Philippine Engineering Journal (1996) XVII (2): 29 - 38

A PRODUCTIVITY INDEX MODEL FOR PHILIPPINE ENGINEERING SCHOOLS

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ABSTRACT

The measurements of the productivity of education systems necessarily rely on numerous interrelated aspects and judgements. This paper illustrates an application of the concepts of multi-attribute utility evaluation of productivity for engineering educational institutions based on the assessment of deans of engineering schools/colleges in the Philippines. The school administrators selected for the surveys and elicitation process were from school that offered both B.S. Chemical and B.S. Mechanical Engineering undergraduate programs. Fifteen schools from the total list of 196 engineering schools (based on the official list of recognized engineering schools as of 1987, Technical Panel for Engineering Education) responded to the survey. Five of these respondents were selected for the further development and assessment of the proposed model.

Seventeen quantitative and qualitative measures of productivity were identified. The assessment produced an additive multi-attribute function with a bilinear sub-model for quality and quantity of research outputs. The model was tested using 4 engineering schools in the National Capital Region. The model was partially successful in evaluating the performance of the selected schools.

The potential application of the resulting aggregate measure is promising. However, it will have to go through refinements and adjustments to be truly representative of the preference consensus of the different school administrators. The development of a model relating the productivity index with a capability index is suggested as the most interesting extension of the model.

1.0 INTRODUCTION

The development of education relies on the financial, material and human resources that are so great that educational activity has become a leading branch of activity in all countries. Education budgets in many countries have more than doubled in the past 10 to 15 years. Because of other important claims on scarce national resources, it can be expected that the annual increments to education budgets will tend to be smaller in the future than in the recent past.

Faced with the dilemma of this widening gap between resources and requirements, educational leaders will need to work harder than ever to find additional revenues. What is even more important, they will need to give more attention to getting more educational results, and better quality results from the already available resources. In short, the improvement of efficiency and productivity has become a matter of urgent necessity for educational systems everywhere. To cope with this situation, educational managers and planners will need the help of improved analytical tools and of fuller information about their educational systems.

Some systems of education have been described as inefficient and others have been criticized of their low rate of productivity. Techniques of systems analysis are now being applied to education, as are other methods, such as cost-benefit analysis, goal programming, and others to determine ways and means by which efficiency and productivity can be improved.

This paper describes the elicitation of a multi-attribute model to represent the measure of productivity in engineering schools in the Philippines. The study focuses on a set of attributes perceived as important factors for the effective implementation of engineering education programs. There are two main reasons for this work:

1. To develop an aggregate measure of productivity in engineering schools using multi-attribute analysis;
2. To indicate the usefulness of multi-attribute models in the evaluation of productivity in the engineering education system.

1.1 Educational Productivity

The use of the concepts of productivity in education is of comparatively recent origin. It marks an extension in the use of the terms originally applied in economics to the traditional productive activities. It is therefore necessary first to examine the nature and define the concept of productivity and relate its meaning in education to that of the same concepts in economics.

Productivity, a theoretical concept, is defined by using the concept of the function of production. It is the quotient of output produced by a given organizational system and quantities of input utilized by the system to produce that output. It is usually expressed as a ratio of index of goods and services vs. resources. As you can see, the concept is quite simple . The ratio OUTPUT/INPUT obtained by quantifying both what the system produces or creates and the specific resources utilized to create those outputs, form an operational measure of the concept of productivity. Usually a distinction is made between over-all and marginal productivity. Whether it is calculated on the basis of absolute figures or increments, productivity is an estimate of the product in factor units.

Other concepts closely associated with productivity, are efficiency and effectiveness. Efficiency is somewhat synonymous to productivity in the sense that it also describes the ability of the system to transform its input requirements to the desired output. However, efficiency includes the factor of cost minimization and timeliness. Thus activities which require minimum effort and apply effective use of resources with least cost at the right time is preferred. Efficiency may also be defined as the capacity of producing maximum results with a constant effort of minimum effort with a constant result. It follows from this definition that efficiency is measured by comparing, whether implicitly or explicitly, one entity with another entity. Hence, the index of comparison of results and efforts may be regarded as an indicator of efficiency.

Effectiveness on the other hand, characterizes the extent to which desired outputs are obtained. It is mainly concerned with the results. A system is said effective if it is able to produce goods and services of desired qualities at required quantities.

Using these two measures, productivity ratios can be made by relating effectiveness measures to efficiency measures. In short, the definitions of the various concepts referred to, all clarify the relationship between the end product and the consumption of any given system.

The contribution of education to overall economic and social development has been demonstrated in several papers. All these studies, whether macro- or micro-economic, or whether based on an analysis of statistical series or resources allocation models attempt:

(a) To check the consistency of educational achievement with regard to objectives;
(b) To identify the contribution of education to economic growth; and
(c) Correlatively, to circumscribe the share allotable to education when distributing the benefits of expansion.

In this case, the concept of productivity as applied to education can hardly be distinguished from that of marginal productivity of economics. The productivity of education is defined exactly as that of capital or labor. The same holds true for efficiency and effectiveness. However, it should be noted that we are making a mistake in terminology as a result of constantly referring to productivity of education when what is really meant is the productivity of the decision-making system. For example, an educational system which produced too many art graduates and not enough scientists does not mean that it is unproductive nor inefficient but just shows that the decision-making system is unresponsive, since there is no consistency between the targets set and the decisions made to achieve them.

The system of reference should be clearly defined. This may be all educational activity of a country, the country's higher education, schools of a given area, or the program of particular university. Consequently, the concepts affecting education must be analyzed in relation to a specific system. The selection and definition of the terms used must depend on the nature of the problems the experts are trying to solve. For that matter, productivity measurement in institutions is selected as the system of reference.

1.2 Educational inputs and products

The definition and choice of concepts applied to education depend directly on the definition of the education sector itself. In order to assess the productivity or the yield power of a system, it is necessary first to define the nature of the factors consumed in the system's process and secondly to determine the end-product of the system.

At the institutional level, the factors entering the system's process represent generally a series of material, financial and human resources which contribute to the functioning of the system. These include fixed capital, faculty and staff, materials and equipment, and student enrollment.

This system supplies more than one sort of output. The products of the system include its graduates, research, publication and extension services. Input factors can fairly easily be defined and measured. However, the products of the system linked with the teaching function cannot simply be measured in terms of number. Both the quantity and quality of its products will have to be taken into account for a more meaningful overall measure of performance.

The following flow diagram taken from Durstine (1968) is illustrative of the general model structure of the education process of the educational institution.

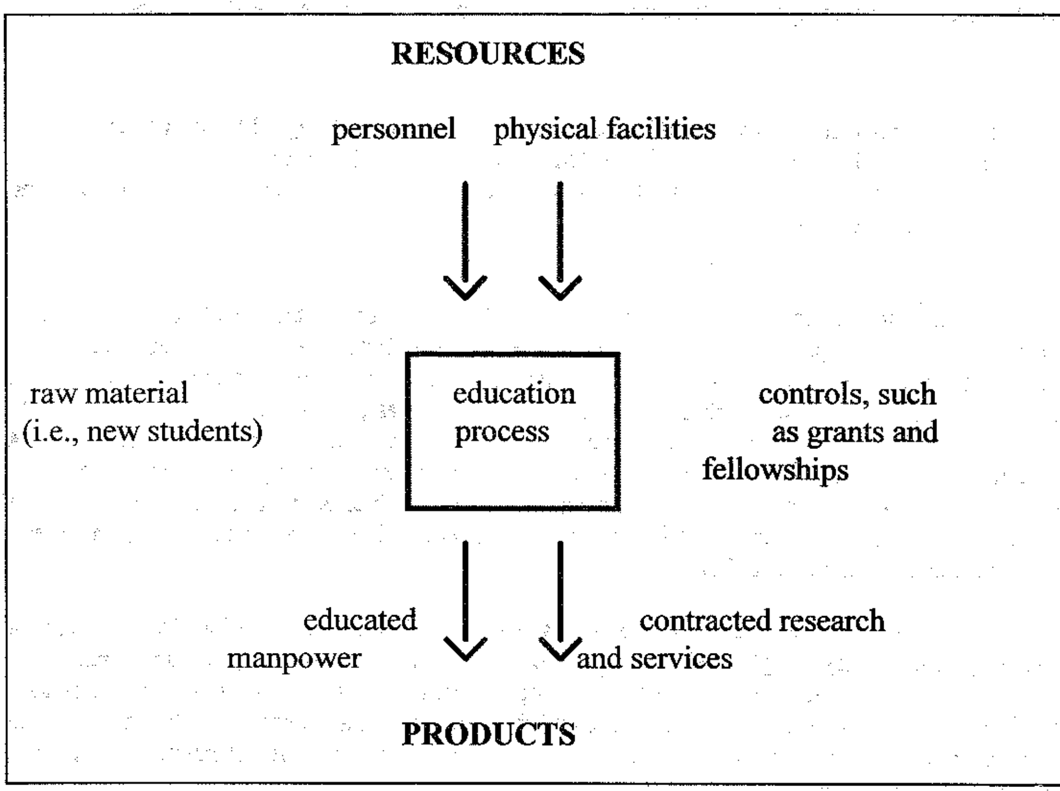

Figure 1. Model of an Educational Institution as a "black box"
Source: Durstine (1968)

2.0 PROPOSED THEORETICAL FRAMEWORK

Education managers continually face the dilemma of how to provide quality education with very limited financial resources. While attempting to achieve the goal of academic excellence, administrators must face the short-run reality of fast rising costs in line with more slowly increasing revenues. Aggravating this dilemma is the fact that the measures of defining academic excellence are either nonexistent or not universally agreed upon, whereas financial deficits are all too real. Consequently there is a danger that the directions taken by universities may be guided by short-run financial considerations than academic goals.

Researchers have never gone beyond assessing the economic aspects of the product of education. Often, Cost-Benefit analysis models have been used to measure the cost of education in relation to productivity. Although systems analysis approaches have been used in accounting for both economic and non-economic effects of education, difficulties in applying the approach are encountered in circumscribing outputs or outcomes since such analysis tries to assess precisely the quantity of knowledge acquired and the degree of success achieved.

In the problem of assessing the operational activity of an educational institution in order to ascertain, if necessary, ways and means of savings, one must fall back on the concept of productivity measured by the quotient of the system's products and the consumption of its factors. Often, the productivity of the institution is measured in terms of the number of graduates produced over a given period of evaluation, performance in professional examinations and the cost of education.

It is important to note that the concern of the educational institution is not confined to the number of quality products it is able to produce. Its responsibility extends to its ability to respond to the needs of its society. Hence, the productivity of the institution should be gauged both in terms of internal efficiency measures as well as external effectiveness measures. Measures of internal efficiency indicate the ability of the institution to make the best use of its resources with the least cost of minimum effort such as cost efficiency, quality and quantity of its graduates whereas external efficiency measures gauge the extent to which the institution is able to respond to the needs of industry, government or community such as employment.

It is relatively easier to measure and control internal efficiency than external effectiveness. The number of graduates and their acquired training can be monitored and addressed by the institution through its curricula, teaching methodologies, student services and others. However, it is very difficult to influence the success of employment of the graduates since other factors beyond the control of the institution take part in the final result (e.g., student preferences and personal objectives, national economic conditions, "luck"). Although graduating from a reputable school gives one an added advantage, if not almost assures of employment, a lot of uncertain quantities affect ones success or failure. Moreover, it would be necessary to establish a monitoring system to track and record the career paths of all its graduates. This would again require a considerable amount of resources.

Other output products must be considered as well. The role of engineering schools is not only to provide the economy and industry with a supply of qualified engineers. It is also the venue for research and development activities. Appropriate attention must be given to research projects, publication and extension services.

Considering the above, an extension of Durstine's "black box" model of the educational process may be drawn to illustrate the complete scope of the educational process whereby it is characterized by an interplay of input, output and outcome quantities. In this respect, we can identify internal efficiency measures from external effectiveness measures. This is illustrated in Figure 2. They are differentiated by the relevant input/output/outcome factors that define the evaluation.

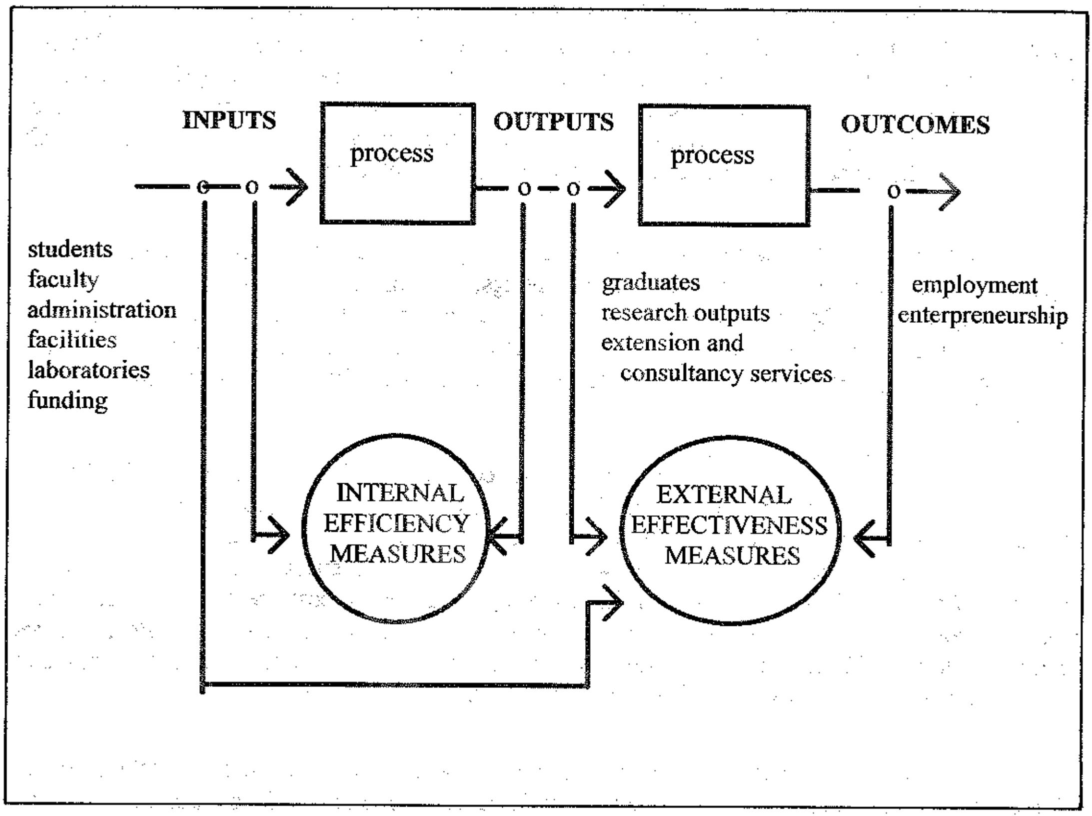

Figure 2. Proposed Theoretical Model
An extension of Durstine's "black box" Model of the Educational Process

Internal efficiency measures are defined by relating output products with the input consumption. On the other hand, external effectiveness measures are defined by relating outcomes with output products or outcomes with input quantities. Productivity should be seen in the light of both internal and external measures of performance.

Productivity measurement is made possible by an identification of the measures of the various components of the educational process. However, these measures will often be only indicators, and some indicators inevitably require judgmental evaluations. The mix of both quantitative and qualitative measures therefore will have to be resolved in the development of a single measure of performance.

Therefore, to develop a productivity value representing a measure of over-all performance which shall form as the ultimate basis for performance evaluation, it should be worthwhile to develop a function that uses the multi-dimensional measures of the quantity and quality of institutional products so that large values represent a greater degree of productivity. This is where the developments in the field of multi-attribute utility theory may prove to be helpful. The methodology makes it possible to assess and describe multiple objectives. It also allows the quantification of qualitative measures in terms of utility function. On this basis, aggregation of all performance measures can be performed. We will call such a function an Engineering Education Productivity Index (EEPI).

The effort of this study is concentrated on the concerns of school administrators (i.e. deans). Moreover, focus is given to engineering education in the Philippines. To consider all disciplines will involve far-reaching and intricate problems.

To establish a homogenous sample, engineering schools belonging to the same institution classification based on programs being offered were isolated. Specifically, these are institutions offering baccalaureate degree programs in at least 3 of the 4 major engineering disciplines (BSCE, BSChE, BSEE, BSME). This consists of 68 out of 196 institutions in the official list of recognized engineering schools by the Technical Panel for Engineering Education (TPEE). Hence, further discussion shall take reference to productivity measurement as far as engineering education productivity is concerned at the institutional level with the above mentioned characteristics.

3.0 METHODOLOGY

The formulation of a multi-attribute evaluation model was obtained using four stages. The first stage involved the identification and operationalization of the attributes or criteria on which the model is based. The elicitation of these attributes were accomplished through a survey of selected engineering schools in the Philippines offering undergraduate degrees in both Chemical and Mechanical Engineering fields. Fifteen (15) deans of engineering schools from different regions of the Philippines responded to this survey. The objective of the survey was to identify the different concerns regarding engineering school administration, their corresponding measures and creating a hierarchy relating them.

Second, an assessment of the utility functions for each attribute was made. Only five (5) out of the fifteen respondents were interviewed for this stage. The utility functions were constructed using the standard lottery procedure or by directly estimating the preference values.

Third, the mathematical form of the aggregate utility function was established. This involved determining the values of the scaling constants and assessing the indifference pair of values or trade-offs between the most important attribute and each of the other attributes. Finally, the performance of the resulting model was validated using actual data.

4.0 RESULTS AND DISCUSSION METHODOLOGY

4.1 Model Structure

Seventeen (17) major concerns relating the perceived measure of educational productivity were conferred by the respondents. The hierarchy of productivity attributes is as follows:

Rank	Variable	Attribute
1	X_6	Probability of engineering employment
2	X_4	Board exam passing percentage
3.5	X_5	Board exam competitiveness
3.5	X_7	Probability of employment
5	X_2	Completion rate
6	X_3	Percent honor graduates
7	X_8	Quality & quantity of research outputs
	X_{81}	No. of completed research projects
	X_{82}	Research impact count
8	X_9	Faculty research involvement
9	X_{12}	Faculty publication involvement
10	X_{15}	No. of sponsored seminars
11	X_{13}	No. of technical papers presented
12.5	X_{10}	No. of published books
12.5	X_{17}	Faculty consultancy involvement
14	X_{11}	No. of published articles/technical papers
15	X_1	Cost efficiency
16	X_{14}	No. of technical lectures delivered
17	X_{16}	No. of consultancy projects

The elicitation process resulted in an additive model described as follows:

$$U(X_1, X_2, \ldots, X_{17}) = 0.04\, U_1(X_1) + 0.07\, U_2(X_2) + 0.065\, U_3(X_3) + 0.095\, U_4(X_4) + 0.085\, U_5(X_5) + 0.10\, U_6(X_6) + 0.085\, U_7(X_7) + 0.06\, U_8(X_8) + 0.05\, U_9(X_9) + 0.04\, U_{10}(X_{10}) + 0.04\, U_{11}(X_{11}) + 0.05\, U_{12}(X_{12}) + 0.05\, U_{13}(X_{13}) + 0.04\, U_{14}(X_{14}) + 0.05\, U_{15}(X_{15}) + 0.04\, U_{16}(X_{16}) + 0.04\, U_{17}(X_{17})$$

where $U_8(X_8) = 0.50\, U_{81}(X_{81})\, [\, 1 + U_{82}(X_{82})\,]$

4.2 Model Validation

In order to evaluate the worth of the multi-attribute model, a comparison of an administrator's rating without using the model and the productivity index derived from the model was performed. Four deans of top engineering schools in the National Capital Region were requested to provide information pertaining to the defined productivity concerns to obtain a productivity index using the derived model. They were likewise requested to rate their respective schools in terms of their perceived productivity performance in a scale of 0-100%. Furthermore, they were also asked to rank the three other schools as well as their own in terms of their perceived productivity performance.

Using the derived model, the corresponding education productivity index computed fell below the perceived productivity ratings. This can be attributed to several reasons. First, the aggregate utility function may not approximate their true preference structure. This just indicates the difficulty in combining preference structures of several stakeholders. Second, possible measurement errors may have been committed in the elicitation process. Other biases may have been present in the assessment procedure especially since the assessment was performed only once. Iterative assessments may need to be conducted to minimize inconsistencies.

5.0 CONCLUSION

Despite the apparent variances, the deans cited that the model was an acceptable approach. It can be further noted that the model has somehow confirmed the rankings of the four schools they provided prior to the computation of the index.

Overall, the model was well received and provided them with a simple and easy to use method of evaluating system performance. The construction of this model opens an avenue for developing alternative methodologies for productivity measurement in the education sector. A lot of potential applications can be foreseen for this approach. Productivity measurement could be an alternative method of classifying and evaluating engineering programs and institutions. It could be used to formulate quantitative standards of education outputs. With a set of standards, it could be used to determine whether an institution is a quality school or a substandard one.

Perhaps the greatest usefulness of the model is the possibility of identifying areas of deficiency as well as its area of strength in engineering schools. Hence, policy programs and priorities could be guided accordingly to strike a balance among competing resources. As an evaluation tool, the model can help assess the performance of the school over different time horizons. As a result of the evaluation, the model would provide administrators with a guide for goal-setting and planning. Having a generally accepted measure available, administrators would be able to bring a larger measure of science to educational methodology, and a larger measure of scientific management to educational administration.

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