Towards knowledge management integrated quality accreditation system for Indian engineering education using system dynamics

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ABSTRACT

The engineering education system of India is becoming more and more complex due to various reasons like unmanageable number of colleges affiliated to universities, wide spectrum of student quality, multi-boss system in management and conflicting interests of stakeholders. Ever since the Accreditation board of engineering and technology (ABET) of US, Malcolm Baldrige National Quality Award (MBNQA) of US and European Foundation for Quality Management (EFQM) of UK have been established, many other countries have developed their own version of national quality award (NQA) and accreditation systems. These NQAs and accreditation systems tend to follow the general framework of the MBNQA or ABET or EFQM with different emphases on criterion. Since MBNQA has a prominent knowledge management (KM) component in it and EFQM has a strong mechanism of measuring outcomes/results, it is attempted to develop a robust framework for Knowledge Quality Management (KQM) by integrating KM and outcome components into it using systems theory. The system dynamics (SD) approach is proposed for the visualization and analysis of quality assessment of undergraduate engineering education in India. Towards this, all possible attributes and indicators to study the interaction and interrelationship of various enablers and results have been identified. Causal loop diagrams (CLDs) for various loops and the integrated CLD for the entire proposed model enabling development of a system dynamics (SD) model is presented.

Keywords: *Accreditation, Knowledge Management, Quality Management, System Dynamics.*

INTRODUCTION

Higher education in general, and engineering education in particular, as it has a direct bearing on the economy of the country, has been proliferated. But maintaining a balance between supply and demand is always a challenging task. Unless the engineering institutes produce engineers who are employable in the market or be entrepreneurs, most of the engineering institutes will be mere unemployment producing centers.

Engineering education system is of paramount importance in generating the technical manpower required for building a strong nation. The demand has resulted in setting up of a large number of colleges in India, offering a variety of programs to meet the demand. With the ongoing liberalization and globalization of the economy, more and more foreign universities/institutes are entering into joint ventures with Indian universities/institutes. For this purpose, an attempt was made to propose effective knowledge performance measures, corresponding enablers and inhibitors.

The approaches and methods adopted to resolve these issues are very important in this situation, for the maintenance and improvement of quality standards of engineering education. A study of the present assessment methods of engineering programs such as Accreditation Board for Engineering and Technology (ABET) of US, National Board of Accreditation (NBA) of India, Malcolm Baldrige National Quality Award (MBNQA) of US, European Foundation for Quality Management (EFQM) of UK has been undertaken in this connection to analyze and compare their capabilities in promoting quality in engineering education. The methods based on the linear thinking and mental models of policy makers and administrators are insufficient to analyze the performance related issues of Indian engineering education system. The insights based on the studies on accreditation processes and also the quality award excellence models of various other countries such as ABET, MBNQA, EFQM etc. motivated us for research towards KM based Quality Management.

Engineering education system is a growing field and to strengthen the system there is a need to effectively assess various engineering institutions. The identification of strong and weak functions (components) is important for quality education to achieve higher standards through continuous improvement. The integration of KM and Quality in engineering education seems to be critical. It is attempted to develop a self assessing tool for Quality in Engineering education by incorporating systems theory and integrating KM as seen in MBNQA, EFQM and ABET. Applying knowledge to decision making has a significant impact on organizational performance than solely processing transactions for KM. Looking at the very complex nature of knowledge as well as quality management issues in

Indian engineering education system, and to study the dynamics it is envisaged that the method of System dynamics can be used.

As Vishwanadhan (2008) pointed out, the following issues may lead to deleterious effects in the Indian Engineering Education system (IEES).

- Wide spectrum of student quality
- Lack of experienced faculty and their quality
- Mushrooming of colleges
- Location of colleges in remote places with non-proximity of industries
- Unmanageable number of colleges affiliated to a single university
- Multi-boss system-AICTE, state government, university and management
- Lack of appropriate performance measures
- Conflict about indicators of quality among experts
- Lack of proper methods of collecting, storage and analysis of information.
- Inadequacy of accreditation process to:
  - Make consensus about the validity of the process
  - Encourage continuous improvement.

The author has also presented the analysis and assessment capabilities of present NBA process of engineering programs to strengthen this argument. This paper contains sections like Literature Review, Problem on hand, Application of SD and Conclusions discussed hereunder.

LITERATURE REVIEW

Engineering institutions are basically the knowledge repositories which exist to equip the future engineers with required level of competence by imparting the underpinning knowledge, skills, attitudes, values, ethics and all other characteristics demanded by the engineering profession. Hence, the institutes should be equipped to transfer both 'explicit' and 'tacit' knowledge (Nonaka and Takeuchi, 1995) to the future engineers. The review of literature covered various facets of the technical education and is presented in brief hereunder.

Quality excellence models and frameworks

Ever since the Malcolm Baldrige National Quality Award (MBNQA) was established in 1987 after the Deming prize, many other countries have developed their own version of a national quality award (NQA). These NQAs tend to follow the general framework of the MBNQA with different emphases on criteria items such as leadership, customer focus, resource management and impact on society. Ten major national quality awards (three European, two North American, four Asia Pacific and one South American) are as follows:

1. MBNQA: Malcolm Baldrige National Quality Award, 1987 (National Institute of Standards and Technology, 1987).

2. EFQM: European Quality Award, 1997 (European Foundation for Quality Managament, 1996).
3. NQAF: Brazil National Quality Award, 1996 (National Quality Award Foundation, 1996).
4. SQA: Swedish Quality Award, 1996 (Swedish Institute for Quality, 1996).
5. NZNQA: New Zealand National Quality Award, 1996 (New Zealand National Quality Awards Foundation, 1996).
6. UKQA: United Kingdom Quality Award, 1996 (British Quality Foundation, 1996).
7. RGNQA: Rajiv Gandhi National Quality Award, 1994 (Bureau of Indian Standards, 1994).
8. SQA: Singapore Quality Award, 1996 (Singapore Productivity and Standards Board, 1996).
9. CAE: Canadian Awards for Excellence, 1997 (National Quality Institute, 1997).
10. GPNQA: Golden Peacock National Quality Award, 1991 (Institute of Directors, India 1991)

While all the above NQAs were generally focused to industrial organisations, National Institute of Standards and Technology (NIST) in 1994 exclusively announced the launch of MBNQA Education Pilot Program, to determine the interest and readiness of education organizations to participate in a nationwide recognition program and to evaluate the Education Pilot Criteria.

The studies that have analyzed MBNQA and EFQM have generally focused on examining their internal structure adopting either a causal approach (Winn and Cameron, 1998, Wilson and Collier, 2000, Meyer and Collier, 2001, Pannirselvam and ferguson, 2001, Flynn and Saladin, 2001, Goldstein and Schweikhart, 2002, Ghosh et al., 2003, Lee et al., 2003, Badri et al., 2006) or a factorial approach (Dijkstra, 1997, Bou-Llusar et al., 2005, Curkovic et al., 2000). However, with the exception of Curkovic et al. (2000) for the MBNQA, none of them analyzed whether the internal structure of the models matches the definition of TQM. Also no study on these models or adapted models used the system dynamics approach. Bou-Llusar et al. (2005, 2009) very recently conducted empirical assessment whether quality award models such as MBNQA and EFQM represent TQM and found that (a) Social and technical dimensions are embedded in the model; (b) Both dimensions are inter-correlated; (c) They jointly enhance results. These findings support the EFQM Excellence model as an operational framework for TQM, and also reinforce the results obtained in previous studies for the MBNQA, suggesting that quality award models really are TQM frameworks.

However the authors of this paper realized that additional research is needed, mainly in the case of the MBNQA and EFQM Excellence model, to study the dynamic interaction among the criterion.

Quality accreditation systems for engineering education

Accreditation of educational institutions all over the world specially engineering institutes has become almost mandatory. In the United States, the Accreditation Board for Engineering and Technology (ABET) is responsible for the specialized accreditation of educational programs in engineering and technology and related fields. It is the responsibility of the institution seeking accreditation of an engineering program to demonstrate clearly that the program meets the required eight criteria (ABET, 1997). These criteria, which are termed as EC 2000, are students, programme educational objectives, program outcomes and assessment, professional component, faculty, facilities, institutional support and financial resources, and program criteria. Similarly Russian Accreditation System for Engineering Education is also built up around eight criteria (RAEE, 2002). Canada follows a three criteria accreditation system (CEAB, 2002) for their engineering colleges. Accreditation Board of Engineering Education of Korea is the accreditation agency in Korea and follow a seven criteria system for the assessment of programmes (ABEEK, 2003). Japan Accreditation Board for Engineering Education (JABEE, 2003) specifies the standards of engineering education in terms of six criteria. ISO 9000 (BSI) is another framework, which is a procedural approach to quality assurance. Here standard of quality is defined according to stated and implied customer requirements, with procedures written and followed to assure that customer requirements are consistently delivered.

THE PROBLEM ON HAND

In the present research, the focus is on the Indian Engineering Education system. As far as Indian engineering education system is concerned, NBA is the official performance assessment mechanism. Through a series of workshops and seminars of academicians, industrialists, and administrators, NBA has finalized the criteria and procedures for the accreditation process (Manual for NBA Accreditation, 2000). NBA has been assisting the stakeholders in technical education to identify those institutions and their specific programmes, which meet the norms and standards and criteria prescribed by AICTE. The process has been reviewed periodically to make it more effective. These revisions indicate a positive shift of assessment from resource perspective to process perspective. Improvements are still possible to reduce subjectivity from the process and to make the accreditation fool proof. NQA Excellence models in India such as GPNQA and RGNQA are in existence but no educational institution in general and Engineering education institutions in particular have applied to undergo the assessment through them.

As observed before, there is a need to have a model (Figure 1) in which KM is integrated with internationally acclaimed Quality Excellence models such as MBNQA and EFQM. This new model should have the capability of assessing the dynamics among various measurements used in the respective NQAs.

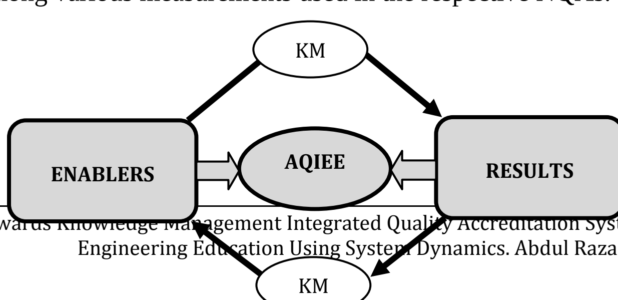

Figure 1: Conceptual research framework

In the proposed model, an additional sub-system capable of measuring, analyzing and managing knowledge has been conceived and integrated with the elements of MBNQA and EFQM models as shown in Figure 2. It is proposed with this enhanced model to facilitate consideration of various scenarios, identify different strategies, generate possible outcomes, analyze the same and assess the effectiveness dynamically. For this the concept of SD has been considered as a study methodology. In order to compare the effectiveness of different strategies, a comprehensive performance measure called as "Accreditation Quality Index of Engineering Education (AQIEE)" has been developed. Figure 2 shows how the evaluation is proposed to be done. The AQIEE is defined as follows:

$$\mathbf{AQIEE} = {}_{I=1}\sum^{n} (W_i * ENB_i) + {}_{j=1}\sum^{m} (W_j * RES_j)$$

In order to carryout different simulation based exercises, the enablers and sub-enablers shown in Table-1 have been identified. The output obtainable will be grouped into different classes of results, which are shown in Table 1.

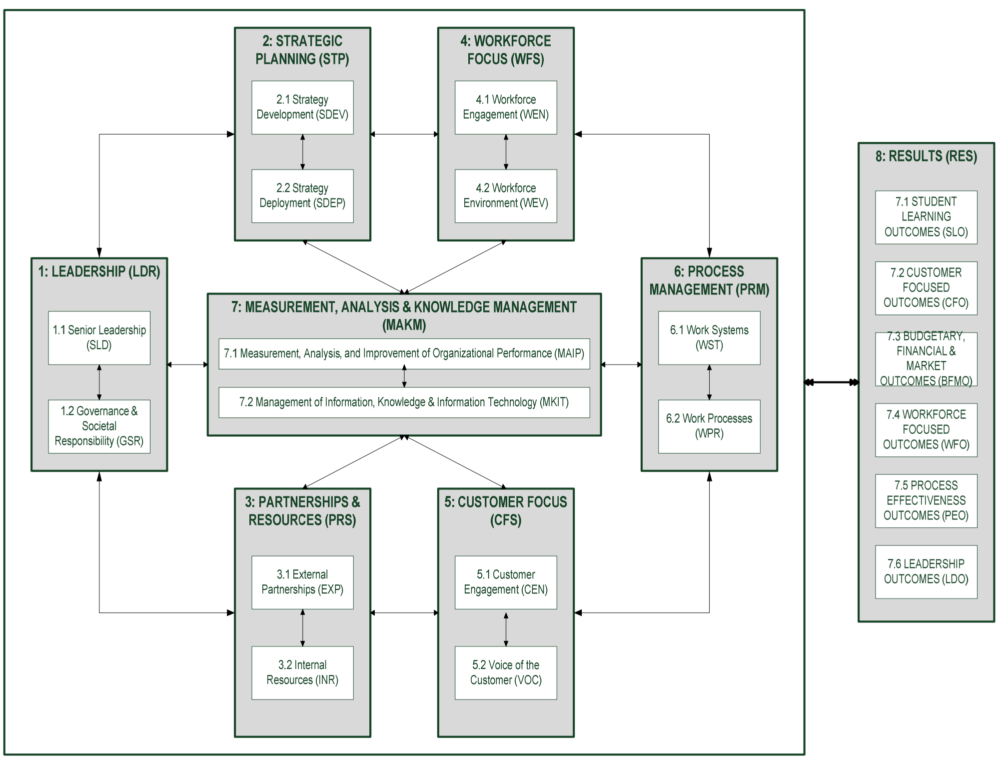

Figure 2: KM integrated Quality Excellence Model

Table 1: List of Variables: Enablers, Results and Others

ENABLERS	SUB-ENABLERS
1. Leadership (LDR)	1.1 Senior Leadership (SLD)
	1.2 Governance & Societal Responsibilities (GSR)
2. Strategic Planning (STP)	2.1 Strategy Development (SDEV)
	2.2 Strategy Deployment (SDEP)
3. Partnerships and Resources (PRS)	3.1 External Partnerships (EXP)
	3.2 Internal Resources (INR)
4. Workforce Focus (WFS)	4.1 Workforce Engagement (WEN)
	4.2 Workforce Environment (WEV)
5. Customer Focus (CFS)	5.1 Customer Engagement (CEN)
	5.2 Voice Of The Customer (VOC)
6. Process Management (PRM)	6.1 Work Systems (WST)
	6.2 Work Processes (WPR)
7. Measurement, Analysis and Knowledge Management (MAKM)	7.1 Measurement, Analysis, And Improvement Of Organizational Performance (MAIP)
	7.2 Management Of Information, Knowledge & Information Technology (MKIT)
8. RESULTS	8.1 Student Learning Outcomes (SLO)
	8.2 Customer-Focused Outcomes (CFO)
	8.3 Budgetary, Financial, and Market Outcomes (BFMO)
	8.4 Workforce-Focused Outcomes (WFO)
	8.5 Process Effectiveness Outcomes (PEO)
	8.6 Leadership Outcomes (PEO)
OTHER VARIABLES	
1. Accreditation Quality Index of Engineering Education (AQIEE)	2. Actual Budgetary, Financial, and Market Outcomes (ABFMO)
3. Gap in Student Learning Outcomes (GSLO)	4. Actual Workforce-Focused Outcomes (AWFO)
5. Gap in Customer-Focused Outcomes (GCFO)	6. Actual Process Effectiveness Outcomes (APEO)
7. Gap in Budgetary, Financial, and Market Outcomes (GBFMO)	8. Desirable Student Learning Outcomes (DSLO)
9. Gap in Workforce-Focused Outcomes (GWFO)	10. Desirable Customer-Focused Outcomes (DCFO)
11. Gap in Process Effectiveness Outcomes (GPEO)	12. Desirable Budgetary, Financial, and Market Outcomes (DBFMO)
13. Actual Student Learning Outcomes (ASLO)	14. Desirable Workforce-Focused Outcomes (DWFO)

15. Actual Customer-Focused Outcomes (ACFO)	16. Desirable Process Effectiveness Outcomes (DPEO)

APPLICATION OF SYSTEM DYNAMICS METHODOLOGY

System Dynamics focuses on the structure and behavior of the systems composed of interacting feedback loops. Causal loop diagramming is a convenient tool, which helps the modeler to conceptualize the real world system in terms of feedback loops. In a CLD, the arrows indicate the direction of influence, and the plus or minus sign indicate the type of influence. All other things being equal, if a change in one variable generates a change in the same direction in the second variable, relative to its prior value, the relationships between the two variables is referred to as positive. If the change in the second variable takes place in the opposite direction, the relationship is negative (Forrestor, 1985; Goodman, 1983; Coyle, 1977). The CLD shown in Figure 3 has been developed. While developing the CLD for AQIEE of Indian Engineering education sector, the following assumptions have been made:

1) Engineering educational organizations are aware of the total quality philosophy in enhancing competitiveness and enable continuous improvement of the system.
2) Engineering educational organizations are aware of Quality excellence models such as MBNQA, EFQM etc. that have contributed significantly towards organizational excellence in developed countries.
3) Engineering educational organizations are aware that Students' learning outcomes, Customers' and workforce satisfaction, financial stability are achieved through effective leadership, strategic planning, proper resources and effective systems and processes.
4) Engineering educational organizations are also aware that measurement and analysis of information and knowledge of the system will enable the system towards excellence.

Morecroft (1988) emphasized that model conceptualization begins with causal loops and moves to rate/level flow diagrams and finally to explicit equations capturing the diagram structure. Thus, the objective of the SD model is to capture the dynamic interaction of different variables that the system has and to analyze the policy decision over a long-term time horizon.

To model the combined effect of different variables, variables have been identified on the basis of earlier research (Agrawal, 2008) suited to Indian conditions. The purpose of modeling using SD methodology is to understand the transition phase of each scenario and to derive policies accordingly to maximize AQIEE. The present study analyzes the complex interactions among enablers and results variables and presents the interaction through a CLD. It must be noted that the key variables used for developing the CLD have been derived from the information provided in Table 1. How the dynamics are intended to be captured in the present study are explained hereunder.

Causal loop relationships: Qualitative analysis

It has been assumed that effective leadership modulates the implementation and thus enhances the AQIEE. Only top management can influence and alter the system, thus its role is crucial. Leadership must guide every system, strategy and method for achieving excellence (Khanna, 2002 and 2004). Thus an "increase" in leadership causes an increase in the AQIEE in the Engineering education sector. A "decrease" in leadership has the opposite effect. Therefore, the feedback loop between leadership and AQIEE is positive.

Similarly, Customer-focused leadership drives employees to: listen to customers and act quickly on what they say; listen specially to dissatisfied customers for they often deliver the most valuable information. The resulting increase in "customer and market focus" means that the organization will set high desired customer satisfaction as a particular goal. This may, if no other action is taken, increase the "gap" in customer satisfaction (the difference between desired customer satisfaction and actual customer satisfaction). Any increased gap in customer satisfaction will have a negative effect on leadership.

Thus the feedback loop between the variables of leadership, customer and market focus, desired customer satisfaction and the gap in customer satisfaction is also negative. As the gap in customer satisfaction increases, it will also have a negative effect on customer and market focus. Thus the feedback loop between the variables of customer and market focus, desired customer satisfaction and gap in customer satisfaction is also negative.

Therefore a detailed examination of the various interrelationships among the AQIEE variables to establish whether the various connecting feedback loops are positive or negative is presented hereunder.

a) Improved (increased) leadership will tend to increase customer focus, which in turn will increase actual customer focused outcomes. Increase in actual customer focused outcomes will reduce the gap in customer focused outcomes, which in turn will increase leadership effectiveness. Thus the feedback loop between leadership, customer focus, actual customer focused outcome and gap in customer focused outcome variables is positive. An increase in the gap in customer focused outcome will also tend to reduce customer focus. Thus the feedback loop between customer focus, actual customer focused outcome and the gap in customer focused outcome is positive.

b) An increase in leadership will tend to increase customer and market focus, which in turn will increase actual customer satisfaction. An increase in actual customer satisfaction will tend to increase the TQM index, which in turn will increase leadership. An increase in customer and market focus will also have a positive effect on the TQM index. Thus the feedback loop among leadership, customer focus, actual customer focused outcome and the AQIEE is positive. Also the feedback loop among leadership, customer focus and the AQIEE is positive.

c) The feedback loop among the variables of leadership, customer focus, actual customer focused outcome, actual Budgetary, Financial and Market outcomes and the gap in Budgetary, Financial and Market outcomes is positive. Also, the feedback loop among the variables of customer focus, actual customer focused outcome, actual Budgetary, Financial and Market outcomes and the gap in Budgetary, Financial and Market outcomes is positive.

d) The feedback loop among the variables of leadership, customer focus, desired customer focused outcome, desired Budgetary, Financial and Market outcomes and gap in Budgetary, Financial and Market outcomes is negative. Similarly, the feedback loop among customer focus, desired customer focused outcome, desired Budgetary, Financial and Market outcomes and the gap in Budgetary, Financial and Market outcomes in negative.

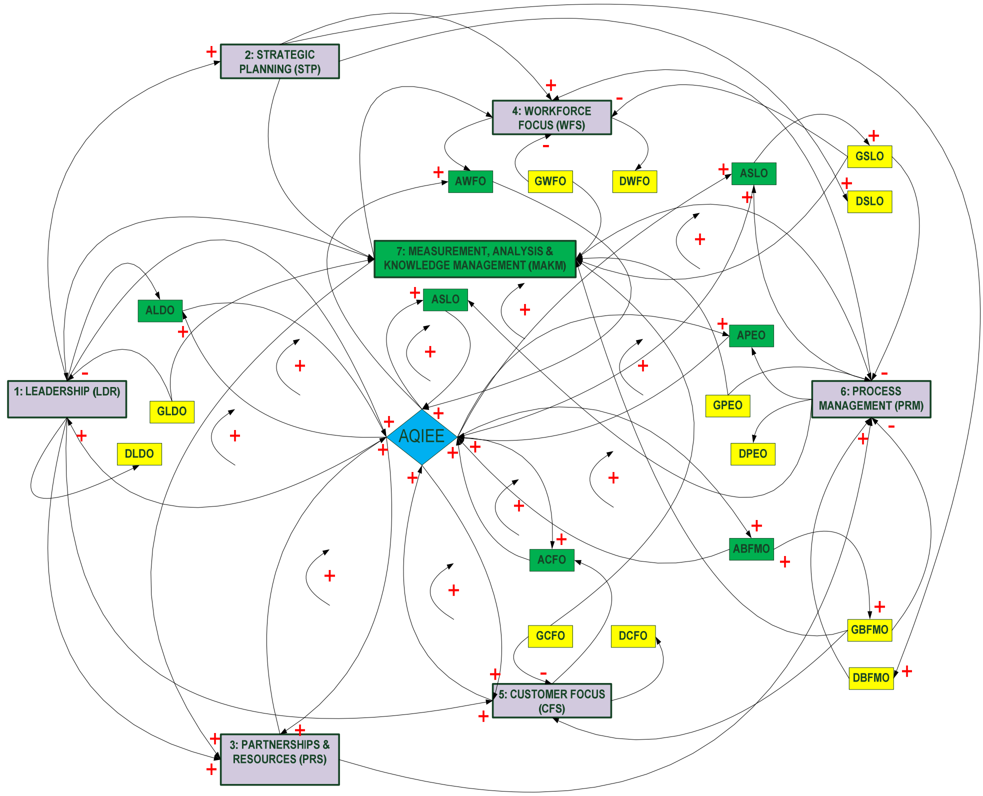

Figure 3: Aggregated CLD for Indian engineering education sector

e) The feedback loop among leadership, customer focus, actual customer focused outcome, actual Budgetary, Financial and Market outcomes and the AQIEE is positive. The feedback loop among customer focus, actual customer focused outcome, actual Budgetary, Financial and Market outcomes and the AQIEE is also positive, as is the feedback loop among actual customer focused outcome, actual Budgetary, Financial and Market outcomes and the AQIEE.

The CLD developed for the present study is shown in the Figure 3.

The CLD provides an insight into understanding the dynamic interactions among subsystems of KQM variables. Though working through the various casual relationships and feedback loops takes some time, it does build an understanding of those relationships, and it allows and organization to take proactive action to ensure the effective implementation of the KQM. The casual loop diagram has been used for KQM modeling of engineering education sector using system dynamic approach subsequently. This model can be used for evaluating long-term strategies, to ensure more effective implementation of the KQM philosophy and an enhanced AQIEE.

THE RESEARCH ISSUES

It is necessary to estimate the weights to be assigned to the criteria set though various criterions from the MBNQA and EFQM were integrated into it. Instead of taking the criterion weights as it is, it is pertinent to estimate in the Indian scenario. In the multi-criteria decision making (MCDM) literature, it is well known that assigning weights to the criteria set is a 'local phenomenon'. This means that the weights will be different for different decision makers. This is logical and a matter of common sense. Therefore it is necessary to obtain weights for the various criteria with respect to engineering education in the Indian context.

CONCLUSION

The literature published on Quality Excellence award models, Accreditation issues of Engineering education etc. was studied with a view to explore and identify a potential research problem. The scope of using SD as a research methodology and scope of carrying out a simulation study is discussed. A structural diagram for KQM system has been developed using the system parameters (enablers and results) identified from the literature and manuals. The proposed methodology, systems approach focuses on the interaction between various "Enablers" and "Results". KQMI variables may have different weights in different contexts, but it aids in understanding and evaluating the institutions' performance based on the realistic weightages. The CLDs for various loops and the integrated CLD for the entire proposed KQM model enabling development of a system dynamics (SD) model have been presented.

The formulation of an operational model of the KQM system is based on specific structural details like rates or policy variables, accumulation of level, auxiliaries, constants, information flows and delays. Flow diagrams represent such details and specific aspects of the model-structure. The causal loop shown for the KQM model will be converted into a stock-flow diagram (SFD) with the help of Stella software. The SD equations will be generated in the model, which represent the dynamics of the systems encapsulating the rate of changes with complex interactions.

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