Modeling and Analysis of Technical Education System: A KM and DEA based Approach

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Abstract: Technical Education System (TES) is a growing field that is bringing a paradigm shift in new future directives. To strengthen TES there is a need to effectively assess various institutes. The identification of strongest and weakest functions is important to impart quality education and hence achieve higher standards. This paper presents the Data Envelopment Analysis (DEA) for efficiency evaluation of TES. DEA is a linear programming method for assessing the efficiency and productivity of decision making units. The effective evaluation identifies the functions that improve the quality of education and bring improvements in the system. The function identification is based on knowledge based evaluation and it provides valuable inputs for further DEA exercise. Knowledge Management (KM) offers a great number of advantages for TES that have been addressed in the paper. The KM and DEA integration represents a step towards a real challenge of the near future. In this application, the final decision is based on the evaluation of a number of alternatives in terms of various inputs and outputs. The suggested approach can assist decision makers in selecting proper institutes to further strengthen the TES in an efficient and effective manner.

Keywords: Technical Education System (TES), Knowledge Management (KM), Data Envelopment Analysis (DEA).

1. Introduction

This is an age of fundamental and accelerated changes characterized by the globalization of organization networks, ubiquitous presence of information technology, dismantling of hierarchical structures, and creation of new organizational focus and networks (Narasimhan, 2003). The infusion of Information Technology (IT) into business operations is drastically changing the way businesses operate. Technical Education System (TES) is an area which significantly improves the various functions by using IT tools. TES is the key source of knowledge generation for any country. Technical Education System (TES) is an important facilitator of economic development. It is estimated that almost 50% of economic development is attributed to technology development globally. Over the years, the capacity of the technical education system has also increased manifolds. Technical education system, which grows at a much faster rate, creates a lot of opportunities but at the same time requires sufficient control over the technical institutes to follow the quality standards of education (Liberatore and Nydick, 1999). This need to monitor and evaluate periodically the performance of the institutes, is based on several functional inputs and outputs (e.g. functional variables). TES is facing a huge challenge because of constraints in resources such as finance, trained teachers, infrastructure, placement, research development, and costly technologies (Bodin and Gass, 2003). There is a growing need for TES to be more flexible and more responsive to a variety of needs. This requires modeling and analysis of the TES to deploy and exploit flexibility in a manner similar to that described by Wadhwa et al (2005). Further, in order to provide potential services to students, the TES should make use of Knowledge Management (KM) as a means of promotion, increased flexibility, sharing knowledge and improvement in the quality of education. One of the approaches to improve TES involves more effective monitoring and evaluation of the existing TES model towards improved quality evaluation. The quality evaluation of the institutes must involve selection and use of important quality factors (HRD and others) or input-outputs based on critical KM based evaluation. Saxena and Wadhwa (2004) suggest growing need for focusing on the influence of knowledge transfer in human resource development (HRD). They have suggested direction to incorporate globalization and knowledge management in human resource development systems in order to meet the digital era goals. For any evaluation it is important to identify important input-output factors. We propose a new direction to select the critical input-output functions based on the knowledge management process. In the process of KM, we build a database in which all the institutes share their critical information. We can extract useful information in the database and can enrich this knowledge using experts' comments. Indeed, we can select a few critical input-outputs based on knowledge sharing and knowledge generation process. KM has the potential to revolutionize the basic tenets of learning by making it individual rather than institution or industry based, more concerned about TES knowledge transfer and training, eliminating clock-hour measures in favor of performance and outcome measures, and emphasizing customized learning solutions. In this paper we have used both KM and Data Envelopment Analysis (DEA) to evaluate efficiency performance of the TES in the presence of multiple resource inputs, multiple outputs, and multiple hierarchical decision-making units (e.g. institutes).

Data Envelopment Analysis (DEA) is a non parametric technique used to assess the relative efficiency of operational units, through the calculation of efficiency score for each unit in a data set. DEA based evaluation of any technical institutes which is facilitated by KM inputs is suggested as an alternative because of present methodology being conflicting, inaccurate, and lengthy. The DEA is an effective approach in dealing with this kind of decision problems. The application of the final decision usually depends on the evaluation of a set of alternatives in terms of a number of decision criteria developed by KM processes. This paper examines 12 institutions based on their input-outputs (as generated through KM processes) and critically evaluates the issues involved. It also suggests the proposition of performance improvement. The method takes into account various changes in the educational system and analyzes the result faster and in a more effective manner.

2. Technical Education System: An Overview

The evolving global paradigm shift is effectively changing the behavior of technical education. In the present industrial context organizations need technically skilled manpower. To fulfill the demand of technical manpower, the number of technical institutes is continuously increasing at a faster rate. Along with the development in technical institutes, there is a growing need to have control over these institutes to maintain quality standards. To exercise control over a technical institute as a system, the term Technical Education System (TES) has come out. Technical education system is not only assessing and monitoring the performance of the technical institutes, but also supporting and facilitating in various ways. TES is striving continually for improvement in technical man power globally. Technical Education is instrumental in making significant contributions to economic development of any country. This is possible by way of imparting useful education and training and developing technologies that are suitable to the needs of industry and society. With the opening up of economy, global competition & advent of IT, the system is to face a variety of challenges to reorient its training methodology and delivery mechanism. In our opinion, knowledge management and decision methodologies can offer several new opportunities and challenges for improving the TES. This may require appropriate system analysis, re-engineering of the various processes, enrichment of teaching material and the level of penetration of quality education throughout the country. It is important to envision new TES architecture well supported by Knowledge management and decision methodologies to become globally competitive. The main strength of the technical education system is that it is well structured; it covers nearly all disciplines and offers programs at a very low cost to the students. It has largely met the skilled manpower requirement of the economy in the past and has the potential to meet the future needs too. It is generally self-reliant and has received international recognition for the quality of desired output. While several institutes in the TES are already world class, some lack the same status. The apparent weaknesses of these includes lack of proper quality assurance, obsolescence in curricula and teaching methodology, poor infrastructure and technology support, lack of autonomy in decision making (both academic and administrative), absence of a global perspective, a failure to attract and retain the talented to the teaching profession, disoriented students, and an overall shortage of financial resources. Some institutions are isolated with little interaction with employers, community, other academic and R & D institutions, and even within themselves. These institutes need special attention towards development.

3. Knowledge Management Inputs: Potential for TES Context

Keeping in view the strength and weakness of the TES context, the role of knowledge management needs to be suitably planned. From TES perspective, the concepts of knowledge management may be effectively used after appreciating what they can offer. "Knowledge Management is the ability to create and retain greater value from core business competencies" (Tiwana, 2000). Whether one learns from books or practical experience, the final result is knowledge. We can assess the acquisition of knowledge by inferring it from an evaluation of competent performance, which has arguably greater value, particularly in the world of work. So, while learning is fundamentally about acquiring knowledge (skill and competence), KM systems behave like learning systems, collecting, organizing and disseminating information in order to make informed decisions- there is even a branch of IT working on 'agents' or 'intelligent agents' capable of learning by themselves. Motivated by the role of KM towards business performance, we focused on a KM-TES-DEA framework based on the ideas proposed by Wadhwa (2001) and summarized in figure 1. It shows a synergy focused KM framework that involves integration between knowledge awareness, knowledge acquisition, knowledge adaptation, knowledge application and knowledge advancements. This ongoing process leads to business performance benefits. The synergy may be achieved through greater knowledge sharing from various knowledge stages. The greater the focus on knowledge use and knowledge sharing, greater will be the KM effectiveness in improving the business system performance. The synergy between University and Industry through concurrent thinking is important.

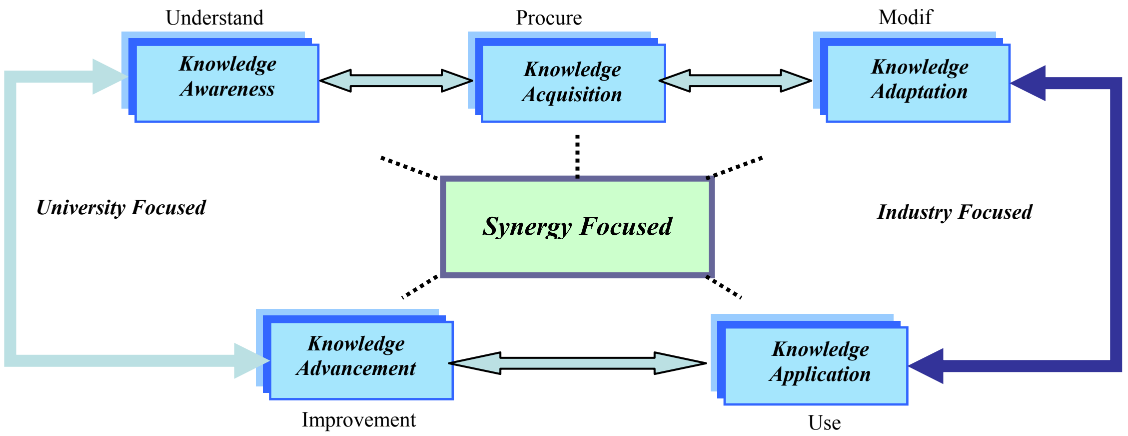

Figure 1: Knowledge Management (KM) Synergy Framework (Adapted from Wadhwa, 2000)

The knowledge synergy based thinking showed in figure 1 can significantly benefit the KM guided SCM endeavors. As indicated earlier each supply chain node is an autonomous node. Conventionally it takes knowledge decisions motivated by self-optimization at the local level. Due to a clear lack of collaborative-knowledge sharing and the associated concurrency, such decisions often become counterproductive. Ananda, and Herath, (2003) have well presented some of these ideas in detail. Wadhwa *et al.* (2002) are of the view that there are tremendous opportunities for adopting best practice KM and e-Business models or innovating new models for evolving new network structures. They propose the use of demo-models for analyzing different strategies from a Decision Information Synchronization (DIS) perspective. This context can be effectively applied in our domain by synchronization of knowledge to create wider benefits. KM shares a common goal that revolves around delivering timely and appropriate transferable knowledge and expertise to the point of performance. Nonaka and Takeuchi 1995, suggested that the cornerstone of the theory of organizational knowledge creation is the substantiate distinction between tacit and explicit knowledge. They define tacit knowledge as personal, context specific knowledge that is difficult to formalize, record, articulate, or encode. KM can be thought of as a program for learning, not only providing an environment in which the individual can gain knowledge and learn, but one in which the organization itself is transformed into a learning organization. The main objective is sharing knowledge and solving problems. The role of KM is dynamic and it needs to change with the changes in customer priorities on cost, quality, time, variety etc as shown in figure 2. One of the aims is to achieve an efficient TES capable of maintaining and improving the quality standards of the educational institutes.

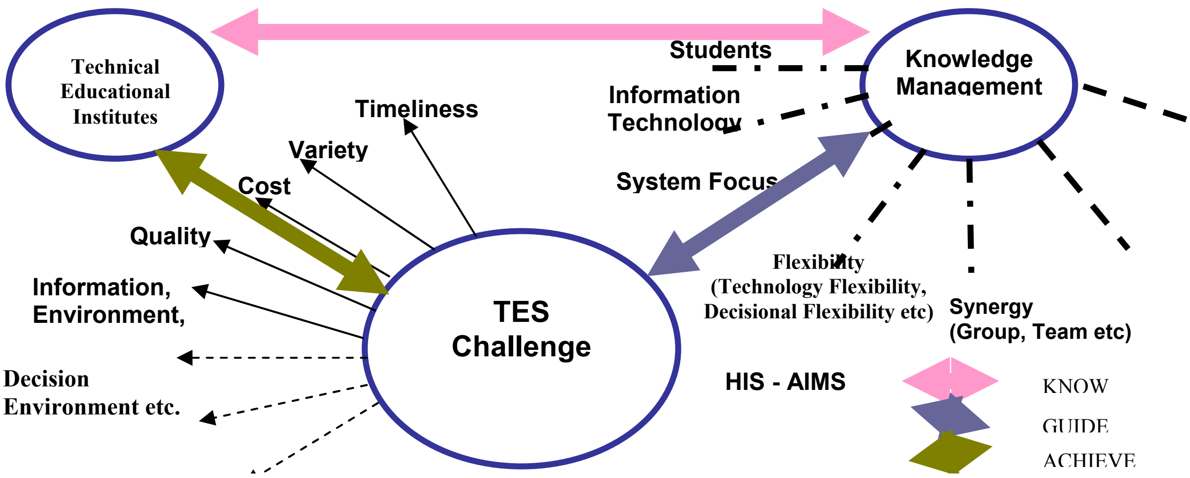

Figure 2: Knowledge Management in TES (Multidimensional Decisional Environment)

The growing KM challenges need some intensive efforts to evaluate the present education system in an effective and efficient manner. TES societies play a vital role in evaluating the technical institutes regularly in order to monitor the performance of the technical institutes and also to ascertain the required essential information to improve the performance of the institutes. This consistent and improved performance is highly dependent on the institutes' evaluation system (e.g. decision making to performance evaluation) that is currently preceded by expert panel on the basis of its individual benchmarks. These need to be changed as the current practices are time consuming, cost incurring, inaccurate and ineffective. Wadhwa and Saxena, 2004 discuss some innovative directions of KM in service sector which can help to improve the traditional effectiveness by adopting new ways to acquiring knowledge.

We propose a knowledge management based framework for identification of critical inputs which may further be used for decision making and problem assessment. Figure 3 supports the knowledge management framework for input generation. The process begins from information sharing by various institutes which may be further extracted as a useful knowledge.

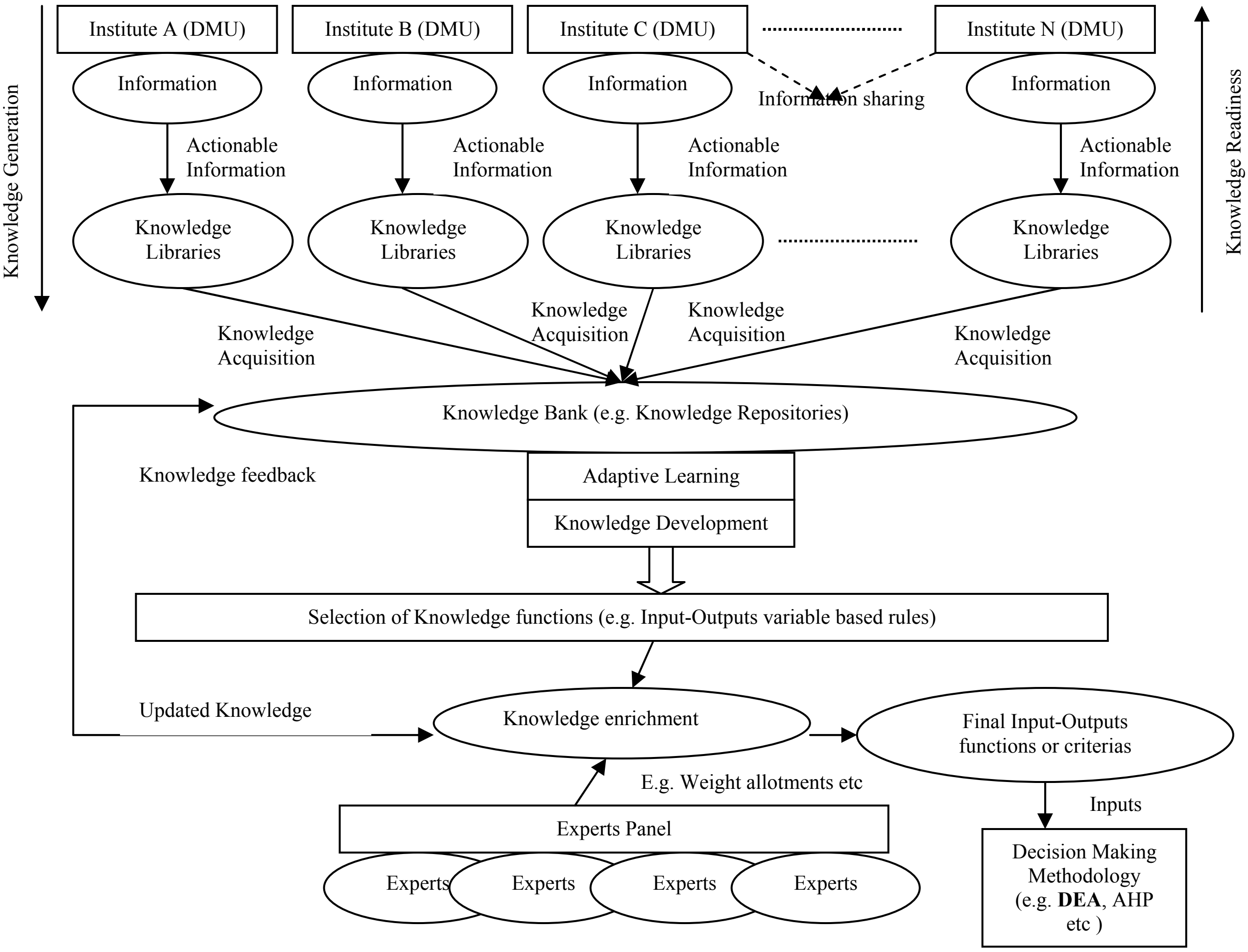

Figure 3: Knowledge Management based Architecture for Inputs and Outputs (e.g. criteria) Selection

This knowledge from various sources builds knowledge libraries which need critical scrutiny for knowledge acquisition. All these knowledge libraries are deposited in a knowledge bank. The knowledge bank is the source for generating knowledge functions (input-outputs variables). Then different experts enrich these knowledge banks with the help of their experiences. Finally the outcomes generate critical parameters (e.g. input-outputs variable or criterias) which may further be used for any decision making analysis (e.g. in our case DEA application).

4. A Vision on TES Supprted By Knowledge Management

We envisage that it may be expedient to evolve the TES to impart three levels of technical education in the country. These levels need to be well supported by KM evolutions. The strategic level may involve development of cutting edge technology based on the global competitive needs. It should be highly agile and capable of quick response to dynamic changes. This will involve significant collaborative and multi-disciplinary approach led by system engineers. The KM processes must be evolved to offer a support of facilitating on-line collaboration amongst multiple learners and experts. The KM processes must facilitate a proactive support to strategic TES. The tactical level TES must support the strategic level. Here the e-learning focus is on knowledge sharing. The KM support here is interactive in nature. Compared to strategic level, this level is close to the present technologies and may focus on the available knowledge about the same. It has some multi-disciplinary knowledge and one is taught how to evolve further knowledge. Finally the operational technical education must support the tactical level. The KM focus at this level is to share information about the various technology components. This is more focused on specialization in a discipline. For instance, the Mechanical Engineering component of the underlying technology is taught in detail at this level to Mechanical Engineers. Similarly the other technical disciplines understand their corresponding information. Compared to higher levels of technical education this level is less multi-disciplinary and less innovation focused. Its emphasis is on mastering the relevant disciplinary information about a known, well-established technology presently used. The KM support here is of a static and reactive nature. This means that a standard procedural support is there. One of the novel features of this three level architecture is that it has a clear technology focus, as opposed to knowing a generic set of engineering principles that may be applicable to multiple technologies.

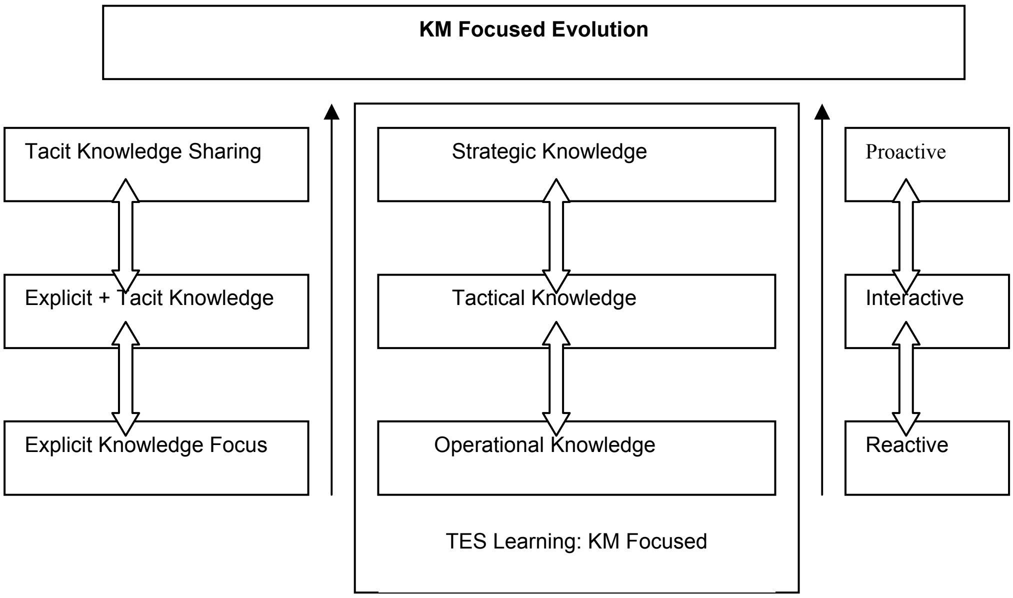

Figure 4: A KM focused Architecture for TES

In one sense it means specialist knowledge of a technology, rather than a broad knowledge about several technologies (i.e. no complete knowledge about any practicing technology). In our opinion it is important to envision, discuss and evolve new TES architectures that are well supported by potential evolutions in KM practices. We briefly outlined one such architecture (figure 4). There is a need to promote more ideas and studies in similar directions. Finally, a positive mind set which is amenable to radical changes towards significant improvements in the TES is required.

Wadhwa et al. 2005 outline a framework for viewing technical education system and governance system where KM discussed as a facilitator with wide implication of application. They have promoted the benefits of KM in the TES systems. In a similar way we are proposing a KM methodology for TES. The present institute evaluation system is based on direct observation that is generally made by experts. But the process is lengthy and also affected by individual expert opinion or his benchmarks. The automization of the evaluation process (e.g. based on input-outputs) with DEA application can overcome the problem satisfactorily and contribute in the improvement of quality of decisions with more synthesis and sensitivity. This may be helpful to identify the strengths and weaknesses of the institutes. KM inputs and DEA applications can not only overcome the limitation of the present method but can facilitate better solution methodology. The proposed process supported by KM environment is shown in figure 5. In our opinion, well-planned investments focusing on the judicious use of IT can maximize the value from the KM efforts in the TES domain. The conceptual case demonstrates the need for more studies to analyze several other processes in this area. It is suggested that the use of IT in form of databases, expert systems, industrial engineering tools, simulation tools and enterprise modeling tools can help in improving many similar processes. An important point for us is to learn from global experiences, but develop our own ingenious solutions for our specific needs. For example, we need to position KM as a support to the TES professionals and not as a replacement of the knowledgeable professionals.

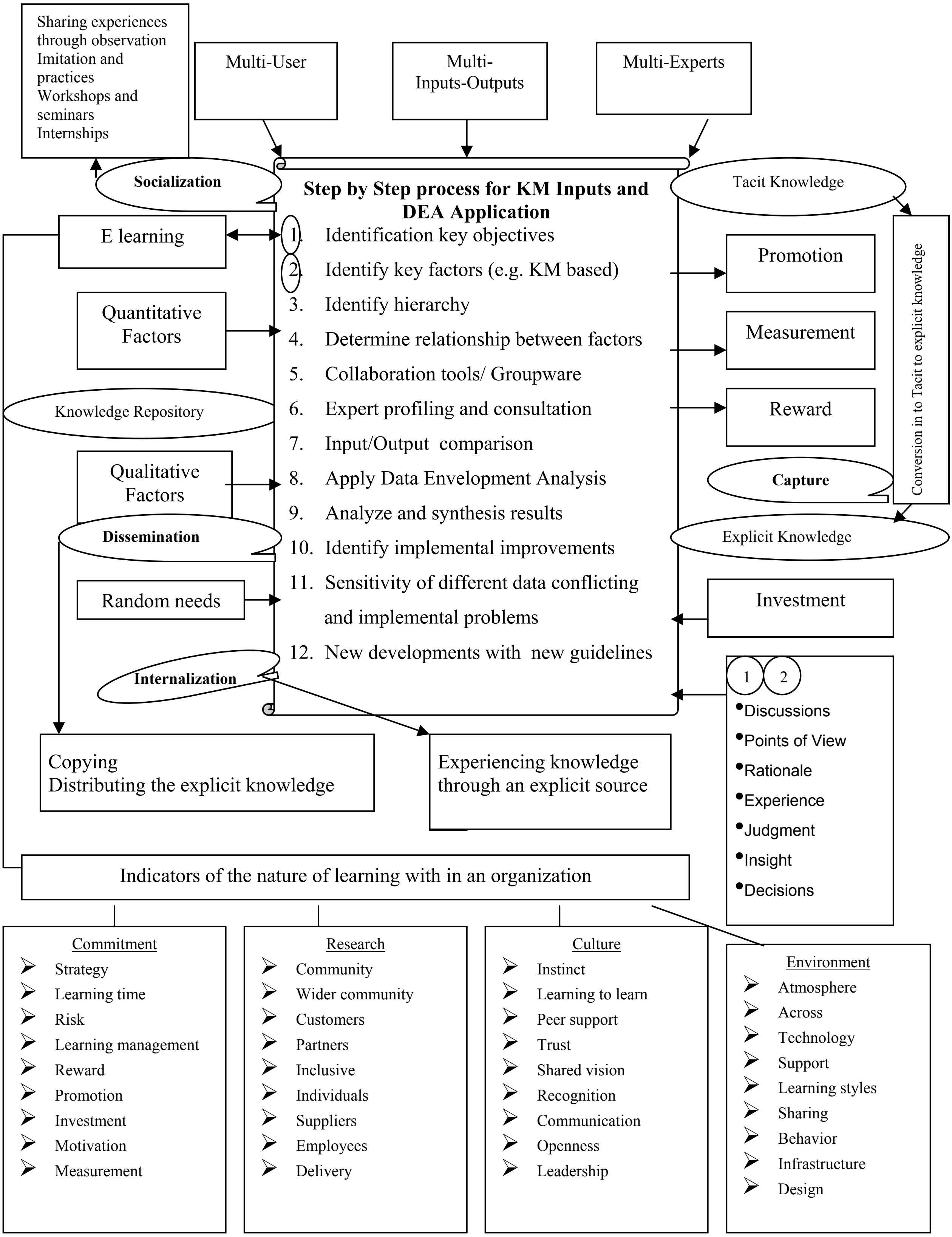

Figure 5: Proposed KM Vision for TES

5. Data Envelopment Analysis: An Approach for Efficiency Measurement

There is an increasing concern with measuring and comparing the efficiency of organizational units such as local authority departments, schools, hospitals, shops, bank branches and similar instances where there is a relatively homogeneous set of units. The usual measure of efficiency, i.e.:

$$Efficiency = \frac{Output}{Input}$$

Efficiency is often inadequate due to the existence of multiple inputs and outputs related to different resources, activities and environmental factors. This problem can be illustrated for depots of a large retailing organization which distributes goods to supermarkets. A formula for relative efficiency incorporating multiple inputs and outputs is introduced now, and the DEA model which allows relative efficiency measures to be determined is developed. The measurement of relative efficiency where there are multiple possibly incommensurate inputs and outputs. A common measure for relative efficiency is, which introducing the usual notation can be written as:

$$\text{Efficiency of Unit j} = \frac{u_1 y_{1j} + u_2 y_{2j} + \ldots}{v_1 x_{1i} + v_2 x_{2i} + \ldots}$$

Where

u_1 = the weight given to output i

y_{1j} = amount of output 1 from unit j

v_1 = weight given to input 1

x_{1j} = amount of input 1 to unit j.

The initial assumption is that this measure of efficiency requires a common set of weights to be applied across all units. This immediately raises the problem as to how such an agreed common set of weights can be obtained. The primary purpose of this section is to outline a number of commonly used efficiency measures and to discuss how they may be calculated relative to an efficient technology. Modern efficiency measurement begins with the work of Farrel (1957) and Debreu (1951) to define a simple measure of firm efficiency that could account for multiple inputs. They proposed that the efficiency of a firm consists of two components: technical efficiency, which reflects the ability of a firm to obtain maximal output from a given set of inputs; and allocative efficiency, which reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices. These two measures are then combined to provide a measure of total economic efficiency.

Data envelopment analysis (DEA) is a non-parametric mathematical programming approach to frontier estimation. In other words, DEA is a method for measuring efficiency of Decision making units (DMUs) using linear programming techniques to "envelop" observed input–output vectors as tightly as possible (Fried et al. 2002). DEA involves the use of linear programming methods to construct a non-parametric piecewise surface or frontier over the data. Efficiency measures are then calculated relative to this surface which can be perceived as the production possibility frontier. It is important to recognize the relation between inefficiency and productivity. Inefficiency can be defined as a measure of the variability of performance within an industry relative to a theoretical production frontier. This measure may not be directly comparable with productivity, measured as ratio of output to input.

The discussion of DEA methodology presented here is brief, with relatively little technical detail. Authors such as Afriat (1972) suggested mathematical programming methods which could achieve the task, but the method did not receive wide attention until a paper by Charnes et al (1978) which coined the term DEA. The need to measure "technical efficiency" led to the development of the Charnes, Cooper and Rhodes (CCR), (1978) ratio method of DEA. The CCR model gives a measure of the overall efficiency of each unit, where both pure technical efficiency and scale efficiency are aggregated into one value. Since then there have been a large number of papers which have extended and applied the DEA methodology. Charnes, et al (1978) and Charnes et al. (1995) proposed a model that is input orientated and assumed constant returns to scale. Subsequent papers have considered alternative sets of assumptions (such as

Banker, Charnes and Cooper (1984)) proposing, a variable return to scale model (e.g. BCC model). The procedure of DEA is based on the selection of Decision Making Units (DMUs), which are units of organizations such as banks, universities, and hospitals that typically perform the same function. A DMU usually uses a set of inputs (resources) to secure a set of outputs (products). One main advantage of DEA is that it allows several inputs and several outputs to be considered at the same time. In this case, efficiency is measured in terms of inputs or outputs along a ray from the origin. The choice of variables in a DEA study is of paramount importance and as a precursor to the study it is important to analyze the processes which will be addressed, to examine the variables and to pick those most appropriate to the goals against which good performance will be measured. The choice of the variables is determined by the process under consideration, as the classification as inputs or outputs. The inputs and outputs that are associated with the business process being analyzed also have to be classified as either controllable or non controllable variables. Controllable variables are those over which the management of the organization has control and so can vary. Outputs are controllable, while inputs may be either controllable or uncontrollable. Uncontrollable variables are those whose characteristics of use are outside the control of the management of the organization.

CCR Model Formulation- constant returned to scale (Charnes et al, 1978)

Envelopment Primal: min θ (contraction factor) - $\varepsilon s^{-} - \varepsilon s^{+}$ (residual adjustment along the frontier) (1a)

s.t. $\sum_{m=1}^{n} x_{im}\lambda_m + s_i^{-} = \theta x_{i0}$

(Input constraint) for i=1 to r inputs and for 1 to n units. (1b)

s.t. $\sum_{m=1}^{n} x_{jm}\lambda_m + s_j^{+} = y_{j0}$

(Output constraint) for j=1 to s outputs and for 1 to n units. (1c)

$\lambda_j \geq 0$ m= 1, 2 …n (1d)

$s^{+}, s^{-} \geq 0$ ε is an infinitesimal (non-Archimedean) (1e)

Objective function (1a) minimize the contraction factor, theta (θ), while seeking to drive input and output slacks ($\varepsilon s^{-}, \varepsilon s^{+}$) to zero. This minimization is subject to the following constraints:

(1b): efficient (contracted) input levels must be greater than or equal to input levels at the frontier.

(1c): observed output, must be less than or equal to frontier output levels.

(1d): non negativity for DMU "weights".

(1e): non-negativity for slacks

BCC Model Formulation: variable return to scale (Banker et al., 1984)

Envelopment Primal: min $\theta - \varepsilon s^{-} - \varepsilon s^{+}$ (2a)

s.t. $\sum_{m=1}^{n} x_{im}\lambda_m + s^{-} = \theta x_{i0}$

(Input constraint) for i=1 to r inputs and for 1 to n units. (2b)

s.t. $\sum_{m=1}^{n} x_{jm}\lambda_m + s_j^{+} = y_{j0}$

(Output constraint) for j=1 to s outputs and for 1 to n units. (2c)

$\sum_{i=1}^{n} \lambda_j = 1$ (Convexity constraint) (2d)

$\lambda_j, s^{+}, s^{-} \geq 0$ (2e)

ε is an infinitesimal (non-Archimedean) (2f)

(2a), (2b), and (2c) are identical to the CCR model corresponding relations, and function in the similar manner. Further, (2e) and (2f) correspond to (1d) and (1e) in the CCR model. The only new constraint is (2d), which is the convexity constraint. By requiring that all DMU 'weights" sum to a value of one, the model allows for variable return to scale.

The DEA technique evolved in the public sector and DMU is used to refer to the operational units being accessed. The technique can be used in circumstances where measure of performance is not cost/ profit related or where no cost information is available. DEA is a process based analysis, in other words it can be applied to any unit based enterprise. To make improvements, realistic and achievable improvements targets have to be identified with sufficient information for experts to be able to work towards them. Although, frameworks such as the performance based on the balanced scorecard (Kaplan and Norton, 1992), account for the financial and non financial measure of performance, they provide little information on how the resources might be increased or decreased in order to improve or maximize efficiency. There is where data envelopment analysis (DEA) comes in.

6. Problem Definition

In a broader canvass, the problem examined by the data envelopment analysis consists of a set of alternatives (e.g. 12 institutes) and set of input-outputs functions. The KM based inputs and DEA is useful to reduce the conflicts between different experts opinion and followed the unique generic procedure. Since most of the time information availability is sufficiently less and not numerical, DEA can be used as a good replacement. In this application, final decision is based on the evaluation of a number of alternatives in terms of relative efficiency. This suggested approach can assist decision makers in selecting proper institutes for further strengthen the TES in efficient and effective manner.

We selected a real life case of 12 technical Institutes (i.e. Institute A1, Institute A2, Institute A3, ..Institute A12) which are evaluated on the basis of 3 outputs and 7 inputs. The detail classification of these factors given below (Table 1):

Table 1: Knowledge based Inputs and Outputs for DEA based Evaluation

Controlled Input	Uncontrolled Input	Output
Management (MGT)	Unknown Resources	Research development and Interaction Effort (RDIE)
Faculty (FAC)	Organization and Government (O & G)	Human Resource – Students (HR-STUD)
Supporting staff (Tech/Admin.) (SS)		Teaching Learning Process (TLP)
Supplementary Processes (SP)		
Financial resources (FR)		
Physical resources (PR)		

The selected inputs and outputs are classified in detail and shown in figure 6. Figure 4 shows the explicit vies of all inputs and outputs and their dependencies. For our problem we have selected 3 outputs, 7 controlled inputs and 2 uncontrolled inputs. The aforesaid factors evaluate the institute's performance and finally the relative efficiency is being used to compare the different alternatives. This evaluation is mostly used for institute promotion and development. This direct evaluation of the institute is more accurate and is provides an absolute rating, but it is still not feasible because of lengthy, time consuming, and unjustified procedures. The traditional procedure encompasses the individual expert opinion to evaluate the institute rating and behavior, but it is not always true because opinion varies from expert to expert. The proposed procedures try to reduce this uncertainty in the decisions by using the mathematical tools like DEA, which have adequate features to improve the performance of the critical factors in output maximization or input minimization.

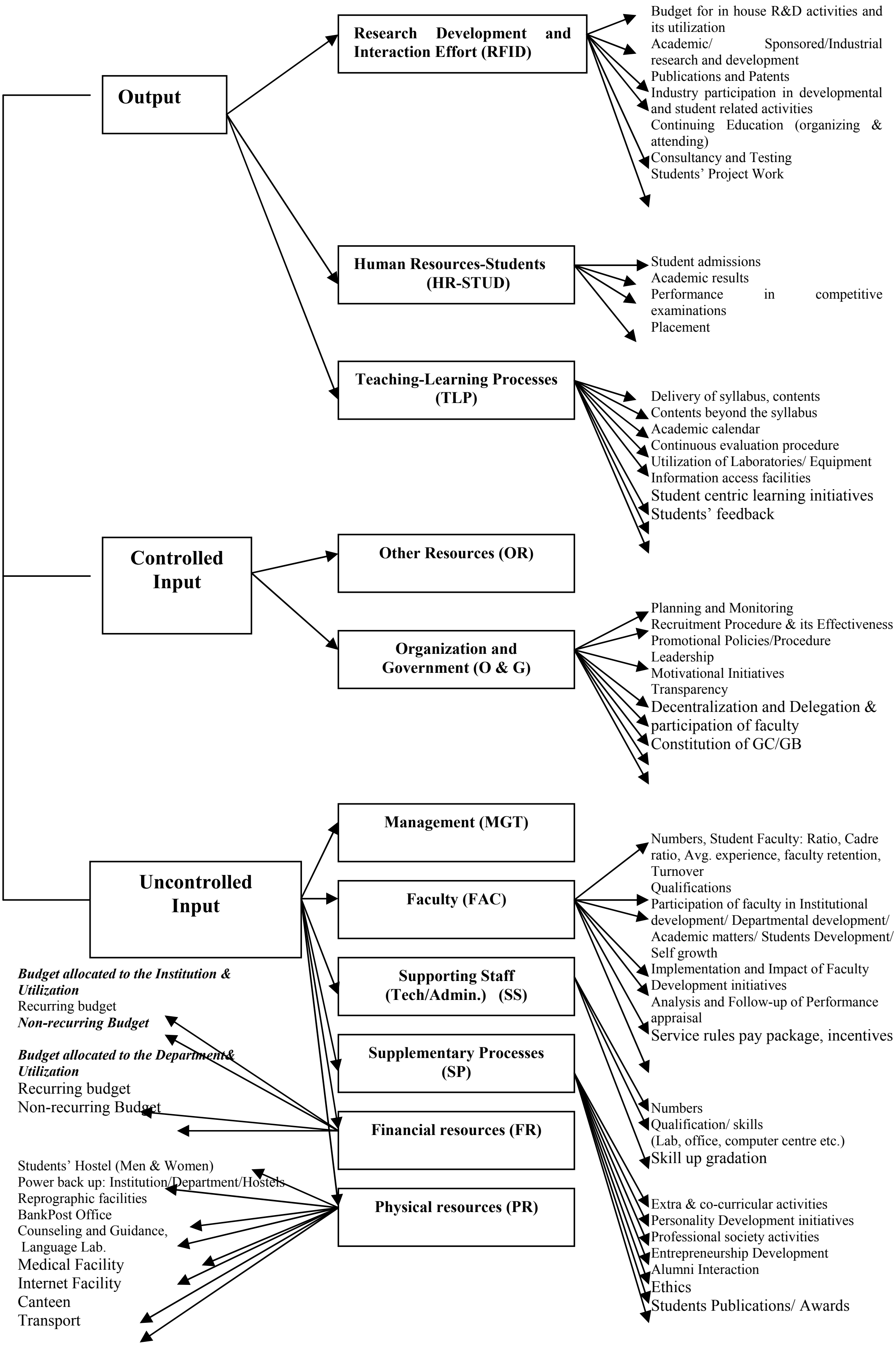

Figure 6: Input/Output Architecture of Technical Education system

The purpose is to explore alternative methods, which can advance the institute's evaluation process and increase effectiveness in the above scenario. The choice of variables in a DEA study is of paramount importance. As a precursor to the study, it is important to analyze the processes, which will be addressed to examine the variables. This is useful to pick the most appropriate variables to the goals against which good performance will be measured. The choice of the variables is determined by the process under consideration, as the classification as inputs or outputs. The inputs and outputs that are associated with the business process being analyzed also have to be classified as either controllable or non controllable variables. Controllable variables are those over which the management of the organization has control and can be allowed to vary. Outputs are controllable, while inputs may be either controllable or uncontrollable. Uncontrollable variables are those whose characteristic of use are outside the control of the management of the organization. A fresh vision of efficiency evaluation may be developed in this regard. Figure 7 gives the detailed information about the emphasis that the analysis uses for each input/output variable. This is a useful indication of the inputs and outputs that have been used in determining efficiency, and the ones that have been ignored (e.g. DEA based formulation).

Unit Name	Active	HR-STUD	RDIE	TLP	U-OR	O & G	MGT	FAC	SS	SP	FR	PR
A1	☑	94.00	96.00	99.00	75.00	99.00	66.00	93.00	99.00	95.00	99.00	91.0
A2	☑	92.00	96.00	92.00	80.00	100.00	82.00	75.00	86.00	85.00	91.00	98.0
A3	☑	84.00	72.00	87.00	70.00	70.00	92.00	86.00	99.00	98.00	93.00	97.0
A4	☑	99.00	79.00	81.00	59.00	70.00	80.00	74.00	86.00	87.00	92.00	90.0
A5	☑	86.00	72.00	88.00	56.00	69.00	71.00	74.00	92.00	89.00	82.00	89.0
A6	☑	84.00	69.00	82.00	56.00	67.00	76.00	76.00	98.00	93.00	80.00	86.0
A7	☑	73.00	78.00	79.00	56.00	82.00	84.00	79.00	94.00	79.00	88.00	90.0
A8	☑	77.00	68.00	74.00	63.00	74.00	75.00	69.00	93.00	85.00	80.00	78.0
A9	☑	65.00	55.00	52.00	80.00	86.00	89.00	83.00	90.00	85.00	78.00	76.0
A10	☑	65.00	66.00	72.00	63.00	70.00	89.00	85.00	96.00	83.00	85.00	78.0
A11	☑	71.00	69.00	55.00	54.00	68.00	80.00	74.00	88.00	59.00	69.00	73.0
A12	☑	78.00	61.00	72.00	61.00	66.00	73.00	65.00	89.00	77.00	88.00	74.0

Figure 7: DEA based Formulation of Input-Outputs Variables and DMU

7. A DEA based Orientation for TES

There are many different ways to view an education system and each view gives a different perspective of the attributes which define "good" performance. Ideally a performance measurement system should give an accurate assessment of how well an organization is performing (based on chosen parameters), along with providing information on how operations can be improved. Information such as how the inputs (resources) are linked to the resultant outputs (product or services), is useful in order to identify what 'drives" result. A DEA data set is simply a group of units (DMUs) and the values of their inputs and outputs, to be included in the analysis. DEA requires a data set of homogeneous units. Homogeneity refers to the degree of similarity between units. The operational goals of the units should be similar, as should their operational characteristics. A certain amount of pre- processing may be required to identify "outliers" in the data. Outliers are units that exhibit markedly different inputs/ outputs values from the rest of the data. Therefore, their operating characteristics may vary in some way. Some of the key features of DEA based analysis is elaborated and justified accordingly.

Peer group (Reference Set): One of the benefits of using DEA is that it identifies peers for inefficient units. A peer is a unit which is found to be efficient, with similar combination of weights as that of an inefficient unit. Where two or more of these efficient units act as peers for an efficient unit, they provide a peer group for the inefficient unit. The peer group is also known as the reference set of an inefficient unit. The characteristics of the units in the reference set provide the targets for the inefficient units to work towards.

Return to scale*:* The choice of which model is to be used for the analysis of the data set depends on the character of the data and the process which is being analyzed. The analysis of returns to scale is the identification of increasing and decreasing returns to scale. The lambda values which result from the solution of the DEA algorithm can be used as part of a further calculation to indicate the state in which a unit is operating – constant, increasing or decreasing returns to scale. If a unit is operating with increasing returns to scale, an increase in the input results in a more than proportionate increase in the output. If a unit is operating at decreasing returns to scale, then an increase in inputs results in less than proportionate increase in outputs. At constant returns to scale an increase in inputs results in a proportionate increase in outputs.

Identifying efficient operating practices: An important feature of DEA is the ability to identify efficient units, the reference set, which can be examined in order to identify appropriate targets for inefficient units to work towards. In the case study, we have identified the most efficient and inefficient institutes. In our view DEA is also enlightened the view of performance improvement and bottleneck remedies.

Distribution of virtual inputs and virtual outputs: The product of the inputs and the optimal weights for those inputs determines the values of the virtual inputs for a unit. Similarly, the product of outputs and the optimal weights for those outputs determines the values of the virtual outputs. Computing these virtual input and output values allows the analyst to determine which inputs or outputs ate the driving factors of a unit's maximum efficiency score.

Weight Restriction: Weight restriction should be used with care. The optimization performed in DEA is unbiased and the analysis will try to show each unit in the best possible light, regardless of whether or not this means that one or more inputs or outputs are effectively ignored.

Setting improvement targets: It is possible to set targets for the inefficient units to achieve desired outputs. A combination of input/output levels can be identified, based on the performance of peers, which act as a benchmark for the inefficient units to work towards. This information shows the input/output changes that must be made for the inefficient units to become efficient.

Resource allocation: DEA identifies inefficient units and provides information about how resources can be more efficiently assigned to give maximum efficiency. However, common sense and the practicalities of the physical world dictate that other factors have to be considered before the re-allocation of resources is actually carried out. It may not be physically possible to transfer resources from one area to another. Alternatively, if resources are redirected from unit A to Unit B because of inefficiency of the former – this might result in increased inefficiency if the target unit then is not able to fully utilize its other resources. Another consideration is that DEA is a method based on observed best practices. Any change made to the input/output profile of one unit will, to some extent, affect the efficiency score of numerous other units, since DEA efficiency is derived relative to other units in the data set and is not based on some definition of an ideal production frontier. Any suggested modifications in the input/output level require the DEA assessment to be repeated to ensure that this change will not have a detrimental effect on the efficiency of the unit being analyzed and that of its peers.

8. Results and Discussion

This section outlines the principle results which show the maximization of each DMU (e.g. Institutes as alternatives) on a variable scale method. The result shows the efficiency scores of these institutes (Table 1). In our case study there are 12 institutes, 3 outputs and 8 inputs. Out of 12 institutes 9 found up to the quality marks (e.g. 100% efficiency). We have selected the variable scale and output maximization to identify the relative efficiency. The maximization problems deals with the current levels of inputs used by a unit and what level of outputs it should be possible to achieve. Thus in our case of the output maximization, an appreciation of whether it is actually possible to achieve the target outputs generated by the analysis is needed. We have used a variable return to scale option because an increase in inputs does not yield the same increase in outputs. So, a non-linier relationship between results and resources has been found. Three units are found to be improved to get 100% efficiency.

Table 2: Efficiency Scores of DMUs (e.g. Institutes)

DMU	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
Score	100	100	98.67	100	100	100	100	100	83.94	97.31	100	100
Scale	Cons.	Cons.	Increasing	Cons.	Cons.	Cons.	Cons.	Cons.	Decreasing	Decreasing	Cons.	Cons.

The summary of synthesis of results is given below:

Potential Improvement: The potential improvement required in various DMU's is shown in figure 8, 9 and 10 (e.g. non efficient units). The percentage change in each input variable (output) that the unit would have to make in order to become efficient is shown in this graph. Input/output variables are along the Y axis, and the potential percentage improvement along the X axis. The percentage difference between these values is displayed in the potential improvement column. In our case, we select the units, A3, A9, and A10, which are less efficient.

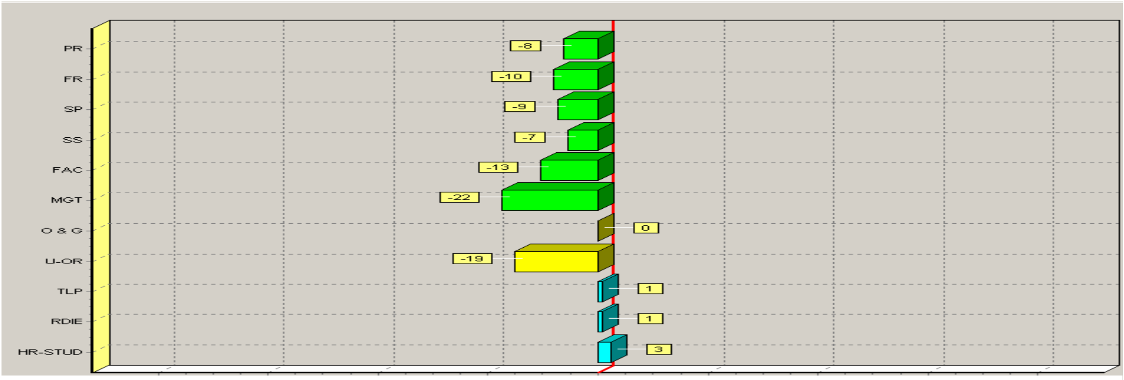

Figure 8: Potential Improvement Summary of Inefficient Decision Unit A3

The graph shows that there is room for improvement in each of the output variables (as in unit A9 have scope to improve TLP by 22%, RDIE by 24 and HR-STUD by 15%). Similarly in other units like A3 and A10 the potential is shown improvement areas. We can notice that the reductions can be made in 6 input variables; even through we choose to optimize outputs.

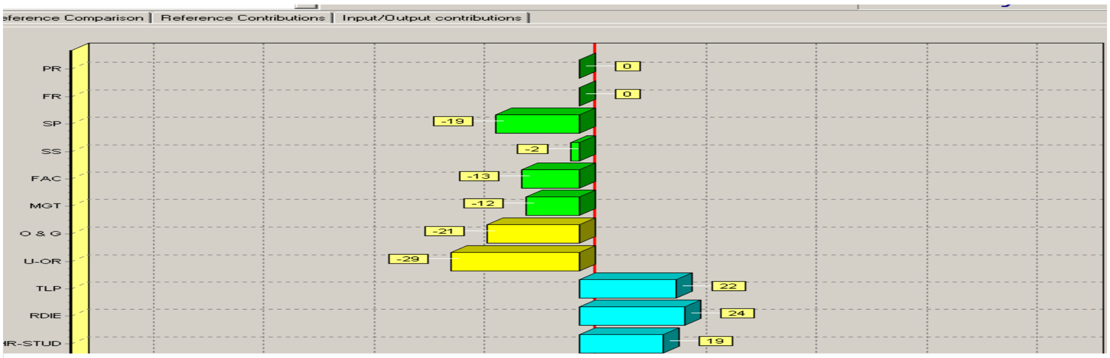

Figure 9: Potential improvement summary of inefficient decision unit A9

This is shown to achieve the score given; the unit did not actually require all of its inputs, but may be interesting information. The analysis is based on known performances of peers, so we can not assume that the unit could do better still, but this information may help to gain a better understanding.

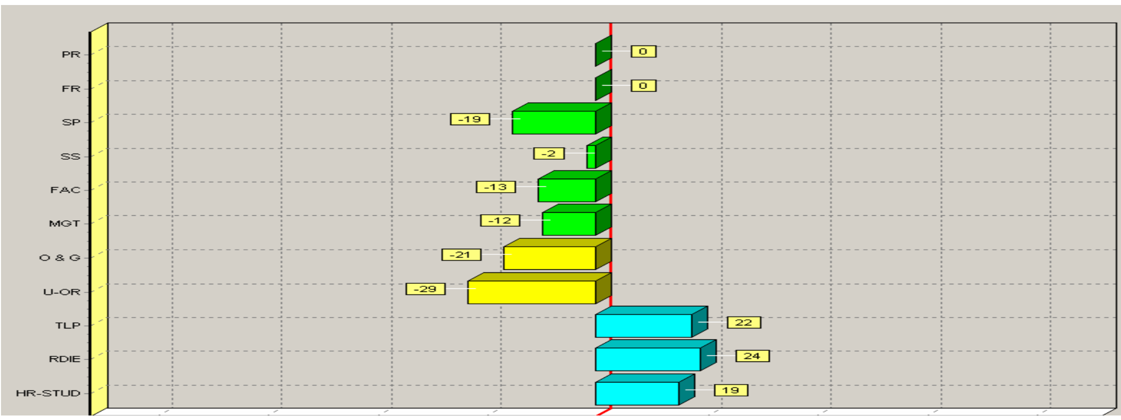

Figure 10: Potential Improvement Summary of Inefficient Decision Unit A10

Reference Comparison: The reference comparison provides information about the unit performance in comparison with its "reference units" or peers. Reference units are 100% efficient units, against which each inefficient unit is compared. An efficient unit will have one or more peers in its reference set. The reference set frequency shows the number of times an efficient unit appears in an inefficient unit's reference set. The higher the frequency, the more likely the efficient unit is an example of good performance. The figure 11 shows that alternative A5 and A4 (e.g. Technical Institute) is the most frequently occurring reference units (i.e. each occurs three times). These units appears in the most reference sets and may be called the global leaders that perform consistently well in comparison with other units. A12, A11 and A1 follow with 2 references. The other units like A6, A7, A8, and A2 have 0 occurrences and so may not be good examples of performance. These units have unusual combination inputs and outputs and as such may not offer best operating practices for inefficient units to emulate.

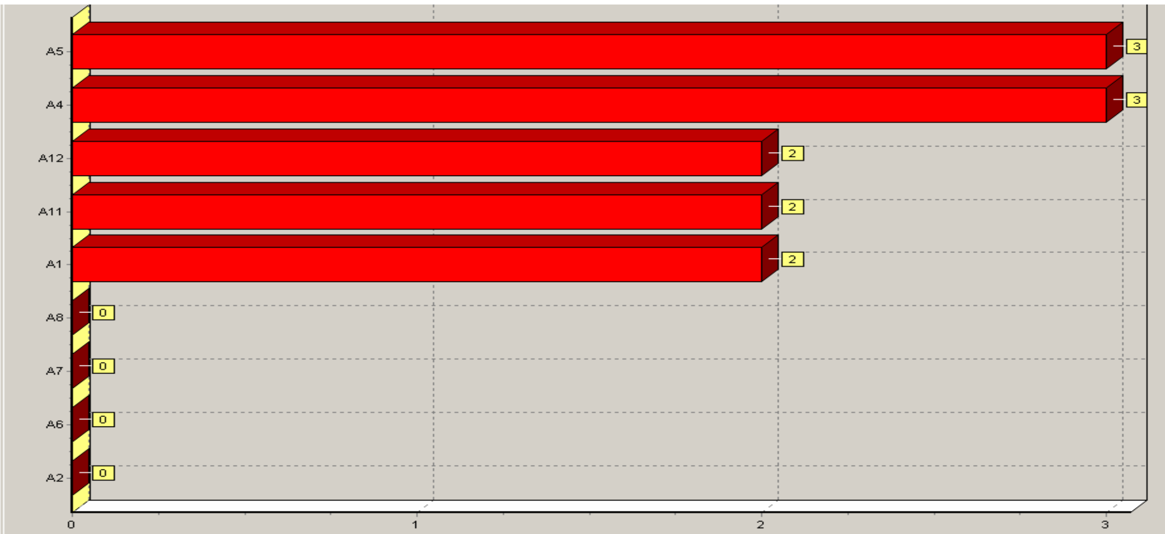

Figure 11: Reference Comparison of Efficient Units

The interpretation of these graphs is very much dependent on the data given. If one of the targets inputs/ outputs is very different, while the other input/output targets are similar to the actual, we should investigate why the unit is apparently so different from the reference. If all the input/outputs are different from their targets then this may typify a bigger problem within the input/ output conversion process. The reference contributions for that efficient peer have been checked.

X-Y Plot: This helps us to establish the variables that should be included in the analysis. If one or more variables have a strong positive correlation with another variable, it may be possible to exclude one of the variables from the analysis. In other words this means that they may represent the same phenomena. The exclusion of such variables would have the benefit of reducing the number of variables used in ensuring better discrimination between the units being analyzed. For this case the two variables, financial resources and physical resources, are fairly highly correlated and as such result, one of these variables could be removed from the analysis. We removed physical resource and this time the correlation is 0.32.

Efficiency Plot (X- Efficiency): The efficiency plot shows the spread of unit efficiencies plotted against the input and output variables. This plot can be useful in identifying if units with particular characteristics are either inefficient or efficient. The correlation between the efficiency and teaching learning process is highest (i.e. 0.59), indicating that there is good relationship between the teaching learning process and the unit efficiency score. Negative correlation can also occur between two variables and this indicates that high values of one factor are associated with low values of the other factor. The results also show that there is strong negative value occurrence in O & G, SS, SP and FAC.

Improvement Summary: The possible improvements are identified by the analysis. The potential improvement is calculated by the DEA analysis for each variable and by the unit count. The result shows that the largest potential improvement is possible for Management (i.e. 15.4) and then followed by U-OR, HR-STUD, FAC, and SP (figure 12).

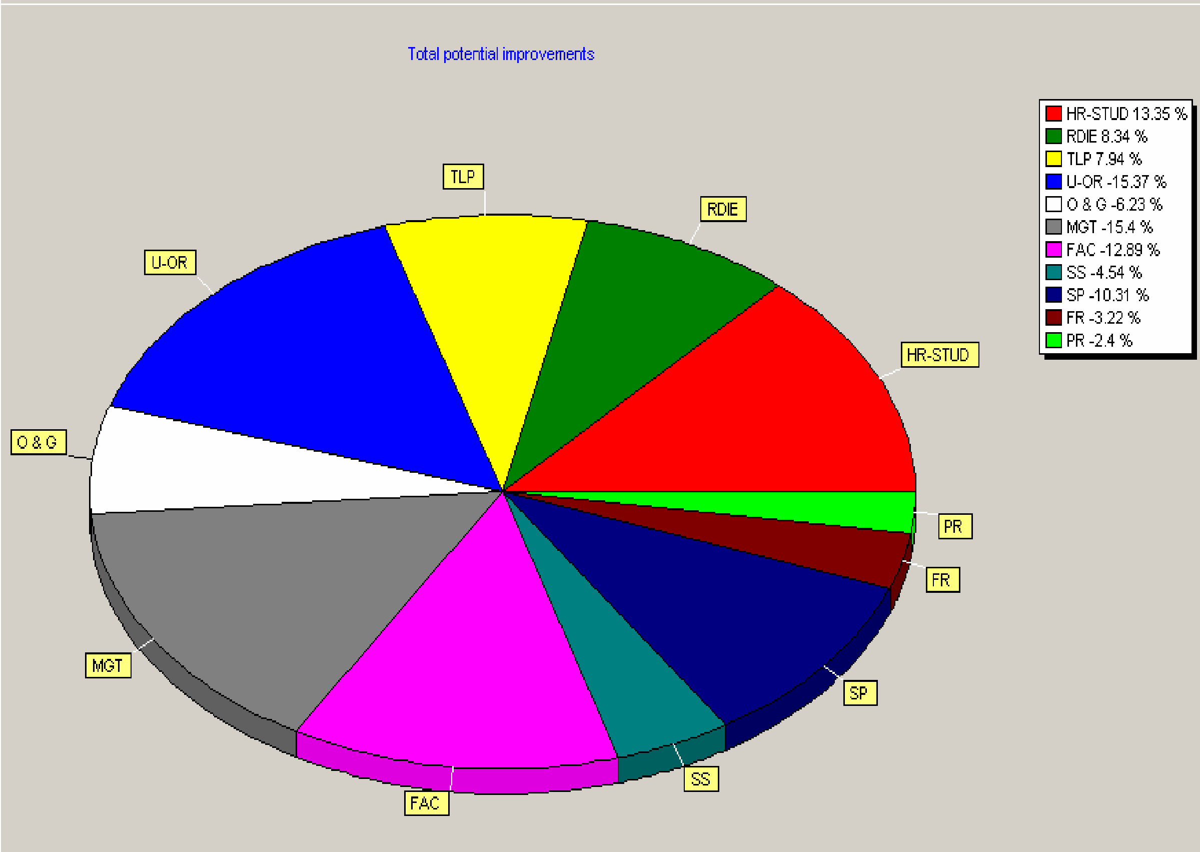

Figure 12: Improvement summary of all the function (e.g. input-outputs variable)

9. Conclusion

There is a growing need to improve the multi-dimensional effectiveness of TES. It faces challenges of flexibility, quality of service and greater value or effectiveness. There is a need to model and analyze ways to improve the quality evaluation of the various institutions. This paper proposes the use knowledge management (KM) and DEA for this purpose. The ability of DEA to identify peer groups, for inefficient units, is one of the main benefits of using this technique. Because the performance assessment is relative, the benchmarks and targets for improvement should be realistic and achievable. The TES must promote a judicious use of IT to continually improve. KM can enhance the effectiveness of the TES processes to make them more efficient and responsive to change (flexible). It is important to envision new TES architectures well supported by KM and DEA evolutions to make them globally competitive. The effectiveness institutes in the TES may increase by adopting DEA based models by creating worthy knowledge (e.g. based on knowledge bank) and giving sufficient privileges to the same. It is suggested to promote greater focus on KM-TES-DEA based integration to explore many new opportunities.

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