. There are 11 educational regions which cover the whole State.

2. Personnel resource requirements are divided into six major categories. There are four categories of 'active teachers':

- class teachers
- administrators
- specialist teachers
- excess teachers

This last category requires some explanation. In the future it is planned to add teachers to the staff of primary schools who will not have direct responsibility for a class. They will be used within the school to relieve class teachers for preparation and act as specialists in areas of competence. These teachers will be incorporated in the staffing schedule, but their appointment to a school will not involve the provision of an additional room.

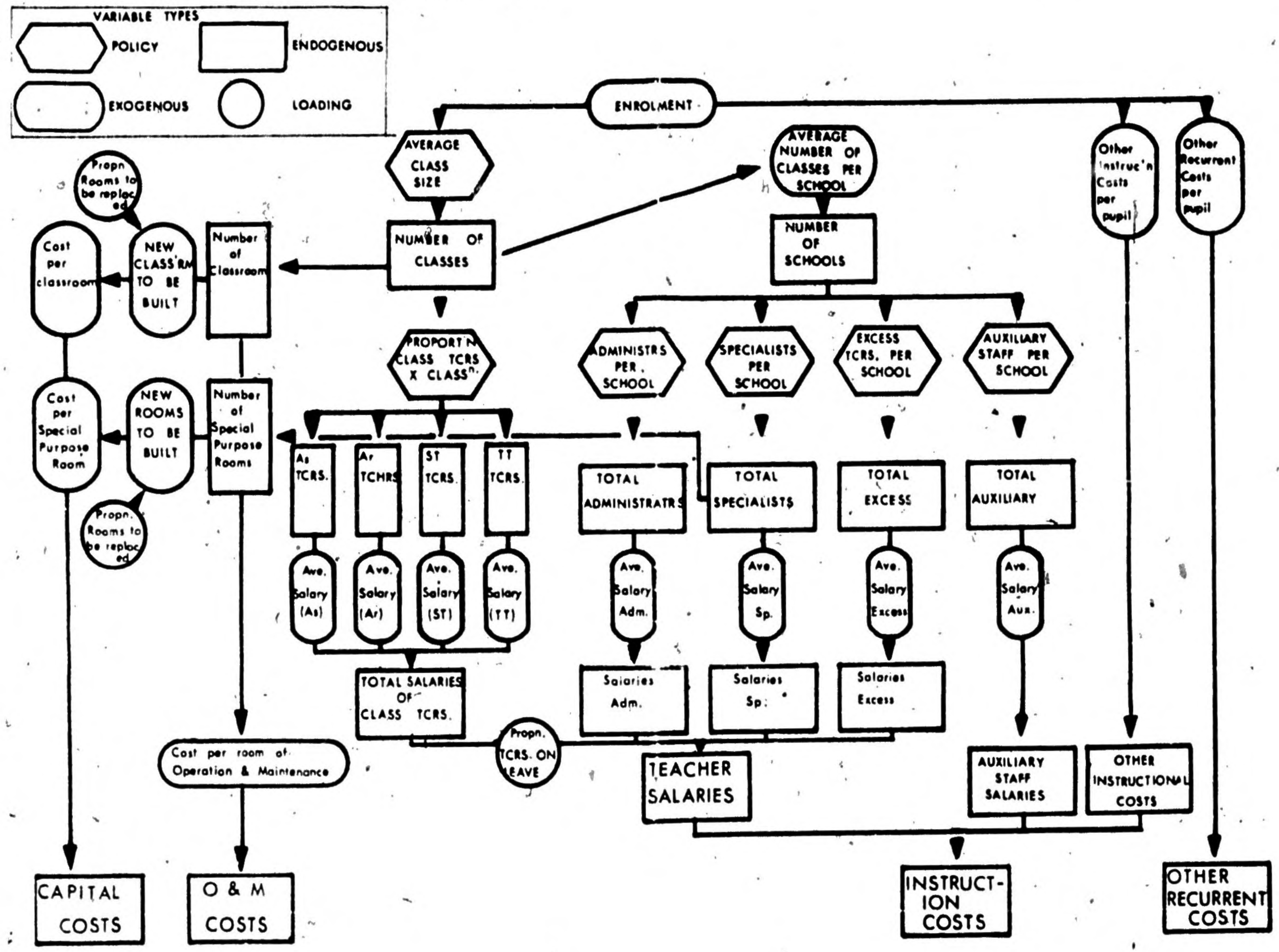
In addition, there is one category of non-teaching auxiliary staff - clerical assistants, teaching aides, for example. Teachers on long-term leave for whom replacements have been provided represent the sixth personnel category. Costs of emergency teachers to replace teachers on short-term leave have not been incorporated, except under the heading of "other instructional costs".

3. Class teachers are further broken down into four categories according to classification. The categories in increasing order of experience and salary are:

- temporary teachers (TT)1/
- assistants (AS)
- assistants with responsibility (AR)
- senior teachers (ST)

1/ This category represents teachers who have not received permanent appointment to the teaching service. They are, in general, fully qualified teachers. They differ from the other categories in that they do not have security of tenure and can be employed on a part-time basis. Their salary scale is that of the assistant class. It was found when analysing teacher salary data that average salaries of temporary teachers were significantly lower than those of permanently employed teachers. While this category of teacher does not represent a very large proportion of total teachers in primary schools, incorporation of the category should improve the predictive ability of the model. As this is the major class teacher category in which part-time teachers are employed, temporary teacher numbers are expressed in effective full-time (EFT) teacher terms in the model.

VARIABLE RELATIONSHIPS IN VICTORIAN MODEL



A resource cost-model of the primary school system of the Education Department, Victoria

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4. Each of the above personnel categories is associated with an average salary figure for the calculation of total teachers' salaries.

5. Other instructional costs include all direct instructional expenditure, other than salaries. The two items together make up Total instructional costs.

6. The remaining items of recurrent expenditure are:

- cost of operation and maintenance
- other recurrent costs.

The latter item includes central and regional administration, superannuation payments, payroll tax and debt charges.

7. Capital expenditure is broken into expenditure on general classrooms and expenditure on specialist rooms. The cost per teaching space incorporates all items of expenditure on the building and grounds. Teaching spaces and the corresponding cost per space are classified by size of school and region in order to make some allowance for differences in costs associated with these factors.

3. Description of the model

(i) Calculation of salary costs

The model receives as input estimates of pupil numbers for each year of the planning period. The number of class teachers is assumed to depend on enrolments and average class size. 1/ As average class size is assumed to differ between schools of different sizes and in different regions, pupil and teacher numbers are broken down according to these categories. The number of class teachers required is subdivided into four classifications of teachers according to the proportion in each classification. The proportion of teachers in each classification is regarded as a policy variable because changes to the staffing schedule can change these proportions. Full implementation of a changed staffing schedule generally takes a number of years, but could be achieved within the three to five year planning period for which the model is designed. Each teacher classification is associated with an average salary figure from which it is possible to estimate total salaries of class teachers. It can be seen that by altering the two policy variables it is possible to demonstrate to decision-makers the effects of these changes on demand for class teachers and the cost of their salaries. As enrolment estimates must be regarded as being accurate only within a range of upper and lower limits, it is also possible to indicate the teacher demand and teacher cost range which can be expected, by running the model with upper, medium and lower enrolment projection assumptions.

Use of average salary figures, by size/type of school and teacher classification, does not necessarily take into account changes in the structure of the teaching force over time. As Chesswas points out: "There are two particularly influential factors of change to be watched: (a) the proportions of the total teaching force who belong to each category, and (b) the proportions of each category on the various points of the salary scale."2/

1/ Use of 'class size' or the term 'class' does not imply the assumption that pupils will necessarily be taught by one teacher in a separate class. Other forms of organization such as team teaching or open classrooms require a number of teachers and a group of pupils. Division of teachers into pupil numbers will give the equivalent of a 'class'.

2/ J. Chesswas, "Factors influencing change in teachers' basic salaries" in IIEP, Educational cost analysis in action: case studies for planners, Vol. I, p. 62

The present model assumes that the first of these proportions can be influenced by policy decisions over the plan period. Changes in resignation pattern, age distribution and promotion conditions will very likely lead to changes in (b), and possibly in both factors, even without policy changes. The method used by Ta Ngoc C. 1/ to partially overcome this problem was briefly outlined in the previous section. Another approach is through the introduction of a teacher supply model. The present model indicates only the demand for teachers, size of school in which they will be required and the regions in which they will be located. Average salary of class teachers is likely to be as much dependent on the supply of teachers as on the demand. The teacher supply model would take as input the number of teachers demanded, by size of school and region. It would compare this with the present stock of teachers, corrected for resignations, deaths, retirements, and promotion, plus movements to administrative, specialist teacher, study leave or long-term leave positions. The difference between demand and supply would be made up of new entrants from colleges and employment of persons from outside the teaching service. The supply model could thus provide a breakdown of teachers by average salary distribution which would take into account the changes in average salary resulting from changes in resignation pattern, age distribution and the effects of promotion. This average salary figure could then be input to the teacher demand model at the average salary point. 2/

The equations expressing the above relationships are set out below, without subscripts indicating the breakdown by size of school and region. They are expressed both in English and in symbolic form. The fully subscripted equations, together with a list of variable symbols, will be found in the Appendix.

Equations for calculation of class teacher salaries:

(1) $C = E/a$

The number of classes (C), and hence the number of class teachers, 3/ is equal to enrolment (E) divided by the average class size (a).

(2) $CS = C\ (pAS.\ as + pAR.\ ar + pST.\ st + pTT.\ tt)$

Total class teacher salaries (CS) equals the number of class teachers (C), multiplied by the proportion of each type of teacher (e.g. pAS), multiplied by the average salary of each type of teacher (e.g. as), i.e. the weighted average of class teacher salaries.

For the calculation of professional support staff (administrators, specialist teachers and excess teachers) and non-teaching auxiliary staff such as clerical staff and teaching aides, a different approach is adopted. The number of schools is estimated from the number of classes, divided by the weighted average number of classes per school. Schools are subdivided by size and region. The numbers of professional and non-professional support staff per school are regarded as policy variables. The number of administrators and excess teachers per school can be changed by alterations to the staffing

1/ Demographic model, op. cit., pp. 298-299.

2/ An assumption implicit in this approach is that methods of obtaining supply of teachers will remain constant over the plan period. I am indebted to Ta Ngoc Châu for this point.

3/ In Victoria, primary teachers are responsible for a class for the full week. Modification would be necessary to apply the model to secondary education where teachers work a set number of periods, but are expected to be present at the school for the whole week.

schedule. The number of specialist teachers per school is also within the control of decision-makers, but supply factors and the availability of space are constraints in the short term. In a similar way, the number of non-teaching auxiliary staff is also within the control of decision-makers. The constraints on decision-makers here will vary, according to the type of auxiliary staff concerned. Provision of teaching aides, for example, involves, at present, little or no training and very little space - the constraint is mainly a financial one. Appointment of school nurses, on the other hand, would involve the provision of space and equipment and possibly transport.

While the number of each type of support staff per school is regarded as a policy variable, it is not suggested that the policy is formed only within the context of resource and cost considerations. Such decisions are a complex of educational, social, political and resource allocation decisions. The only contribution made by the model is to illustrate the direct resource and cost consequences of alternative decisions on the level and type of support staff. Even in this limited area, the model indicates only the consequences in terms of numbers and salary and, in the case of specialist teachers, the additional costs of operation and maintenance and capital expenditure. As was indicated in the example of increased numbers of school nurses, these appointments may have additional cost implications through the provision of space, equipment or transport. Thus the model does not replace detailed costing and makes only a limited contribution to resource allocation decisions.

Having established the numbers of support staff required, these are multiplied by average salary figures to obtain the total salary bill for each category of support staff. In the case of administrators, average salary is assumed to be related to school size, so different average salary figures are used for each size of school. In the case of the other three categories of support staff, salaries are assumed to be independent of school size 1/ and a single average salary figure is used for each category. All average salary figures, including those for class teachers are assumed to be independent of location of the school, so no breakdown of average salary by region is attempted. Each of the above assumptions would need to be tested by analysis of salary differences in terms of size of school and region. The results of such analysis could be incorporated in the model at a later date. The previous discussion on the use of a teacher supply sub-model to provide average salary figures applies also to average salaries of professional support staff.

Teachers on long-term paid leave are incorporated in the model by introducing a weighting coefficient dependent on the proportion of total teachers on leave.

Equations for calculation of support staff salaries:

(3) $S = C/_b$

The number of schools (S) is equal to the number of classes (C) divided by the weighted average number of classes per school (b).

(4) (a) $DS = S.\ d.\ ds$

Total salaries of administrators (DS) is equal to the number of schools (S) by the number of administrators per school (d) by the average salary of administrators (ds).

(b) $FS = S.\ f.\ fs$ (Total salaries of specialist teachers).

1/ The numbers of each category of support staff per school is, of course, related to the size of school. This factor is taken into account in the calculations of the numbers of support staff per school.

(c) GS = S. g. gs (Total salaries of excess teachers)

(5) TS = (CS + DS + FS + GS) (1 + q)

Total teacher salaries (TS) are equal to the sum of the salaries of class teachers (CS), administrators (DS), specialist teachers (FS) and excess teachers (GS), multiplied by a loading factor to allow for the proportion of teachers on leave (1 + q).

(6) HS = S. h. hs

Total salaries of non-teaching auxiliary staff (HS) are equal to the number of schools (S), multiplied by the number of auxiliary staff per school (h), by the average salary of auxiliary staff (hs).

(ii) Calculation of other instructional costs

This item is assumed to vary in proportion to the number of pupils in the system. These items represent only six to seven per cent of total instructional costs, the only ~~significant item~~ being cost of pupil transport.

(7) K = E. k

Other instructional costs are equal to enrolment (E), multiplied by other instructional costs per pupil (k).

(8) I = TS + HS + K

Total instructional costs are equal to the sum of teachers salaries (TS), auxiliary staff salaries (HS) and other instructional costs (K).

(iii) Operation and maintenance

The unit used for calculation of this item is the teaching space, defined as general classrooms and specialist rooms. Adoption of this unit rather than the pupil is based on the assumption that costs for operation and maintenance will vary more directly with the number of classrooms than with the number of pupils.1/ A very small school of 15 pupils, for example, requires a classroom of much the same size as does a class of 30 pupils. If operation and maintenance costs are based on pupil numbers, the small school would be regarded as only half as expensive to operate and maintain. Apart from possible differences in wear and tear, there appears no valid reason for accepting this. It could be argued that circulation and office space requirements are greater per pupil in large schools and that this justifies the use of per pupil figures rather than 'per teaching space' figures which must incorporate ancillary spaces in the cost per classroom. Based on United Kingdom experience, Maureen Woodhall wrote: "Small schools typically require a larger area per pupil than large schools, because certain minimum administrative, assembly and circulation areas are required irrespective of the number of pupils."2/

Although based on a very small sample of schools, this statement would appear reasonable and to provide some justification for the approach adopted in the model. It is, at best, a rough

1/ The 'square metre' would be a better unit, but this data is not available at present.

2/ M. Woodhall, op. cit., p. 159.
See also OECD, Development and economy in educational building (Paris, OECD, 1968), par. 70, p. 41, which makes a similar point in relation to Spanish schools.

approximation to the factors influencing building operation and maintenance. Further analysis is needed and new data is required if a suitable approach to this item is to be found.

(9) M = m (CR + FR)

Total maintenance and operation costs are equal to the sum of classrooms (CR) and specialist rooms (FR), multiplied by the cost of maintenance per teaching space (m).

(iv) Other recurrent costs

Costs of central and regional administration and fixed charges are included in this item. These costs are expressed per pupil and total costs estimated from this. ~~Here again, further work is needed on~~ the relation between enrolment increase and cost of these items. It seems likely that administration does not increase in proportion to enrolment increase. Fixed costs include three major items, each of which is likely to be dependent on different factors. Superannuation payments are related to the number of teachers in some previous period in a quite complicated way. These are payments made by the Victoria Government as its contribution to the pension of retired teachers. Edding 1/ suggests that this amount should be added to salaries of teachers but this does not help when the aim is to estimate future costs. The projected amount of superannuation payments would have to be separately estimated using data on age, life expectancy and average salary. Payroll tax, as a percentage of total salaries, is directly related to teacher numbers and salaries. Debt charges, which is by far the largest item, is related to past capital expenditure. Each element in the cost item could be separately estimated using the unit appropriate to it. Such a breakdown could fairly readily be incorporated in the model if it was considered necessary. For short-term planning with the major aim of assessing the cost and resource consequences of alternative policy decisions, detailed analysis of this item is probably not justified.

Calculation of other recurrent costs:

(10) R = E. r

Other recurrent costs (R) are equal to the product of enrolment (E) and other recurrent costs per pupil (r).

(v) Capital costs

These are calculated on the basis of the estimated number of classrooms and special purpose rooms required, compared with the present stock of rooms. The number of new rooms to be built is the difference between present stock and required rooms, plus a loading for replacement of existing rooms. These rooms are classified by size of school and region as are the corresponding cost per teaching space figures. Classification by size of school will make some allowance for differences between schools in the amount of space required for circulation, office and amenities space. The breakdown by region will provide some information on where classrooms are needed and some basis for exploration of the possibilities of alternative uses for excess capacity. The number of classrooms and special purpose rooms needed are multiplied by separate cost per classroom and cost per special purpose room to give a total capital expenditure figure.

1/ Friedrich Edding, Methods of analysing educational outlay (Paris, Unesco, 1966), pp. 17-18.

Strictly speaking, the capital expenditure figure arrived at does not relate to the same time period as recurrent expenditure. Resource needs, and hence costs, relate to the situation at the beginning of each school year. As additional space would need to be available by then, part at least of expenditure would be made in the previous financial year, while planning for the new facilities would need to begin 18 to 24 months before the year for which the space was required. The importance of this time factor would depend on the purpose for which the model was being used. If the purpose was to aid in budget planning, this time difference would be important; if the purpose was to explore the consequences of alternative resource allocations, it would be less important. There could be advantages in developing a separate capital expenditure model which took its input from the resource model estimates two to three years in the future.

4. The problems involved in widening the model to incorporate other levels of education

If the model was to be widened to incorporate secondary-level education, a number of additional factors would need to be taken into account. In summary these factors are:

- the different cost structures dependent on form level, sex and subject
- the range of teacher qualifications
- the range of teaching spaces to be provided
- the need to incorporate a room utilization factor and a pupil-station (desk or chair) utilization factor.

In addition, a greater breakdown of resource categories would be necessary. For example, instead of a single class teacher figure, teachers need to be classified according to the activity they teach and the form levels at which they are teaching. Finally, there is the matter of timing which becomes important when considering secondary education in Victoria. The model is designed to explain the position at the beginning of each school year, in February. Enrolment projections are now made at the census date (August). In the primary school no significant error is likely to be introduced by this time difference, but at the secondary level we can expect 5,000 to 8,000 fewer pupils in August. This loss of pupils is particularly pronounced in the upper forms of the secondary school. The effect on resource needs is, however, likely to be marginal as the loss represents only about two to three per cent of secondary enrolments, spread over the whole State. But note that the percentage at the higher levels is well in excess of this. Importance is dependent on whether loss of pupils results in lower resource requirements - for example, would classes be amalgamated?

5. The problems involved in widening the model to provide a more complete model of the Victoria education system

Two additional sub-models could be incorporated in the short term. The present student enrolment model projects enrolments for a period of ten years. Enrolments are broken down by age, form level and sex. If this model were incorporated it would need to be developed in two ways. A breakdown by region would be necessary. This development is already planned and the data is available. In addition, it would be valuable to provide a range of projected enrolments based on low, medium and high population increase assumptions. The model could then translate these enrolment estimates into resource requirements based on different enrolment assumptions.

The teacher supply area is also well developed, with estimates being provided for the next ten years. The value of incorporating this sub-model in order to estimate future average salary figures has already been commented upon. The basic structure of such a sub-model is already in existence and the data is available.

In the long term two other sub-models would be extremely useful. The first of these is a sub-model of the private education system. This system, which provides education for 25 per cent of all pupils in the State, impinges on the State system in a number of ways. Changes in policy by this sector and changes in government policy in relation to the private sector influence the government education sector. An attempt should also be made to incorporate relationships between economic and social factors, on the one hand, and the Victoria Government education system on the other. Such a model could be used to explore such factors as the influence of economic factors on retention rates in the higher forms of secondary schools, and the influence of the socio-economic status of parents on retention rates in secondary schools.

It is worth noting here the warning issued by Alper 1/ as to the dangers inherent in combining sub-models into a single system. He stresses the twin concepts of 'controllability' and 'observability' and comments: "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 output. 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 the overall system. Because sub-systems 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 sub-systems."

6. The model in use

An attempt was made to verify the model by using 1974 data in a limited pilot run. Taking actual 1974 enrolments in each region and size of school, the equations of the model were manually solved to estimate total salaries of class teachers, administrators and specialist teachers. The results of such a limited trial run can do no more than give a broad indication of how the model might perform in a real planning situation. It did however point out a number of factors which were not given sufficient consideration in the original formulation of the model. In addition, a number of improvements to the model were suggested by the trial run. 2/

The equation which estimates the number of classes and hence class teachers gave good results for the smaller schools. The number of classes in special class schools (enrolment more

1/ P. Alper, "SOM and control theory" in A critical examination of SOM, op. cit., pp. 90-91.

2/ It is recognized that the fairly detailed considerations dealt with in this section could prove confusing to readers unfamiliar with the Victoria system. It is included because it illustrates the complexity which is no doubt part of every education system and which is so often overlooked in model construction.

than 500 pupils) was, however, underestimated by approximately 2.5 per cent. One factor contributing to this would be the wide spread of enrolments within the size category. Schools range in size from 500 to 1,000 pupils and it seems likely that average class size will differ within this wide range. One solution would be to use a larger number of size categories, on the assumption that each category would represent a more homogeneous group. This would be a satisfactory solution, provided the size categories co ld be combined to make groupings corresponding with the department's size groupings which are used or staffing purposes. If this is not achieved, the practical application of the model's results is unlikely. Another approach which was tried was to compute the regression function of the relationship between the number of classes and enrolments in special class schools. This was done for a sample of special class schools and the following regression function was computed:

$$C = 0.03\,E - 0.004$$

where C = number of classes
E = enrolment.

The standard error of estimate was 0.98.

Use of this equation would enable the calculation of confidence bands for the predicted values of the number of classes. Although the predicted number of classes for each region are identical by the two methods, the estimates of confidence bands possible when the regression function is used would make this approach preferable. In future developments of the model both suggested approaches - the use of smaller size groupings and regression function - will be adopted.

The second major improvement suggested by the trial run was in the area of teacher salaries. Additional data has recently become available which gives the number of teachers in each salary subdivision. In the lowest (assistant) class this represents 14 salary subdivisions which could be used in preference to the weighted average salary for the class. Such a breakdown would be impractical to operate manually but would be feasible for computer operation. It is however debatable whether such a detailed breakdown is warranted unless a teacher supply model is used to provide data on the future sources, ages and retirement characteristics of teachers. Without the teacher supply model it would be necessary to proceed on the assumption that the distribution of teachers over the 14 subdivisions of the assistant class would remain constant over the planning period - a far more tenuous assumption than the present one that the distribution of teachers between the four major classification groups will remain constant for this time. The situation where changes within major teacher categories take place over time is just the one the teacher supply model would be designed to meet.

Another factor which complicates the calculation of total salaries of class teachers is the payments of allowances to certain categories of teachers. The most important of these are responsibility allowances (currently £1,000) and head teacher allowances (currently £395 and £525) paid to teachers in the assistant class. The present form of the model has assistants with responsibility as a separate teacher category with the responsibility allowance incorporated in average salary. The simplest approach to the incorporation of allowances for head teachers of small schools is that adopted in the model at present, where these allowances are incorporated in average salaries of AS and AR teachers. It seems likely that this approach will overstate teacher salary costs of the two largest sizes of school categories and understate these costs in the smaller schools. This occurs because head teacher allowances, which are costs of running small schools, are incorporated in the average salaries of all teachers in the assistant class, whether they teach in small schools or large schools. A better approach would be to attach head teacher allowances to schools of the appropriate size category.

What this means in practice is that the category administrators would incorporate both full-time administrators and part-time administrators. For special class and class 1 schools, total administrators would include principals and vice-principals without responsibility for class teaching. Average salary would be the full salary for these persons. For the remaining school size categories, total administrators would include all teachers receiving head teacher allowances, but the average 'salary' would represent only the allowance. The base salary would be calculated in the AS and AR class teacher categories. This approach would have two advantages: (i) the true cost of administering each size of school could be isolated; (ii) administration costs in small schools would not be incorporated in the costs of larger schools.

Some consideration has also been given to ways the section of the model dealing with classroom needs could be improved. Data availability remains a problem, but data on the present stock, on a classroom area per pupil basis, is available. This data could be tabulated by size of school and region. For new and replacement schools the model needs to incorporate norms of classroom area per pupil, plus a loading for other non-teaching spaces such as circulation, staff rooms, offices. These norms would need to be established on a size of school basis. Specialist teaching space provision could probably best be incorporated on the basis of area norms based on size of school. It also appears that insufficient attention has been given to the costs of furniture, equipment and land costs. At present these are assumed to be incorporated in total building costs, but if, as was suggested earlier, a separate capital expenditure model was developed, it would be important to incorporate these items separately. This is necessary because of the time differences between costs incurred for land, buildings, furniture and equipment.

Two other shortcomings of the present form of the model have become evident from efforts made to operate the model and assess its relevance to the planning needs of the department. Both concern its relation to departmental budgeting.

Although expenditure headings are those used for reporting education department expenditure and these are in turn based on expenditure categories used for treasury budget estimates, the model is not at present readily adaptable for budget planning. This is illustrated in the calculation of total teacher salaries. The model estimates the number of teachers and salary costs for all teachers working in the schools plus those who are on long-term leave. A number of other teachers who are part of the primary teaching strength but not in schools will be included under other instructional costs, although the model will give no estimate of their numbers. There are, in addition, primary teachers working in other programmes of the system who are nevertheless costed under the primary programme for budget purposes. This means that the model will underestimate total primary teacher salaries compared with budget estimates. This will limit the value of the model for budgeting purposes. The most satisfactory solution would be for budgeting to be undertaken on a programme basis rather than on the basis of the section of the teaching service to which the teacher belongs.

The second factor which limits the value of the model as a budget-planning tool is the timing of the basis of costs. Resources are calculated as at the beginning of the school year (February). The costs calculated by the model are thus for the calendar year while budgeting is based on the financial year which ends on 30 June. This problem is not insurmountable but would involve taking the final six months of one year and the first six months of the following year. A more difficult problem of timing cost estimates is that previously mentioned in relation to capital costs, some of which are incurred in the years preceding that in which the model estimates them. Both of these problems have implications beyond the limits of control of the model maker. Their solution would involve far-reaching policy changes on budgeting procedures. In its present form the model could operate only as a broad indicator for budget purposes. It could still operate effectively to illustrate the resource and cost implications of alternative policy decisions.

7. Criticisms of the Victoria model

Earlier sections have indicated some possible developments of the present model, but it must be judged now in terms of whether it achieves its present limited aims. It aims to provide information only on resources and costs; it deals only with the quantitative aspects of resource allocation decisions and takes no explicit heed of qualitative considerations; it does not provide an optimum solution to any resource allocation question; it is based on assumptions which have yet to be verified; it is, finally, specifically designed to answer the type of question which arises in short-term planning. Many of these limitations are common to the models reviewed in Section I of this paper, but work on the Victoria model raises four additional questions which will be briefly dealt with below. They will, inevitably, remain as questions - answers must wait on a full-scale application study of the model.

The first question is concerned with the value of constructing a model based on assumptions rather than on detailed analysis of the relationships between variables. This is of course a criticism which can be levelled at any simulation model, but one which confuses the mathematical model applicable when the system is relatively simple and its relationships well understood, and the simulation model which enables the user to explore the relationships and identify those which warrant detailed analysis, in a system which is both complex and changing. Cutt explains the features of simulation thus: "In essence, simulation relates to the structure of a system rather than to its formal relationships, serves to explore the consequences of a wide range of assumptions about that system structure, and may thus be seen as the beginning of theory rather than the application of a completed body of theory."1/

The attempt to construct a model which could operate as a short-term planning tool, highlights the question of the applicability of such a model to the problems of short-term planning. If use is made of the simulation facility, the model can provide a range of results to illustrate the effects of alternative resource allocation decisions. While this is valuable, it seems likely that decision-makers will require optimum solutions to many short-term planning questions. A development paralleling that of model application should therefore be the exploration of optimization techniques. There is, of course, no reason why both simulation and optimization should not be used on the same problem - simulation indicating the possibilities and optimization techniques providing a final answer.

1/ James Cutt, Programme budgeting and higher education (Canberra, Australian National University; 1972), Department of Accounting and Public Finance, Public Finance Monograph No. 1, p. 37.

With a number of generalized models available, the question of the value of a 'tailor made' model for the Victoria system is inevitably raised. The present model would be expensive to make operational and would remain much simpler than SOM, for example, until experience was gained in its use. Construction of the model has, however, highlighted the peculiarities of the Victoria system which can be incorporated in a model specific to the system. While all education systems have the same broad features, the detailed structure of each system is likely to be unique to that system. If a model is to go further than broad generalization in prediction and if model results are to be an integral part of planning the following characteristics would appear to be at least desirable. The model should:

(a) Reflect crucial features of the real system. The tendency is to add more and more detail to the model until its complexity approaches that of the system itself. Even if such a model can be operated, the difficulties of interpreting the output will limit its application. Isolation of the crucial features can be, in itself, a valuable side effect of model development. In analysing data on average class size, for example, it was found that while significant differences in class size exist between schools of each size, average class size does not appear to vary significantly between regions. This finding suggests that the model would have the same predictive power if average class size was calculated only for each size of school. In a system with decentralized staffing of schools, however, location of school could well be a crucial factor in class size.

(b) Be related to structures within which decision-makers operate. This means, for example, that resource categories for which the model provides predicted values must be those about which decision-makers make decisions. These categories will vary from system to system. It means also that the organizational structure of the system needs to be reflected in the model through, for example, the breakdown according to programme and the choice of regional units.

(c) Present results in a form which facilitates 'steering' of the system. This characteristic is closely related to the previous two. Unless the model pinpoints those variables which decision-makers can control and which are crucial to the operation of the system it will not be an effective planning tool. While it is possible to isolate those variables which are generally within the control of decision-makers, factors such as the time needed to effect change, control which is exercised by more than one decision-maker and the extent of decentralization of decision making will vary from system to system. A model which does not fully reflect both the opportunities of and constraints on decision-makers in steering the particular system can be of only limited value.

This is not to say that generalized models have no place in educational planning. The generalized models reviewed in Section I were designed to be as flexible as possible. They offer a quick and relatively inexpensive entry to model use, but, as the demands on the model are increased, the model will need to be substantially adapted or a new model made. By this time considerable experience will have been gained in the use of models.

Stress has already been laid on the fact that models of this type are essentially computational tools. While this should be kept in mind, the side effects of the development of such a tool are substantial. The model should act as a guide to systematic data collection and should lead to more effective use of available data. Through its emphasis on the needs of decision-makers the model provides a planning orientation to data collection and analysis. Decision-makers require more than an information service. The model helps to ensure that data is provided in a form which emphasizes the possible alternative decisions.

8. Conclusion

Section I concluded with a comment which was meant to suggest that, despite its limitations, SOM could be a valuable tool in the context of Victoria's long-term planning needs. A similar conclusion is, I think, warranted in relation to the Victoria model and to models of the education system in general. Provided that the limitations of such models are remembered, there is no reason why they should not be included, along with other planning tools, among the techniques used to display to decision-makers the likely effects of alternative decisions.

Appendixes

Appendix A

LIST OF VARIABLES AND SYMBOLS

Policy variables	Symbol
Average class size	a
Proportion of class teachers in each classification	p
Number of administrators per school	d
Number of specialist teachers per school	f
Number of scheduled excess teachers per school	g
Number of non-teaching auxiliary staff per school	h
Endogenous variables	
Number of classes	C
Number of classrooms	CR
Number of schools	S
Number of specialist rooms	FR
Number of assistant class teachers	AS
Number of assistant class teachers with responsibility	AR
Number of senior teacher class teachers	ST
Number of temporary teachers	TT
Number of administrators	D
Number of specialist teachers	F
Number of scheduled excess teachers	G
Number of non-teaching auxiliary staff	H
Total salaries of class teachers	CS
Total salaries of administrators	DS
Total salaries of specialist teachers	FS
Total salaries of scheduled excess teachers	GS
Total teacher salaries	TS
Total salaries of non-teaching auxiliary staff	HS
Total other instructional costs	K
Total instructional costs	I
Total other recurrent costs	R
Building operation and maintenance cost	M
Capital cost	X
Total costs of education	T
Exogenous variables	
Enrolment	E
Average number of classes per school	b
Other instructional costs per pupil	k
Other recurrent costs per pupil	r
Number of new classrooms to be built	CN
Cost per classroom	u
Number of new special purpose rooms to be built	FN
Cost per special purpose room	w
Average salary of assistant class teachers	as
Average salary of assistant with responsibility teachers	ar
Average salary of senior teacher class teachers	st
Average salary of temporary teachers	tt
Average salary of administrators	ds

	Symbol
Average salary of specialist teachers	fs
Average salary of scheduled excess teachers	gs
Average salary of non-teaching auxiliary staff	hs
Cost per room of building operation and maintenance	m

Loading factors

Proportion of teachers on leave	q
Proportion of classrooms to be replaced	t
Proportion of special purpose rooms to be replaced	v

Level of aggregation

Variables are broken down by - Size of school = i (1 ...... 6)
Region = j (1 ...... 11)

Appendix B

EQUATIONS OF THE VICTORIA MODEL

(1) $C = E/a$

The number of classes, and hence the number of class teachers, is equal to enrolment divided by the average class size.

(2) $CS = C\ (pAS.\ as + pAR.\ ar + ST. + pTT.\ tt)$

Total class teacher salaries, equals the number of class teachers (c) multiplied by the weighted average of class teacher salaries, i.e. the proportion of each classification of teacher multiplied by the average salary of each classification of teacher.

(3) $S = C/b$

The number of schools is equal to the number of classes divided by the weighted average number of classes per school.

(4)(4a) $DS = S.\ d.\ ds$

Total salaries of administrators are equal to the number of schools by the number of administrators per school by average salary of administrators.

(4b) $FS = S.\ f.\ fs$ (specialist teachers)

(4c) $GS = S.\ g.\ gs$ (scheduled excess teachers)

(5) $TS = (CS + DS + FS + GS)\ (1 + q)$

Total teacher salaries are equal to the sum of the salaries of class teachers, administrators, specialist teachers and excess teachers, multiplied by a loading factor to allow for the proportion of teachers on leave.

(6) $HS = S.\ h.\ hs$

Total salaries of non-teaching auxiliary staff are equal to the number of schools, multiplied by the number of auxiliary staff per school, by the average salary of auxiliary staff.

(7) $K = E.\ k.$

Other instructional costs are equal to enrolment, multiplied by other instructional costs per pupil.

(8) $I = T.S. + H.S. + K.$

Total instructional costs are equal to the sum of teachers salaries, auxiliary staff salaries and other instructional costs.

(9) $M = m\ (CR + FR)$

Total maintenance costs are equal to the sum of classrooms and specialist rooms, multiplied by cost of maintenance per teaching space.

(10) $R = E.\ r$

Other recurrent costs are equal to the product of enrolment and other recurrent costs per pupil.

(11) $X = (CN.\ u)\ (1 + t) + (FN.\ w)\ (1 + v)$

Total capital costs are equal to the number of new classrooms to be built by the cost per classroom multiplied by a loading for classrooms to be replaced. To this is added the number of specialist rooms by the cost per room, again multiplied by a loading for specialist rooms to be replaced.

(12) $T = X + M + I + R$

Total costs of education equals capital costs plus cost of building operation and maintenance plus instructional costs plus other recurrent costs.

Appendix C

SUBSCRIPTED EQUATIONS OF THE VICTORIA MODEL

(1) $C_{ij} = E_{ij}/a_{ij}$ $(i = 1 \ldots\ldots 6)$ $(j = 1 \ldots\ldots 11)$

The number of classes in the i^{th} size of school in the j^{th} region (C_{ij}) is equal to enrolment in the i^{th} size of school in the j^{th} region (E_{ij}) divided by the average class size in the i^{th} size of school and j^{th} region (a_{ij}).

NOTE. In all other equations, the subscripts have the same meaning and the basic equations are identical with those in Appendix B.

(2) $CS_{ij} = C_{ij} (AS_{ij} . as + AR_{ij} . ar + ST_{ij} . st + TT_{ij} . tt)$

(3) $S_{ij} = C_{ij}/b_{ij}$

(4)(4a) $DS_{ij} = S_{ij} . d_{ij} . ds_{ij}$

(4b) $FS_{ij} = S_{ij} . f_{ij} . fs_{ij}$

(4c) $GS_{ij} = S_{ij} . g_{ij} . gs_{ij}$

(5) $TS_{ij} = (CS_{ij} + DS_{ij} + FS_{ij} + GS_{ij}) (1 + q)$

(5a) $\sum_{i=1}^{6} TS_{ij} = \left(\sum_{i=1}^{6} CS_{ij} + \sum_{i=1}^{6} DS_{ij} + \sum_{i=1}^{6} FS_{ij} + \sum_{i=1}^{6} GS_{ij} \right) (1 + q)$

Total teacher salaries totalled by region

(5b) $\sum_{j=1}^{11} TS_{ij} = \left(\sum_{j=1}^{11} CS_{ij} + \sum_{j=1}^{11} DS_{ij} + \sum_{j=1}^{11} FS_{ij} + \sum_{j=1}^{11} GS_{ij} \right) (1 + q)$

Total teacher salaries totalled by size of school

(5c) $\sum_{i=1}^{6} \sum_{j=1}^{11} TS_{ij} = \left(\sum_{i=1}^{6} \sum_{j=1}^{11} CS_{ij} + \sum_{i=1}^{6} \sum_{j=1}^{11} DS_{ij} + \sum_{i=1}^{6} \sum_{j=1}^{11} FS_{ij} + \sum_{i=1}^{6} \sum_{j=1}^{11} GS_{ij} \right) (1 + q)$

Total teacher salaries for all sizes of schools in all regions.

NOTE. Each of the following values can also be summed for each size of school, for each region and for all sizes in all regions.

(6) $HS_{ij} = S_{ij} . h_{ij} . hs_{ij}$

(7) $K_{ij} = E_{ij} . k$

(8) $I_{ij} = TS_{ij} + HS_{ij} + K_{ij}$

(9) $M_{ij} = m (CR_{ij} + FR_{ij})$

(10) $$R_{ij} = E_{ij} \cdot r$$

(11) $$X_{ij} = (CN_{ij} \cdot u)(1 + t) + (FN_{ij} \cdot w)(1 + v)$$

(12) $$T_{ij} = X_{ij} + M_{ij} + I_{ij} + R_{ij}$$

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OCCASIONAL PAPER No. 39 makes a fairly detailed examination of four separate models of the educational system (one of them developed for the Norwegian system and the others, respectively, by O. E. C. D., Unesco, and the I. I. E. P.) and then attempts to apply the lessons of this examination to constructing a model of primary education in Victoria, Australia.

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