

Growth, Employment and Education: An Application of Multicriteria Analysis to Pakistan

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1. INTRODUCTION

Development planning is a multicriteria problem. Apart from economic goals (like economic growth, income distribution, employment, price stability, balance of payments, etc.) a set of basic human needs (like food, health, housing, clothing, education, etc.) has to be fulfilled within a limited time horizon. Of course, not all targets of economic policy can reach desirable levels within a plan period given scarce resources and trade-offs between goals and basic needs. Priorities have to be formulated and goals and needs have to be weighted against another. Multicriteria analysis can contribute to this weighing process by circumscribing feasible areas and by quantifying above mentioned trade-offs.

The purpose of this paper is to present an illustration of multicriteria analysis in which at least two goals of economic policy (growth and employment) and one basic human need (education) are incorporated. The model is applied to Pakistan due to data access.

Hitherto, Pakistan has paid little attention to the development of human resources. The budget for education is very small, the literacy rate is low compared to other developing countries and systematic educational and manpower planning is not involved in national Five-Year Plans. Education is not sufficiently valued as a development goal as such nor as an instrument for growth.

The Manpower Planning Unit (MPU) of the Ministry of Labour and Manpower has made a first step to develop an educational and manpower planning model in 1981.¹ This simple model estimates occupational and educational manpower requirements and supply of the Fifth Five-Year Plan period 1978–83. Starting from planned sectoral production targets the model calculates manpower requirements disaggregated according to occupational and educational levels. Further, on the basis

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¹Pakistan Ministry of Labour and Manpower, *A Study of the Occupational and Educational Manpower Requirements and Supply of the Fifth Five Year Plan, 1978–83*, Islamabad, 1981. The first author was attached to the MPU at that time.

of planned enrolment rates, transition rates, participation rates, etc. the model estimates manpower supply by level of education. The confrontation of manpower requirements and supply by level of education gives an insight in imbalances (shortages and/or surpluses) between levels of education required to achieve plan targets and the estimated educational structure of the labour force during the plan period. A series of *ad hoc* simulations with the model shows possible directions for both the demand and the supply side to smooth these imbalances.²

Instead of using *ad hoc* simulations a more formal procedure for smoothing imbalances has been applied by rebuilding the model first into a linear programming model (updated to the Sixth Five-Year Plan period 1982-83 – 1987-88),³ and later into a multicriteria model which is presented in this paper.

The plan of the paper is as follows. Section 2 discusses manpower planning aspects of the model. Section 3 presents the structure of the multicriteria model, while results are discussed in Section 4.

2. THE MANPOWER PLANNING PART OF THE MODEL

A manpower planning model consists out of three parts, a demand part, a supply part, and a part dealing with imbalances between demand and supply. First, future demand for labour depends on overall growth, on future sectoral composition of the economy, on sectoral labour/output ratios, on sectoral occupational structures and on educational requirements for each occupation. Secondly, future manpower supply by level of education depends on the existing educational structure of the labour force, on birth, death and retirement rates, on inflows and outflows of the educational system, and on various participation rates. Thirdly, imbalances are calculated by comparing demand and supply for different educational levels. The present model contains more than 400 equations and constraints, with the following contents:

Demand Side

Equations: Quantifying marginal sectoral capital-output ratio's. A certain set of sectoral production growth levels requires a certain amount of investments by sector. Seven sectors have been distinguished, i.e. agriculture and forestry, manufacturing and mining, electricity and water and gas, construction, wholesale and retail trade,

²See K.W. van Elk, *Some Aspects of the Analysis of Strategies for Manpower Development: An Application to Pakistan* (unpublished doctoral thesis Erasmus University Rotterdam), Islamabad and Rotterdam, 1981.

³See J. Kuikman, *A Manpower Planning Model for Pakistan in the framework of the Sixth Five-Year Plan 1982-83 – 1987-88* (unpublished doctoral thesis Erasmus University Rotterdam, written in Dutch), Rotterdam, 1986.

transport and communication, and private and public services.

Quantifying sectoral labour-output ratio's.

Manpower requirements by occupation. Since the occupational structure varies by sector, a so-called sector-occupation matrix is defined by which total occupational requirements can be calculated for each set of sectoral production levels. Seven occupational groups are distinguished, i.e. professional and technical workers, administrative and managerial workers, clerical workers, sales workers, service workers, agricultural workers, and production workers.

Educational requirements. Since educational requirements vary by occupational group, a so-called occupation-education matrix is constructed by which total educational requirements can be calculated given by a certain set of occupational requirements. Five levels of education have been distinguished, i.e. less than primary, primary, matric, degree, and post-graduate.

Intermediate deliveries between sectors. All technical coefficients including input-output coefficients are assumed constant during the plan period.

Constraints: Final demand per sector may deviate between plus and minus 20 percent from official sectoral plan figures at the end of the plan period.

Sectoral investments may deviate between plus and minus 10 percent from official plan figures at the end of the plan period.

The sum of sectoral import requirements may not exceed total planned imports during the plan period.

Supply Side

Equations: Plan figures concerning enrolment rates, transition rates from one class to the next class, and inflow into the educational system during the plan period.

Estimates on labour force participation rates for graduates and other school leavers at each educational level.

Estimates about the educational structure of the existing labour force and about death and retirement rates.

Estimates about costs per student by educational level.

Constraints: The inflow into the educational system may be 10 percent higher than planned which, of course, requires a higher educational budget.

Transition rates may be 10 percent higher than planned due to qualitative improvements of the educational system implying higher costs per student.

Imbalances

Constraint: Sufficient manpower must be available in the country at each level of education.

While running various simulations of the model it appeared that no feasible

solution can be found without violating the constraint of required manpower with only basic education. Nevertheless, it can be assumed that illiterates (a surplus category) will do the job with lower productivity.

3. THE STRUCTURE OF THE MULTICRITERIA MODEL

A multicriteria linear programming model can be written as:

$$\begin{aligned} \text{optimize} & : Cx \\ \text{subject to} & : Ax = b \\ & x \geq 0 \end{aligned}$$

where C is a $(k * n)$ – matrix of objective function coefficients;

x is a (n) – vector of decision variables including slack and surplus variables;

A is a $(m * n)$ – matrix of technical coefficients; and

b is a (m) – vector of constraints.

The present model has seven objectives ($k = 7$), i.e.:

1. Maximize growth of GDP.
2. Minimize the number of illiterates in the labour force.
- 3 – 7. Minimize manpower shortages and surpluses at each level of education.

In finding a solution to the multicriteria problem the so-called *ideal* and *anti-ideal* solution vectors play an important role. These vectors are reference points in the optimization process. The ideal (optima of individual objective functions) and the anti-ideal (minimal aspiration levels of objective functions), respectively pulls and pushes the optimizing solution as a magnetic force. The ultimate Pareto efficient solution of the multicriteria problem is a feasible solution nearest to the ideal, taking also minimum aspiration levels of individual objective functions into account.

The *ideal* or *utopia* solution of the problem is found by successively optimizing individual objective functions using the simplex procedure.⁴ In other words, seven LP-problems with seven different objective functions are individually solved taking the values of the six other objective functions for granted. These individual optima

⁴The computer programme LINDO (running on DEC and VAX mainframes and on IBM-compatible PC's) has been used to solve the seven single objective LP-problems.

of objective functions are presented in the diagonal of the pay-off matrix (Table 1). It is clear that this ideal situation can never be achieved due to trade-offs between various objective functions.

By simply optimizing one objective function taking other objectives for granted, it is not sure that the resulting solution vector (the values of seven objective functions) is Pareto optimal. In case of multiple solutions another solution vector may exist where the value of at least one of the six non-optimal objective functions is better than the original solution with equal values of other objective functions. A Pareto optimum (or in multicriteria terminology: efficiency) can be achieved by adding the six remaining objective functions with a very small weight to the objective function that has to be optimized. In other words, optimizing $c_i x + \sum_j \epsilon c_j x$ approximates the solution of optimizing $c_i x$ if ϵ is sufficiently small and guarantees Pareto efficient solutions.⁵ These weighing procedures are used in constructing the pay-off matrix in Table 1. Column i of the pay-off matrix presents the solution of optimizing objective function i . The individual optimum of objective function i is indicated in row i (the diagonal); other rows present the resulting efficient values of the six remaining objective functions.

The anti-ideal solution vector contains elements whose value is marginally

Table 1

Pay-off Matrix of Optimal Individual Objective Functions

	Growth	Illiter	Unemp1	Unemp2	Unemp3	Unemp4	Unemp5
Growth	317	271	317	260	287	274	281
Illiter	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Unemp1	0.51	2.11	0.51	2.35	1.70	2.08	2.02
Unemp2	-0.83	-0.40	-0.85	-0.28	-0.53	-0.42	-0.5
Unemp3	-0.05	0.15	-0.03	0.21	0.00	0.13	0.09
Unemp4	-0.01	0.02	-0.01	0.03	0.00	0.00	0.00
Unemp5	0.06	0.07	0.07	0.07	0.06	0.08	0.06

Growth : increase of GDP during plan period, in billion rupees.

Illiter : number of illiterate workers at the end of the plan period, in millions.

Unemp(i) : number of unemployed workers with educational level i at the end of the plan period, in millions.

⁵ See a.o. H. Isermann, Proper Efficiency and the Linear Vector Maximum Problem, *Operations Research*, Vol. 22, 1974.

acceptable; values worse than the anti-ideal are unacceptable. In principle, policy-makers can interact with planners and readjust their minimum aspiration levels depending on feasibility of alternative solutions.⁶

By lack of policy-makers in this paper we make our own (rather arbitrary) value judgement by selecting the most pessimistic values of Table 1 as minimal acceptable values. Since the anti-ideal is far from efficient and the ideal is not feasible, it is clear that any optimal, feasible, and efficient solution must be somewhere between the ideal and the anti-ideal. Of course, an overall optimal solution depends on relative weights of the various objective functions. If objective function i gets total weight and other objectives get almost zero weight, the overall optimum is equal to column i of the pay-off matrix. In that case the distance from element i of this optimum to element i of the ideal solution is zero, while the distance from some other elements to the ideal is positive. These distances are important in finding the overall optimal solution.

Minimizing a distance measure gives a feasible optimum nearest to the ideal. But distances from individual elements of an overall optimum to the ideal may not be the same for all objectives implying different weights for different objectives. With equal weights a solution is considered optimal if the largest (relative) distance from the various elements to the ideal is minimized (Tschebycheff-norm). In formula:

$$\min : [\max | w_i d_i |]$$

where d_i is the distance from element i to the ideal $d_i = z_i^* - c_i x$

where z^* is the ideal solution vector; and where the scaling factor w_i can be alternatively be defined as:

$$w_i = (z_i^* - n_i)^{-1} \quad \text{or} \quad w_i = (z_i^*)^{-1}$$

where n_i is the anti-ideal value of element i . The first alternative has the advantage that the anti-ideal affects the ultimate solution. Policy makers may readjust minimum aspiration levels after considering an intermediate solution. Thereafter, the problem can be run again. This interactive procedure will finally result in an acceptable optimal solution. To find the overall optimum with equal weights for the seven

⁶See Nijkamp, P. and J. Spronk, Interactive Multiple Goal Programming: An Evaluation and Some Results, in G. Fandel and T. Gal (eds), *Multiple Criteria Decision Making: Methods and Applications*, Springer, Berlin, 1980.

objective functions a new programming model is formulated:⁷

$$\begin{aligned} \min : & \quad \left[\max \left| \frac{z_i^* - c_i x}{z_i^* - n_i} \right| \right] + \epsilon (z^* - Cx) \\ \text{subject to:} & \quad Ax = b \\ & \quad x \geq 0 \end{aligned}$$

The second term of this objective function is added to guarantee Pareto efficiency. Calling the first term y , the new LP-problem can be written as follows:

$$\begin{aligned} \min : & \quad y + \epsilon (z^* - Cx) \\ \text{subject to :} & \quad c_i x + (z_i^* - n_i) y \geq z_i^* \\ & \quad Ax = b \\ & \quad x \geq 0 \\ & \quad y \geq 0 \end{aligned}$$

The feasible solution nearest to the ideal is determined by the largest relative distance over the entire feasible set. Without the second term of the objective function the solution is not necessarily efficient. The current formulation guarantees efficiency implying that relative distances from individual optima to the ideal may differ (see Table 2 in the next section).

4. RESULTS

Though the present model has more than 400 equations and constraints, the level of aggregation is still too high for concrete policy recommendations; only seven sectors, seven occupational groups and five levels of education are distinguished. Further, technical coefficients of the A-matrix based on data of the Fifth Five-Year Plan period 1977-78 – 1982-83 are applied to the Sixth Five-Year Plan period 1982-83 – 1987-88. Accordingly, these coefficient are assumed constant during the plan period so that – like in many linear programming models – economies of scale cannot be realized. Besides and much more important, only seven

⁷ See Kok, M and F. A. Lootsma, Pairwise Comparison in a Multi-objective Energy Model, in: Y.Y. Haimes and V. Chankong (eds.) *Decision Making with Multiple Objectives*, Springer, Berlin, 1985.

objectives are considered ignoring targets of economic policy like the level of prices, balance of payments situation, income distribution, satisfaction of various basic needs like food, health, housing, clothing, etc. In principle, these issues can be introduced in the model either in the form of additional constraints or as additional objectives. A more serious problem – as Kemal very rightly highlights – is the rather poor quality of available data on manpower issues.⁸

With these considerations in mind we present the results of the (equally weighted) multicriteria problem in Table 2. As mentioned before, the compromise solution vector is somewhere between the infeasible ideal and the inefficient anti-ideal solution. The relative distance from the compromise solution to the ideal is equal for four objectives (growth, unempl, unemp2, and unemp3, i.e. 0.47), whereas for three objectives the distance to the ideal is zero (illiter, unemp4 and unemp5).

Table 2

*A Comparison between the Ideal, the Anti-ideal, the Optimal Solution
Assuming Equal Weights and Plan Figures*

	Ideal	Anti-ideal	Compromise	Plan
Growth	317	260	290	289
Illiter	22.1	22.1	22.1	22.4
Unemp1	0.51	2.35	1.37	1.83
Unemp2	-0.28	-0.85	-0.55	-1.04
Unemp3	0.00	0.21	0.07	0.17
Unemp4	0.00	0.03	0.00	-0.01
Unemp5	0.06	0.08	0.06	0.08

Growth : increase of GDP during plan period, in billion rupees.

Illiter : number of illiterate workers at the end of the plan period, in millions.

Unemp(i) : number of unemployed workers with educational level *i* at the end of the plan period, in millions

The compromise solution is better than plan figures with respect to all objectives. Apparently, higher increase of GDP, more educated persons, less unemployment, and better tuning of manpower planning with production planning can be achieved with an even lower budget for investments and education. The sum of

⁸ A. R. Kemal, *Pakistan's Experience in Employment and Manpower Planning*, in: Rashid Amjad (ed.), *Human Resource Planning; the Asian Experience*. ILO (ARTEP), New Delhi, 1987.

physical and human capital investments during the plan period is more than ten billion rupees lower in our compromise solution than in the plan document. Further, the allocation of this budget – endogenously determined in the model – differs from plan figures in a number of ways. First, a higher percentage of total budget is spent on education and a lower percentage on capital investments. Secondly, basic education gets more priority in total educational expenses. Thirdly, the allocation of capital investments among sectors differs from plan figures (within the limits of plus and minus 10 percent being included in the model in the form of constraints).

Table 2 can also be used for determining implicit relative weights of plan targets. The planned growth target does not differ much with our (equal weight) optimal solution, but the resulting number of illiterates in the labour force is considerably higher in the plan than in this optimum and the required manpower with basic education is by far not sufficient to achieve the planned growth target. The implicit plan 'target' on the number of illiterates in the labour force is even worse than our anti-ideal which may indicate that this kind of analysis can be useful in the stage of plan preparation.

- (1) Maximize the growth (increase) in GDP.
- (2) Minimize the number of illiterates in the labour force.
- (3-7) Minimize the shortages and surpluses (in demand for labour) at each level of education.

SHAFIQ DRABANT

As is evident from the notes of Tabel 1 (which provides the optimal values of various objective functions), the objective function 1 is in billions of rupees and objective functions 2 - 7 are in millions of workers. Hence, it is quite obvious that function (A) would be technically incorrect if the same value of ϵ is used for all the functions. This implies that a reduction of one illiterate person, or of one unemployed worker, has the same impact on the objective function as an increase of Rs 1000 in the GDP.

(3) One would have appreciated some explanation as to why the plan targets differ (i.e. are 'worse') from the optimal values achieved by the model. The result of the model can diverge from the plan targets if the model used by the planners is not the appropriate model or due to the different set of assumptions (expressed as constraints in this model) being used in the two models.

(4) The demand constraint 3 is quite stringent. One fails to understand as to why such a constraint was necessary when a relatively less stringent constraint of the type 1 and 2 could have been easily incorporated.

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Policy Measures & Scenarios	Economic Indicators
Increase in Investment	GDP
Increase in Government Expenditure	Income Distribution (Rural/Urban and Poor/Other Households)
Increase in Indirect Tax	Rural and Urban Employment
Increase in World Prices of Manufactures	Exports, Imports and Trade Balance
Decrease in Tariff Rates	Price of Capital
	Price of Consumer Goods

II. MODEL SPECIFICATION AND DATA REQUIREMENTS

Due to space limitation it is not possible to give a complete and formal description of the model here, however its main features can be summarized as shown in

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**Comments on
"Growth, Employment and Education:
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This paper appears to be a part of a more comprehensive study/research project, and as such it fails to provide some of the details which a reader would have liked to be aware of, and which one can assume have been provided in the comprehensive version.

The paper advocates the use of a multicriteria model in the formulation of plans in Pakistan. Intuitively, this suggestion has considerable merit, but the paper spends more than required effort in explaining the multicriteria model, the details of which are available in a number of published sources. As not much effort is displayed on the empirical aspect, the task of the discussant becomes extremely difficult.

(1) One would have preferred to know the sources from which data were obtained and the methodology used to calculate the coefficients of the matrices used in the analysis. One would have also liked to know the reasons for this particular aggregation of employed persons in the given sectors, occupational and educational categories. For example, mining has been aggregated with the manufacturing sector, whereas data on all variables required for computation of the various coefficients are available on disaggregated basis.

(2) No information is provided about the weight ϵ . One is at a loss to understand the objective function used to arrive at the 'Pay-off' matrix of Table 1. The objective function is given to be:

$$c_i x + \sum_j \epsilon c_j x_j \dots \dots \dots (A)$$

where $c_i x$ is the value of the objective function i . One can clearly see the objective functions should have been $c_j x$ and the way its written is a minor typographic error, but whether the weight(s?) used for other objective functions is assumed to be the same for all functions or whether it varies with each function is not explicitly mentioned though one gets the feeling that a constant (small) value is used for all functions. Intuitively, one feels that weights should vary with the objective functions. The seven objective (functions) considered in the analysis are to: