

## A PRACTICAL MODEL FOR DEVELOPMENT OF VIABLE ENGINEERING EDUCATION INSTITUTIONS IN AFRICA: WITH A FOCUS ON MANAGEMENT AND QUALITY OF ENGINEERING EDUCATION

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*One of the crucial elements that determine the competitiveness of nations is the population density of, and quality of, its engineers. This view has been corroborated by researchers such as Bilich (1989), Garelli et al (1997), and Gharajedaghi (1986). Unfortunately, most African countries are not performing well on this front. Engineering education institutions, entrusted with the task of improving these measures, find themselves in the unenviable position of attempting to operate in environments in which governments are continuously reducing funding to education in general. The objective of this paper is to develop a conceptual model which can aid engineering institutions overcome the financial constraints, increase throughput of engineers, and improve the quality of engineering education. The model is based on the cybernetics paradigm and is validated through structural and multiplicative corroboration.*

### 1 INTRODUCTION

In his book titled *Science and Technology Planning and Policy*, Bilich (1989)[1] argued that based on the empirical evidence from the detailed research he undertook, one of the critical elements which determine the competitiveness of nations is the population density of, and quality of, its engineers. This, he argued, was the key to the success of countries such as Japan and the USA, and it could be directly linked to the emergence of the Newly Industrialising Countries. This argument has been corroborated by other researchers, for example Garelli et al (1997)[2] and Gharajedaghi et al (1986)[3]. The key to understanding the importance of engineers is to note that an economy is constituted of assets (accumulated wealth) and transformation process (production, etc.) (Garelli 1994)[4]. Competitiveness combines assets and processes; Assets which are inherited (e.g. natural resources) or created (e.g. infrastructure); Process which transform assets into economic results (e.g. manufacturing); and then Internationalisation which tests the formula in international markets to create world competitiveness. The world competitiveness formula can be expressed as:

$$C_{\text{assets}} \times C_{\text{processes}} = W_{\text{world}} C_{\text{competitiveness}}$$

The key lesson to be learned by developing countries is that a "poor" country, which has few accumulated assets, can become competitive through a very efficient transformation process. For example, thirty years ago, Singapore was classified as a poor country. Today, through Science and Technology - led development, it is classified as a Newly Industrialising Country (NIC), and in the World Competitiveness Reports (WCRs) of 1994 and 1995, it was ranked second after the USA in world competitiveness<sup>1</sup>.

In Africa, only South Africa participates in the world competitiveness report, and its performance is below par. The WCR (1995) ranked South Africa 42 out of 48 countries. Mchunu (1997)[5] and Ryan et al. (1997)[6] argue that aggravating the latter is the low population density of engineers. For example, Japan has 4836 engineers per million people whilst South Africa has only 106. Ryan et al. (*ibid.*) also argue that compounding the problem is the low quality of engineers produced by the institutions. It is unlikely that other African countries fair better than South Africa. In addition, engineering education institutions in most African countries find themselves in the unenviable position of attempting to operate in environments in which governments are continuously cutting their funding to education in general. This makes long-term viability of engineering education institutions a critical issue.

We can thus infer that the following ought to be the key objectives of engineering education institutions in Africa:

- To increase the throughput of engineers through the education institutions.
- To improve the quality of engineering education
- To ensure long-term institutional viability.

The objective of this paper is to attempt to formulate a practical model which can be used to aid engineering institutions in Africa in their strive to attain the above objectives. The model is validated through both structural and multiplicative corroboration. The reference data used to develop the model is theoretical. However, this data was corroborated by participants of the workshop on Financing and Management of Engineering Education in Africa (FMEEA)<sup>2</sup>.

<sup>1</sup> based on the following factors: domestic economic strength, internationalization, government, finance, infrastructure, management, science and technology, and people.

<sup>2</sup> The workshop on the Financing and Management of Engineering Education was held in Gaborone, Botswana, 9-11 August 2000.

<sup>1</sup> The World Competitiveness Report is published annually by Garelli et al. It ranks countries according to their global competitiveness which is based on their aggregate performance

## 2 DEVELOPMENT OF CONCEPTUAL MODEL

### 2.1 Situational analysis of the means for attainment of the objectives

It is important to note that the three objectives mentioned above are interrelated in that they influence each other. An attempt to increase the throughput of engineers will aggravate the quality of education and transitively aggravate institutional viability if no attempt is made to improve these issues. The aggravation of institutional viability will in turn aggravate the throughput of engineers. Hence, we are dealing with objectives in a cyclical relationship, as shown in Figure 1.

Naturally, this complicates the issues. For the sake of simplicity, we will focus on the goal of institutional viability, an objective that can not be achieved without taking into account the other two objectives.

A system is viable if it can survive in a particular environment. Hence, the laws of viability are concerned with the dynamic structure that determines the adaptive connectivity of the sub-systems. The organization or system should be immune to infection and be adaptive to environmental change if it is to avoid the threat of extinction. Our engineering organisations are, fortunately, not extinct, but to what extent are they able to learn, adapt, and evolve in their particular environment?

Viability of an institution implies a forecast of the future, and this implies good sense of judgement and an element of luck since it is a matter of balancing probabilities of all possible variables. In the many instances, we fail to come out with viable solutions because we fail to formulate the problem correctly. The answers we get are a result of the questions we ask. Are we asking the right questions? C. West Churchman (1968)[7] argues that finding the right question to ask is the hardest part of problem solving. Russell Ackoff (1974)[8] says that it is more helpful to get a wrong answer to the right question than to get a right answer to the wrong question. Whilst there is no formula that tells us what the right questions are, there are a number of questions that arise from the paradigm of cybernetics and that have proven to be generally useful. Answering these questions will aid us in developing viable institutions. These questions are stated below:

1. What is the real purpose of the system? What purposes of the system might we infer if we looked at what the system is actually doing rather than thinking about the rhetoric on purpose? What purpose would we like the system to have?

2. What are the constraints on the system? Which of the recognized constraints are truly constraints and which are avoidable? Which of the currently recognized constraints could be avoided by redefining the system or redefining the environment or redefining the purpose?
3. What is the definition used for thinking about the system? What built-in constraints, assumptions, and beliefs does this language contain? Does this language create unsolvable problems for us? Can we invent a definition that removes or dissolves the problem?

The following section attempts to illustrate the utility of the said questions in aiding engineering institutions to evolve into viable organizations.

### 2.2 Purpose

The purpose of an engineering education programs is typically couched in terms of change in the engineers or would-be engineers, or in terms of competencies/skills/experiences the engineers should get during the course of the programme. Owing to the fact that our purpose is merely to change the student, we set up a learning process that is essentially narcissistic and blind (i.e. it focuses inward) and essentially no connectivity to reality except that which we assume exists between a set of engineer characteristics and that reality. This purpose tends to simplify our work to the detriment of the industry – a major stakeholder.

An improved purpose formulation may be stated as *to impact positively the institutions in which the engineers work*. The usual objection to this purpose is that it is impossible to assess. However, assuming we are serious, we can set up a learning process that focuses squarely on our relations to the realities we are supposed to ultimately affect. At undergraduate level, significant credits (say up to 10% of total credits) may be awarded for industrial training. At post-graduate level, students may be full-time industry based, and their performance may be based on their ability to address problems encountered in industry.

During the FMEEA workshop, the issue of quality of engineering education was raised, and there was convergence of opinion on the need to ensure that our engineering education is industry focused.

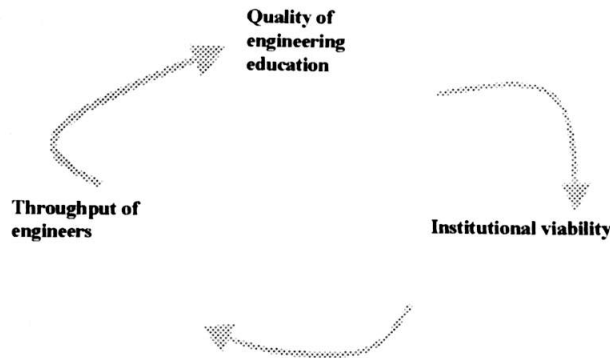


Figure 1. Relationship between the objectives

The following is a brief list of the workshop recommendations:

- The Faculty Boards could be made more representative by incorporating members from the industry. This exercise has proven to be effective at the University of Canterbury Christchurch, New Zealand.
- There is a need to encourage more industry-focused research at graduate level by forming research partnerships with some of the major industries in the nation. For example, the University of Durban-Westville, South Africa, has been successful in forming such partnerships with Eskom (power corporation), South Africa, and the Department of Water Affairs. Such partnerships not only improve the quality of engineering education, but also generate income for the institution.
- There is a need to encourage industrial training. The University of Botswana has been very successful in this venture and currently offers two industrial training attachments of 20 weeks duration each in its undergraduate programme. The result of this is that industry in Botswana perceives engineering graduates of the University of Botswana to be better than those from abroad.

The practical engineer is frequently faced with complex and tough problems. It therefore makes

sense to focus the student's training on trying to assist practicing engineers in solving or at least being part of the solution to these problems. This suggests that the programme of training, rather than focusing on a set of courses to be taken, should focus on applied research teams whose task it is to assist managers with their real problems. The advantages of this approach are manifold: it motivates students, exposes them to real engineering problems, gives them confidence and reinforces their will of focus. Another major advantage of putting students to work on real problems is that it gets both the staff and students out into the field and hence makes it possible to assess the validity and currency of the programme in the real world of engineering.

### 2.3 Constraints in the System

One area of seemingly unresolvable difficulty is that of poor teaching resulting from the infamous **PP** (*Publish or Perish*) syndrome. In most universities, professional tenure, promotion and status depend almost entirely upon publications, and usually, the research that leads to publication is typically quite separate from the teaching. Therefore, the rational response is to minimize the time put into teaching and devote more time to research. The result, of course, is that most university teaching is scandalously bad and the staff strenuously ignores attempts to improve it. A better formulation of the situation would be: make professional tenure, promotion, and status depend upon publications, and/or teaching, and services.

This reformulation takes cognizance of the fact that partnership is superior to competition. Rather than create an environment of *publish or perish*, an environment which fails to take cognizance of the primary goal of

engineering education institutions – to teach, it is better to allow some members of staff to focus on improving delivery of engineering education whilst others focus on improving the discipline. In this environment of partnership, colleagues share experiences through faculty/department seminars and in the end both teaching methods and the disciplines are advanced. The University of Cape Town has been successful in adopting this policy. It has the largest concentration of A rated scientists in Africa and is continuously advancing teaching methods, especially for large classes. There is thus a parallel progression to professorship through technical research and/or teaching methods research. It is also important to note that improved teaching methods which undoubtedly increase the reputation of the institution, lead to increased students intake and hence increased throughput of engineers, thus increasing the nation's density of engineers.

## 2.4 System Redefinition

The average age of African countries since independence is about 30 years. African countries are thus relatively young as compared to other developed countries. In a country like Botswana, which was rated as one of the ten poorest countries in the world at the time of its independence in 1966, education had to be financed fully by government. This has tended to create a dependency syndrome on government funding of education. This syndrome is, undoubtedly, unhealthy, in particular so for engineering education institutions which now have to operate in an environment of diminishing government funding owing to competing national projects. Engineering education institutions were defined as *institutions for the production of quality engineers*, and the issue of funding was the government's responsibility. There is a need for redefinition to reflect what we mean and what we expect of these engineering education institutions. It may be better to redefine them as *financially viable institutions for the production of quality engineers*.

This new definition requires a revolution in the mental models of those managing engineering institutions. To be financially viable, engineering institutions have to engage in activities such as the following:

- Consultancy
- Short courses
- Fund raising
- Autonomous business ventures

Adopting an *ad hoc* approach to do the above negatively aggravates the quality of engineering

education. Lecturers tend to devote less time to teaching, and hence quality drops, with severe repercussions on the future fortunes of the nation.

These conflicts can however be resolved by using the Viable Systems Modelling (VSM), a method developed by Stafford Beer (1981)[9]. It will aid the institutions to ensure that they do not sacrifice effectiveness for efficiency. It will also delimit the tendency of institutions to adopt unrealistic policies. For example, during the FMEEA workshop, one of the presenters stated that at his institution, they are facing a 45 % budget deficit which they would like to raise through manufacturing of parts for the industry. Through VSM, the institution would know that such a venture would not be viable if the workshops for manufacturing the parts are the same ones used by the students.

## 2.5 Practical Model

Management of engineering institutions ought to have an image of the desired outcome. This may include quality of engineering education, financial viability as well as institutional viability. These ought to be the primary goals of all engineering institutions. Institutions may, however, add secondary goals to the list.

Proper formulation of the current problem is of paramount importance. It often happens that in the majority of cases, the problem is already formulated and the current situation may be the present solution to the problem. This is especially true in re-structuring the management of running institutions. There are serious dangers associated with the formulation of such problems, as it is easy to become biased and lose one's objectivity when dealing with an existing institution.

Formulation of the problem can be aided by a "black-box" approach where the solution to the problem is visualised as a black box of unknown, unspecified contents, having Inputs and Outputs. A transformation process must take place in going from Inputs to Outputs. Also, there has to be more than one method of accomplishing the transformations, and there has to be unequal preferability of these methods (otherwise no problem exists).

The black box approach facilitates a proper identification of the inputs and outputs during problem formulation. It is important that the problem is formulated as broadly as is practically possible within the economic, time constraints and organisational boundary limits.

After formulation of the problem a detailed phrasing of the characteristics of the problem, including restrictions, should be carried out. This will involve considerable fact gathering, and care should be taken to separate the real

restrictions from the fictitious ones. Just because something has been done the same way for the past 20 years does not justify it to be a real restriction. Since the process of fact gathering brings us face to face with the present solution to the problem, it is important that we make every effort to avoid being biased in our thinking. It is also here that appropriate criteria should be identified for use in evaluating alternative solutions to the problem.

The search for alternative solutions to the problem consists of the specification of alternative contents of the black box employed in the formulation of the problem. Here, we should have as big a number of alternatives as possible. In search for alternatives, we should strive to be creative and divorce ourselves thinking from the present solution. We should also avoid conservatism and premature rejection or satisfaction. Reference should be made to analogous problems for ideas, and we should consult as widely as possible. It is important that during this process of

idea generation, we should remain conscious of the limitations of the mind.

Once the set of alternatives has been generated, an evaluation of the alternatives should be performed. This consists of the measurement of the alternative solutions, using suitable criteria as a basis for comparison.

Management ought to continuously monitor the current situation and compare it with the image of the desired outcome. If there is no discrepancy between the desired outcome and the current outcome, then the status quo ought to continue. If there is, action should be taken to influence the output. As discussed earlier, there may be a need to review the system purpose, system definition, or system structural viability.

The following practical model can thus be induced from the above to aid in developing viable engineering institutions:

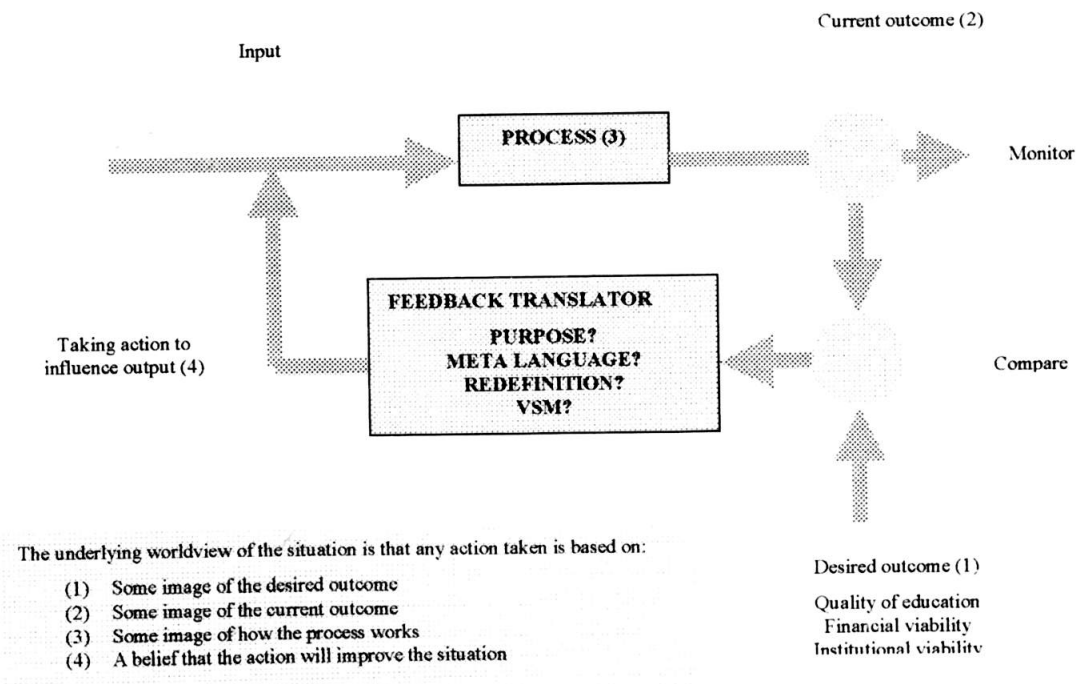


Figure 2. Practical Model For Managing Engineering Institutions

#### 4 CONCLUSIONS

The conceptual model presented in this paper can aid engineering education institutions in Africa

to overcome the financial constraints, improve the quality of engineering education and increase the throughput of engineers. Both multiplicative and

structural corroboration have been used to validate the model.

Induced from the paper are the following:

- There is an urgent need for increased throughput of engineers and improvement of quality of engineering education in Africa to enable African nations to compete globally. Achieving this is, however, made more complex by the fact that engineering institutions are operating in an environment in which governments are reducing their funding for education in general owing to competing projects of national importance.
- The paradigm of cybernetics can aid us in dealing with the problems of engineering education institutions by enabling us to ask the right questions; for example, is the purpose of the system appropriate? Is there any need for a redefinition of the issues? Is there a need for system redefinition? Is the organization structure designed for institutional viability?

The above questions are useful in enabling institutions to steer their organisations towards desired ends as derived by the stakeholders by taking appropriate action to ensure that there is no discrepancy between the desired outcome and the current outcome of the system. The practical model is shown in Figure 2.

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