CENTER OF PLANNING AND ECONOMIC RESEARCH

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A GOAL PROGRAMMING MODEL FOR RESOURCE ALLOCATION IN THE SCHOOL SYSTEM OF GREECE

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INTRODUCTION

There have been increasing efforts during the last few years to apply operations research and systems analysis to solve problems of educational systems (6). This tendency has undoubtedly been spurred by the increasing awareness of quantitative techniques and by their successful applications to business and industrial problems. However, this is true for the case of the developed countries only. The less developed countries have not yet taken advantage of quantitative approaches in optimally allocating their scarce resources and planning their educational system. There have been, of course, some reports of such applications in less developed countries, particularly in Central and South America; but the majority of the less developed countries have never applied such techniques to educational problems.

There are a number of difficulties encountered in applying quantitative techniques to solving problems existing within the environment of a less developed country. Therefore, the first objective of this paper is to discuss the decision environment within which the educational problems of the less developed countries exist. This environment has presumably a considerable impact upon all the phases of the problem solving process. Particular reference will be made to the relevant decision environment existing in Greece, but similar characteristics appear in many other less developed countries. The second objective is to consider goal programming as a possible aid to the educational policy makers and administrators of a less developed country with respect to determining: (a) how to allocate the available resources among the different subsystems of the educational system and among the different components within each subsystem; (b) the quality level of education which the country can afford; and (c) the

financial sacrifices necessary for different levels of improvement. This again will be done in context with the educational system of Greece.

A few applications of goal programming have been reported in the case of college planning. Lee and Clayton (4) use a single-period model that allocates resources within a college. We have used the same approach for allocating resources within the system of primary and elementary education of a less developed country. In Lee and Clayton's approach, the ranking of the goals implies that no amount of a higher ranked goal can be traded in exchange for an amount of a lower ranked goal. To cope with this deficiency, we have fragmented each goal into different subgoals with incremental achievement levels for each one of them. Wallhaus (9) and Schroeder (8) use multiple period goal programming formulations, although with different flows and decision variables. Aubin and Naslund (1) and Benson (2) use an interactive multiple criteria optimization algorithm. Our choice among these approaches was affected first by its simplicity for implementation in a less developed country and, second, by the fact that the solution aims at providing general policy directions rather than an exact allocation of resources.

The Educational System of Greece

The educational system in Greece is very briefly described by Figure 1. There are six grades in primary education and six in secondary education. The primary education and the three first grades of the secondary are compulsory. There is an input of approximately 160 thousand pupils to primary education each year and a total enrollment of approximately one million. The corresponding figures for secondary education are approximately 120 thousand input and 460 thousand total enrollment. Those who graduate from high school amount to approximately

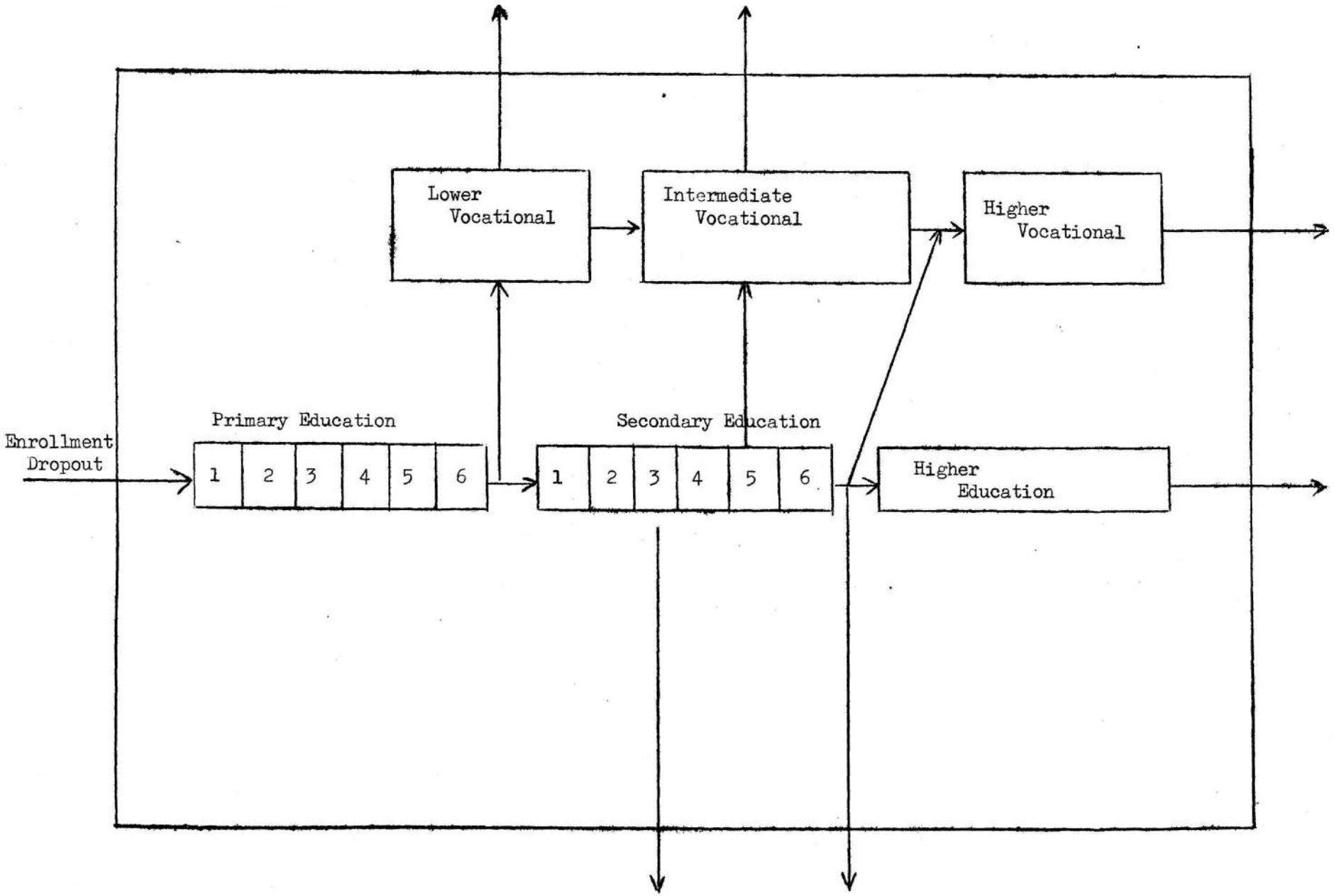
Lower
Vocational
Intermediate
Vocational
Higher
Vocational
Primary Education
Secondary Education
Enrollment
Dropout
1
2
3
4
5
6
1
2
3
4
5
6
Higher
Education

FIGURE 1

40 thousand, 15 thousand of which are accepted by the higher educational institutions of the country. The difference between input to primary education and output from secondary education consists of dropouts, most of which go to vocational education. Approximately 90% of the primary and secondary education students attend the public schools. Their operation is administered by the Greek Ministry of Education. All the teachers in the public schools are appointed by the Ministry of Education. Those appointed to the elementary schools have to have a teachers college degree, while those appointed to the high schools have to have a university degree. Those at the elementary schools are appointed at a rank lower than that at which high school teachers are appointed. There are no appointments at a rank other than the first rank for each level of education. The salaries follow the standard civil servants salary scale, which is a function of rank and number of years in the civil service. This means that there is no merit system for salary adjustments.

The student-to-teacher ratio is as an average approximately 34 to 1 but it varies in the different parts of the country. All the children at the elementary schools follow exactly the same programme of studies determined by the Ministry of Education. The same is the case for the first three grades of secondary education. Beyond that grade secondary education is divided into two different programmes, with the one giving higher emphasis to sciences and the other to humanities. Classes meet for half of the day six days a week usually with one-half of the students at each school attending morning classes and the other half attending evening classes, to take full advantage of the usually limited classroom space.

The Decision Environment

Education in Greece, and the less developed countries generally, is usually a state function. It is being recognised by almost every sector of the country and every political group that education is going to play an important rôle in the economic and social development of the country. However, there is a considerable deviation in opinions as to the emphasis that should be put on each part of the educational system. Some are in favour of technical education, in opposition to others who are in favour of humanistic education, or some would like to see more emphasis on vocational education than on higher education. These differences of opinion in connection with the usually existing high degree of political instability, have serious consequences. The most serious of them is the resulting educational instability. Thus, a child going through high school may have switched back and forth to opposing educational orientations many times during his/her elementary and high school education.

Political instability and the political influences that, to a smaller or larger degree accompany it, result on many occasions in the wrong educational policies and allocation of resources within the educational system, either geographically or among the different components of the system. Given the urban and social structure of the country, where most of the population and the facilities are concentrated in the capital and a few more large cities, most of the experienced teachers try to get a position in these cities. This results in unequal distribution of teachers among the provinces and the large cities for the different specialties of teachers. Also unequal is the distribution of other resources such as school buildings and teaching aid media. A bureaucratic system and an unwillingness to change are additional factors which complicate every decision process. Thus, the solution to a problem may

take such a long time before a relevant decision is made and the decision is actually implemented, that the solution is by all means outdated by that time.

It is imperative, therefore, that any attempt to apply quantitative analysis in solving such educational problems, should aim at influencing the formation of general policies rather than at suggesting exact and detailed changes. This becomes even more apparent if one takes into account the fact that these countries lack adequate and accurate data. Establishment of the necessary procedures for collecting and presenting the relevant information takes time, and it is possible only after some changes in the mentality of the decision makers and the other human components of the system. These and many other factors mentioned elsewhere (7) make the following goal programming approach a reasonable first attempt to introduce analytical decision making in the educational system of a less developed country.

The Technique of Goal Programming

Linear programming has been used extensively in allocating in an optimum way the scarce resources of various organisations. In most of the cases the assumption is made, explicitly or implicitly, that the organisation has only one goal to achieve, such as profit maximization or cost minimization. However, there have been some cases where more than one objective is considered and an attempt is being made to express the outcomes relevant to the different organisational objectives in terms of one objective criterion, which is not an easy task.

It has been widely recognised recently, more than at any other time in the past, that business organisations have more than one objective to pursue. Non-business organisations have even more objectives to achieve and,

therefore, the application of linear programming becomes even more difficult. An educational system has a number of conflicting goals to achieve, some of which are not achievable because of a number of constraints. The nature of these constraints varies, but most of them are usually financial. Goal programming can provide the educational administrators with some idea of the extent to which they can achieve their goals under the existing circumstances, as well as the changes in the input and output rates necessary to make feasible the achievement of those goals, which cannot be achieved otherwise.

In goal programming there are multiple goals and/or subgoals to be pursued, and it is necessary that management be able to provide an ordinal ranking of these goals and subgoals in terms of their importance to the organisation. Although in linear programming the objective function to be maximized or minimized comprises the objective criterion directly, in goal programming it comprises the deviations between goals and what can be achieved within the existing constraints; these deviations, weighted on the basis of their importance to the organisation, are to be minimized. The general GP model can be expressed as follows:

$$\text{Minimize} \quad Z = \sum_{r=1}^{k} \left[P_r \sum_{i \in R_r} W_i \left(d_i^+ + d_i^- \right) \right]$$

subject to the constraints:

$$\sum_{\zeta=1}^{n} a_{ij} X_j - d_i^+ + d_i^- = b_i \qquad (i = 1, 2, \ldots, m)$$

$$X_\zeta, \; d^+, \; d^- \geq 0$$

where there are m goals to be achieved and they are classified in k ranks.

R_r : set of goals classified in the same rank r

d_i^+ : overachievement of the goal i (= 0 if overachievement is acceptable)

d_i^- : underachievement of the goal i (= 0 if underachievement is acceptable)

b_i : level to be achieved of goal i

X_j : variable related to the subgoal j

a_{ij} : coefficient expressing the unit contribution of the subgoal j to the achievement of the goal i

P_r : priority factor by which the importance of the deviations from the goals classified in rank r are weighted; the following relationship should apply among the priority factors

$$P_r >>> n P_{r+1} \qquad (r=1, 2, \ldots, k)$$

which implies that P_r remains always greater than P_{r+1} even if P_{r+1} is multiplied by a very large number n.

w_i : weight of the deviational variable i classified with others under the same rank r; given that the objective is to minimize the opportunity cost or regret, it implies a coefficient of regret assigned to the deviational variable i on the same goal level.

Given that goal programming is a special case of linear programming, the SIMPLEX method has been modified to solve the goal programming problem [5]; a computer programme has also been written by Sang M. Lee [5] which could handle quite a few practical problems.

A Case Study General Model

The objective of this case study is to give a general model which could be used to form policies regarding the planning of allocation of re-

sources in part of the educational system of Greece. Only part of the system is included in the model, i.e. that of primary and secondary education. As soon as the relevant data is collected and this model is tried on that part of the system, then it could gradually be expanded to include vocational and university education. Eventually it could further be expanded to include more details, such as the effects of the private school system, planning by geographical or other sections of the country and by specialty of teachers, and planning for more than one period.

In forming the model the peculiarities relevant to the educational system of Greece are reflected upon the formation of goals and constraints as well as the definition of variables. There are eight ranks of teachers in primary education and seven ranks in secondary education. All the appointments are made at the first rank for each subsystem at a standard salary. All the grades of both primary and secondary education follow a standard programme of contact hours and subjects determined by the Ministry of Education. Consequently, there are no elective courses or other deviations from this programme.

A. The Goals

A list of the possible goals of the educational administrators is first compiled: it includes goals relevant to the improvement of the conditions under which the system operates. These goals are ranked according to their importance to the educational policy makers, as this is seen by the author. In the case of an actual implementation of this model, the ranking should be done by the decision makers themselves, by the use of some systematic approach such as the DELPHI approach, the Churchman-Ackoff evaluation method [3],

and so on, or a combination of them. Let the ranked goals be as follows:

Rank	Goals and/or Subgoals
1.	Provide free education.
2.	Breakeven.
3.	Do not compulsorily retire any teachers and maintain current promotion and retirement procedures.
4.	Provide an adequate number of primary education teachers to improve the teacher-to-student ratio and to decrease the class size by a first 5%.
5.	Provide an adequate number of secondary education teachers to improve the teacher-to-student ratio and to decrease the class size by a first 5%.
6.	Increase the average classroom space per student in primary education by a first 5%.
7.	Increase the average classroom space per student in secondary education by a first 5%.
8.	Increase teachers salaries in secondary education by a first 5%.
9.	Increase teachers salaries in primary education by a first 5%.
10.	Provide an adequate number of primary education teachers to improve the teacher-to-student ratio and to decrease the class size by a second 5%.
11.	Increase the average classroom space per student in primary education by a second 5%.
12.	Provide an adequate number of secondary education teachers to improve the teacher-to-student ratio and to decrease the class size by a second 5%.

13. Increase the average classroom space per student in secondary education by a second 5%.

14. Increase teachers salaries in secondary education by a second 5%.

15. Increase teachers salaries in primary education by a second 5%.

16. Improve the educational aid media in secondary education by a first 10%.

17. Improve the educational aid media in primary education by a first 10%.

18. Improve the educational aid media in secondary education by a second 10%.

19. Improve the educational aid media in primary education by a second 10%.

20. Provide an adequate number of secondary education teachers to improve the teacher-to-student ratio and to decrease the class size by a third 5%.

21. Provide an adequate number of primary education teachers to improve the teacher-to-student ratio and to decrease the class size by a third 5%.

22. Increase teachers salaries in primary education by a third 5%.

23. Increase teachers salaries in secondary education by a third 5%.

24. Improve the educational aid media in secondary education by a third 10%.

25. Increase the average classroom space per student in primary education by a third 5%.

26. Increase the average classroom space per student in secondary education by a third 5%.

27. Provide an adequate number of secondary education teachers to improve the teacher-to-student ratio and to decrease the class size by a fourth 5%.

28. Proyide an adequate number of primary education teachers to improve the teacher-to-student ratio and to decrease the class size by a fourth 5%.

29. Improve the educational aid media in primary education by a third 10%.

30. Improve the educational aid media in secondary education by a fourth 10%.

31. Increase the average classroom space per student in primary education by a fourth 5%.

32. Increase the average classroom space per student in secondary education by a fourth 5%.

33. Improve the educational aid media in primary education by a fourth 10%.

B. The Variables and Constraints

The variables of the model are defined on the basis of the above stated goals and the structure of the educational system in Greece as discussed above. The constraints stand for parameters that will have to be estimated in the case of an implementation of the model. They are defined as follows:

Variables

x_1 = number of primary education teachers, rank 1 (lower rank).

x_2 = number of primary education teachers, rank 2.

x_3 = number of primary education teachers, rank 3.

x_4 = number of primary education teachers, rank 4.

x_5 = number of primary education teachers, rank 5.

x_6 = number of primary education teachers, rank 6.

x_7 = number of primary education teachers, rank 7.

x_8 = number of primary education teachers, rank 8.

x_9 = number of secondary education teachers, rank 1 (lowest rank).

x_{10}= number of secondary education teachers, rank 2.

x_{11}= number of secondary education teachers, rank 3.

x_{12}= number of secondary education teachers, rank 4.

x_{13}= number of secondary education teachers, rank 5.

x_{14}= rank of secondary education teachers, rank 6.

x_{15}= rank of secondary education teachers, rank 7.

s_1 = additional classroom space, primary education (in square feet).

s_2 = additional classroom space, secondary education (in square feet).

s_3 = additional investment on educational media, primary education (in $).

s_4 = additional investment on educational media, secondary education (in $).

Y_1 = payroll increase from prior year resulting from new hiring and salary increase in primary education.

Y_2 = payroll increase from prior year resulting from new hiring and salary increase in secondary education.

r = total budget available.

h_1 = new hirings at rank 1, primary education.

h_2 = new hirings at rank 1, secondary education.

Y_3 = budget for books provided free to each student in primary education.

Y_4 = budget for books provided free to each student in secondary education.

Constants

The constants which are related to the teachers i.e., current salary, current number, proportion of teachers in each rank to be promoted to the next rank and proportion of teachers in each rank retiring voluntarily, are given in the following table:

Category of teacher	Anerage current salary	Current number	Proportion to be promoted to next rank	Proportion to retire voluntarily
Rank 1, primary education	C_1	t_1	P_1	q_1
Rank 2, primary education	C_2	t_2	P_2	q_2
Rank 3, primary education	C_3	t_3	P_3	q_3
Rank 4, primary education	C_4	t_4	P_4	q_4
Rank 5, primary education	C_5	t_5	P_5	q_5
Rank 6, primary education	C_6	t_6	P_6	q_6
Rank 7, primary education	C_7	t_7	P_7	q_7
Rank 8, primary education	C_8	t_8		q_8
Rank 1, secondary education	C_9	t_9	P_9	q_9
Rank 2, secondary education	C_{10}	t_{10}	P_{10}	q_{10}
Rank 3, secondary education	C_{11}	t_{11}	P_{11}	q_{11}
Rank 4, secondary education	C_{12}	t_{12}	P_{12}	q_{12}
Rank 5, secondary education	C_{13}	t_{13}	P_{13}	q_{13}
Rank 6, secondary education	C_{14}	t_{14}	P_{14}	q_{14}
Rank 7, secondary education	C_{15}	t_{15}		q_{15}

Other constants are:

a_1 = enrollment forecast, primary education.

a_2 = contact hours per week per student, primary education.

a_3 = teaching load per week per teacher, primary education.

a_4 = current average class size, primary education.

a_5 = total current classroom space, primary education.

a_6 = current enrollment, primary education.

a_7 = current student-to-teacher ratio, primary education.

a_8 = current investment in educational media, primary education.

a_9 = cost of building new classroom space ($/ft^2).

a_{10} = enrollment forecast, secondary education.

a_{11} = contact hours per student per week, secondary education.

a_{12} = teaching load per week per teacher, secondary education.

a_{13} = current average class size, secondary education.

a_{14} = total current classroom space, secondary education.

a_{15} = current enrollment, secondary education.

a_{16} = current student-to-teacher ratio, secondary education.

a_{17} = current investment in educational media, secondary education.

a_{18} = average cost of books provided to each student, secondary education.

a_{19} = average cost of books provided to each student, secondary education.

b_1 = total budget allocated to primary education.

b_2 = total budget allocated to secondary education.

C. The Constraint Equations

The equations of the model, expressing the constraints and/or goals can eventually be formed. The right hand side of each constraint equation is defined by the respective goal and it will be equal to a value, once the values of the constants have been estimated. The left hand side of each constraint comprises the relevant variables together with the two deviational variables d_i^+ and d_i^- which stand for overachievement and underachievement of the goal respectively. The set of equations together with information as to whether overachievement or underachievement of the goal is acceptable, is given in the following:

Goal 1: $$r + d_1^- - d_1^+ = b_1 + b_2$$

$$y_3 + d_2^- - d_2^+ = a_1\ a_{18}$$

$$y_4 + d_3^- - d_3^+ = a_{10}\ a_{19}$$

Goal 2: $$r - \left[\sum_{i=1}^{15} c_i x_i + \sum_{i=1}^{4} y_i + a_9 \ (z_1 + z_2) + z_3 + z_4) \right]$$

Goal 3:

$$X_1 + h_1 + d_5^- = (1 - P_1 - q_1)\ t_1$$

$$X_2 + d_6^- - d_6^+ = (\ 1 - P_2 - q_2)\ t_2 + P_1 t_1$$

$$X_3 + d_7^- - d_7^+ = (1 - P_3 - q_3) t_3 + P_2\ t_2$$

$$X_4 + d_8^- - d_8^+ = (1 - P_4 - q_4) t_4 + P_3\ t_3$$

$$X_5 + d_9^- - d_9^+ = (1 - P_5 - q_5) t_5 + P_4\ t_4$$

$$X_6 + d_{10}^- - d_{10}^+ = (1 - P_6 - q_6) t_6 + P_5\ t_5$$

$$X_7 + d_{11}^- - d_{11}^+ = (1 - P_7 - q_7) t_7 + P_6\ t_6$$

$$X_8 + d_{12}^- - d_{12}^+ = (1 - q_8) t_8 + P_7\ t_7$$

$$X_9 + h_2 + d_{13}^- - d_{13}^+ = (1 - P_9 - q_9) t_9$$

$$X_{10} + d_{14}^- - d_{14}^+ = (1 - P_{10} - q_{10}) t_{10} + P_9\ t_9$$

$$X_{11} + d_{15}^- - d_{15}^+ = (1 - P_{11} - q_{11}) t_{11} + P_{10}\ t_{10}$$

$$X_{12} + d_{16}^- - d_{16}^+ = (1 - P_{12} - q_{12}) t_{12} + P_{11}\ t_{11}$$

$$X_{13} + d_{17}^- - d_{17}^+ = (1 - P_{13} - q_{13}) t_{13} + P_{12}\ t_{12}$$

$$X_{14} + d_{18}^- - d_{18}^+ = (1 - P_{14} - q_{14}) t_{14} + P_{13}\ t_{13}$$

$$X_{15} + d_{19}^- - d_{19}^+ + (1 - q_{15}) t_{15} + P_{14}\ t_{14}$$

Goal 4: $$\sum_{i=1}^{8} X_i + h_1 + d_{20}^- - d_{20}^+ = a_1 a_7/.95$$

$$\sum_{i=1}^{8} X_i + h_1 + d_{21}^- - d_{21}^+ = a_1 a_2 /(.95 a_3 a_4)$$

Goal 5: $$\sum_{i=9}^{15} X_i + h_2 + d_{22}^- = a_{10} a_{16}/.95$$

$$\sum_{i=9}^{15} X_i + h_2 + d_{23}^- - d_{23}^+ = a_{10} a_{11}/(.95 a_{12} a_{13})$$

Goal 6: $$z_1 + d_{24}^- - d_{24}^+ = (1.05\ a_1 a_5/a_6) - a_5$$

Goal 7: $$z_2 + d_{25}^- - d_{25}^+ = (1.05\ a_{10} a_{14}/a_{15}) - a_{14}$$

Goal 8: $$y_2 - \left[1.05 c_g h_2 + .05 \sum_{i=9}^{15} c_1 X_i\right] + d_{26}^- - d_{26}^+ = 0$$

Goal 9: $$y_1 - \left[1.05\ c_1 h_1 + .05 \sum_{i=1}^{8} c_i X_i\right] + d_{27}^- - d_{27}^+ = 0$$

Goal 10: $$d_{20}^+ + d_{28}^- - d_{28}^+ = (a_1 a_7/.90) - a(a_1 a_7/.95)$$

$$d_{21}^+ + d_{29}^- - d_{29}^+ = (a_1 a_2/.90 a_3 a_4) - (a_1 a_2/.95 a_3 a_4)$$

Goal 11: $$d_{24}^+ + d_{30}^- - d_{30}^+ = .05\ a_1 a_5/a_6$$

Goal 12: $$d_{22}^+ + d_{31}^- - d_{31}^+ = (a_{10} a_{16}/.90) - (a_{10} a_{16}/.95)$$

$$d_{23}^+ + d_{32}^- - d_{32}^+ = (a_{10} a_{11}/.90\ a_{12} a_{13}) - (a_{10} a_{11}/.95\ a_{12} a_{13})$$

Goal 13: $$d_{25}^+ + d_{33}^- - d_{33}^+ = .05\ a_{10} a_{14}/a_{15}$$

Goal 14: $d_{26}^{+} - .05 \quad c_9 h_2 + \left[\sum_{i=9}^{15} c_i X_i \right] + d_{34}^{-} - d_{34}^{+} = 0$

Goal 15: $d_{27}^{+} - .05 \left[c_1 h_1 + \sum_{i=1}^{8} c_i X_i \right] + d_{35}^{-} - d_{35}^{+} = 0$

Goal 16: $z_4 + d_{36}^{-} - d_{36}^{+} = (1.10\ a_{10} a_{17} / a_{15}) - a_{17}$

Goal 17: $z_3 + d_{37}^{-} - d_{37}^{+} = (1.10\ a_1 a_8 / a_6) - a_8$

Goal 18: $d_{36}^{+} + d_{38}^{-} - d_{38}^{+} = .10 a_{10} a_{17} / a_{15}$

Goal 19: $d_{37}^{+} + d_{39}^{-} - d_{39}^{+} + .10\ a_1 a_8 / a_6$

Goal 20: $d_{37}^{+} + d_{40}^{-} - d_{40}^{+} = (a_{10} a_{16} / .85) - (a_{10} a_{16} / .90)$

$d_{32}^{+} + d_{41}^{-} - d_{41}^{+} = (a_{10} a_{11} / .85 a_{12} a_{13}) - (a_{10} a_{11} / .90 a_{12} a_{13})$

Goal 21: $d_{28}^{+} + d_{42}^{-} - d_{42}^{+} = (a_1 a_7 / .85) - (a_1 a_7 / .90)$

$d_{29}^{+} + d_{43}^{-} - d_{43}^{+} = (a_1 a_2 / .85\ a_3 a_4) - (a_1 a_2 / .90\ a_3 a_4)$

Goal 22: $d_{35}^{+} - .05 \left[c_1 h_1 + \sum_{i=1}^{8} c_i X_i \right] + d_{44}^{-} - d_{44}^{+} = 0$

Goal 23: $d_{34}^{+} - .05 \left[c_g h_2 + \sum_{i=9}^{15} c_i X_i \right] + d_{45}^{-} - d_{45}^{+} = 0$

Goal 24: $d_{38}^{+} + d_{46}^{-} - d_{46}^{+} = .10 a_{10} a_{17} / a_{15}$

Goal 25: $d_{30}^{+} + d_{47}^{-} - d_{47}^{+} = .05\ a_1 a_5 / a_6$

Goal 26: $d_{33}^{+} + d_{48}^{-} - d_{48}^{+} = .05\ a_{10}a_{14}/a_{15}$

Goal 27: $d_{40}^{+} + d_{49}^{-} - d_{49}^{+} = (a_{10}a_{16}/.80) - (a_{10}a_{16}/.85)$

$d_{41}^{+} + d_{50}^{-} - d_{50}^{+} = (a_{10}a_{11}/.80a_{12}a_{13}) - (a_{10}a_{11}/.85\ a_{12}a_{13})$

Goal 28: $d_{42}^{+} + d_{51}^{-} - d_{51}^{+} = (a_{1}a_{7}/.80) - (a_{1}a_{7}/.85)$

$d_{43}^{+} + d_{52}^{-} - d_{52}^{+} = (a_{1}a_{2}/.80a_{3}a_{4}) - (a_{1}a_{2}/.85a_{3}a_{4})$

Goal 29: $d_{39}^{+} + d_{53}^{-} - d_{53}^{+} = .10\ a_{1}a_{8}/a_{6}$

Goal 30: $d_{46}^{+} + d_{54}^{-} - d_{54}^{+} = .10\ a_{10}a_{17}/a_{15}$

Goal 31: $d_{47}^{+} + d_{55}^{-} - d_{55}^{+} = .05\ a_{1}a_{5}/a_{6}$

Goal 32: $d_{48}^{+} + d_{56}^{-} - d_{56}^{+} = .05\ a_{10}a_{14}/a_{15}$

Goal 33: $d_{53}^{+} + d_{57}^{-} - d_{57}^{+} = .10\ a_{1}a_{8}/a_{6}$

Excluding the constraints for goals 1,2 and 3, where neither overachievement nor underachievement is acceptable, for the rest of the goals overachievement is acceptable.

D. The Objective Function

The objective function minimizes the sum of the products of the deviations d_i and their priority factors P_r, as determined by the ranking of the respective goals. For the cases where overachievement or underachievement are acceptable, the deviations d_i^{+} and d_i^{-} respectively are not included in the

objective function. It takes the dollowing form:

$$\text{MINIMIZE } Z = P_1 \sum_{i=1}^{3} (d_i^- + d_i^+) + P_2 (d_4^- + d_4^+) + P_3 \sum_{i=5}^{19} (d_i^- + d_i^+) +$$

$$+ P_4 (d_{20}^- + d_{21}^-) + P_5(d_{22}^- + d_{23}^-) + P_6 d_{24}^- + P_7 d_{25}^- +$$

$$+ P_8 d_{26}^- + P_9 d_{27}^- + P_{10}(d_{28}^- + d_{29}^-) + P_{11} d_{30}^- + P_{12}(d_{31}^- + d_{32}^-)$$

$$+ P_{13} d_{33}^- + P_{14} d_{34}^- + P_{15} d_{35}^- + P_{16} d_{36}^- + P_{17} d_{37}^- +$$

$$+ P_{18} d_{38}^- + P_{19} d_{39}^- + P_{20}(d_{40}^- + d_{41}^-) + P_{21} (d_{42}^- + d_{43}^-)$$

$$+ P_{22} d_{44}^- + P_{23} d_{45}^- + P_{24} d_{46}^- + P_{25} d_{47}^- + P_{26} d_{48}^-$$

$$+ P_{27}(d_{49}^- + d_{50}^-) + P_{28}(d_{51}^- + d_{52}^-) + P_{29} d_{53}^- +$$

$$+ P_{30} d_{54}^- + P_{31} d_{55}^- + P_{32} d_{56}^- + P_{33} d_{57}^-$$

E. Solution and Sensitivity Analysis

The solution of the model provides the subset of goals that can be achieved on the basis of the available budget for primary and secondary education. A computer programme given by Lee [4] could be used in this respect, probably with minor modifications, to provide for the necessary core space needed by larger problems. This programme gives the subset of goals achieved and those not achieved as well as the optimum values of the choice variables and their deviations from the desired values. In addition to that, there is more information provided in the output of the computer programme. Such information is valuable in carrying out the post-optimal sensitivity analysis which

will determine the sensitivity of the solution to errors in estimating the input information [5].

Moreover, sensitivity analysis can be carried out with respect to different rankings of the goals, goal levels, budget levels, changes in the laws determining personnel policies, and so on. For example, a modification of the model would give the budget level necessary to achieve all the above goals of the educational policy makers.

Conclusion

The less developed countries have not yet taken advantage of the quantitative approaches in optimally allocating their scarce resources and planning their educational system. There are a number of difficulties encountered in applying quantitative techniques within the environment of a less developed country, of which the most important are: (a) the suspicion with which the decision makers view the application of sophisticated processes in problem solving; (b) the existence of a bureaucratic system and of a resistance to change; and (c) the lack of accurate and systematic quantitative data.

In this paper the use of goal programming is suggested as a possible aid to the educational policy makers and administrators of a less developed country with respect to determining (a) how to allocate the available resources within the educational system; (b) the quality level of education the country can afford; and (c) the financial sacrifices necessary for different levels of improvement. A general goal programming model was developed dealing with the primary and secondary educational system of Greece. Different goals and their improvement by small increments are considered and ranked on a hypo-

thetical basis and the constraint equations and objective function are constructed. From its solution and the application of sensitivity analysis, valuable information could be obtained. From such a systematic approach, the educational policy makers of the country could gain a lot more than just the solution. Deficiencies of the existing system in terms of data, facilities and personnel would be uncovered and measures could be taken for their correction. This would result in a series of more successful applications of quantitative techniques and a continuous improvement of decisions made on educational problems in less developed countries.

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