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A Graph Theoretic Approach for Quantitative Evaluation of NAAC Accreditation Criteria for the Indian University

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***Abstract*—**Estimation of the quality regarding higher education within a university is practically long drawn process besides being difficult to measure primarily due to lack of a standard scale. National Assessment and Accreditation Council (NAAC) evolved a methodology of assessment which involves self-appraisal by each university/college and an assessment of performance by an expert committee. The attributes involved in assessing a university may not be totally independent from each other thereby necessitating the consideration of interdependencies. The present study focuses on evaluation of assessment criteria using graph theoretic approach and fuzzy treatment of data collected from the students. The technique will provide a suitable platform to university management team to cross check assessment of education quality by considering interdependencies of the attributes using graph theory.

***Keywords*—**Graph theory, NAAC accreditation criteria, Indian University accreditation process.

I. Introduction

HIGHER educational institutions have grown exponentially in India specifically in last two decades. One of the primary reasons is the manifold increase in the participation of private sector in higher education due to relaxation of government policies. Though it should have been a welcome step as a nation building exercise, the quality required from the passing students was in general a miss. With the proliferation of higher educational institutions, the responsibility was set on government to monitor the quality of educational institutions. Since the success achieved in life by a student is dependent on the quality of education received, hence monitoring the quality of education was required for sustenance and further improvement of educational quality.

To address the issues of quality of higher education in India, the NAAC was established in 1994 with its headquarters at Bangalore. It is an autonomous body established by the University Grants Commission (UGC) of India to assess and accredit institutions of higher education in the country.

NAAC has based its quality assessment of higher education institutions (HEIs) on 32 key aspects defined under seven major criteria. The key aspects specifically focus on the outcomes based on student learning and development. NAAC manual consists of set of questions based on key aspects to be asked from each HEI. The key aspects within criteria may depend on one another. Similarly, criteria may also affect each other. Thus, the issues addressed within the criteria and key aspects are closely inter-related and may appear to be overlapping. The criteria and the key aspects do not cover everything which happens in every HEI and hence may not be considered as set of standards or measurement tools by themselves. They are just taken as reference points for evaluating the quality of the institution under assessment.

The interdependencies between the criteria and key aspects can be understood by forming directed graphs (digraphs) among them. These digraphs can then be quantified using a suitable scale to find University Education System Quality Index.

II. Literature Review

Since its inception, NAAC had been trying hard to promote the concept of quality amongst the Institutions of Higher Education. The functional aspects specifically pedagogy and administration of an institution has been greatly influenced by NAAC. The process followed by NAAC for quality measurement of an institution has shifted the onus on institutions themselves for its quality matters [1].

During the past ten years, NAAC has made significant progress in promoting quality assessment, quality sustenance and quality enhancement in HEIs of the country. Many policy makers at the centre as well as the states, educational administrators, practitioners in the field of education and various stakeholders have contributed to the development of the NAAC [2].

NAAC has been entrusted with the responsibility of Quality Assessment, Sustenance and Enhancement of HEIs in the country. The assessment and accreditation process has resulted in tremendous quality consciousness in institutions and has also created an awareness to deal with the emerging challenges of higher education [3].

Many countries consider accreditation as the best and the oldest known seal of collegiate quality. Its main objective is to provide quality improvement and quality assurance respectively. It is widely believed that it will bring self-regulation to achieve better results [4].

The book “Higher Education in India” stated that due to the

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wave of liberalization, privatization and globalization, there have been both qualitative and quantitative changes in the system of higher education in India. The author of this book discusses on various emerging issues on Indian Higher Education system like impact of globalization on Indian higher education including privatization, commercialization and internationalization, quality in higher education, financing of higher education, higher education through distance learning, extension as third dimension of higher education, value oriented higher education etc. [5].

TABLE I
NAAC MARKING SYSTEM FOR UNIVERSITIES

Criteria (Designation)	Key Aspects (Designation)	Universities
I. Curricular Aspects (C_1)	1.1 Curriculum Design and Development (C_{11})	50
	1.1 Curricular Planning and Implementation (C_{11})	--
	1.2 Academic Flexibility (C_{12})	50
	1.3 Curriculum Enrichment (C_{13})	30
	1.4 Feedback System (C_{14})	20
	Total	**150**
II. Teaching-Learning and Evaluation (C_2)	2.1 Student Enrolment and Profile (C_{21})	10
	2.2 Catering to Student Diversity (C_{22})	20
	2.3 Teaching-Learning Process (C_{23})	50
	2.4 Teacher Quality (C_{24})	50
	2.5 Evaluation Process and Reforms (C_{25})	40
	2.6 Student Performance and Learning Outcomes (C_{26})	30
	Total	**200**
III. Research, Consultancy and Extension (C_3)	3.1 Promotion of Research (C_{31})	20
	3.2 Resource Mobilization for Research (C_{32})	20
	3.3 Research Facilities (C_{33})	30
	3.4 Research Publications and Awards (C_{34})	100
	3.5 Consultancy (C_{35})	20
	3.6 Extension Activities and Institutional Social Responsibility (C_{36})	40
	3.7 Collaborations (C_{37})	20
	Total	**250**
IV. Infrastructure and Learning Resources (C_4)	4.1 Physical Facilities (C_{41})	30
	4.2 Library as a Learning Resource (C_{42})	20
	4.3 IT Infrastructure (C_{43})	30
	4.4 Maintenance of Campus Facilities (C_{44})	20
	Total	**100**
V. Student Support and Progression (C_5)	5.1 Student Mentoring and Support (C_{51})	40
	5.2 Student Progression (C_{52})	40
	5.3 Student Participation and Activities (C_{53})	20
	Total	**100**
VI. Governance, Leadership and Management (C_6)	6.1 Institutional Vision and Leadership (C_{61})	10
	6.2 Strategy Development and Deployment (C_{62})	10
	6.3 Faculty Empowerment Strategies (C_{63})	30
	6.4 Financial Management and Resource Mobilization (C_{64})	20
	6.5 Internal Quality Assurance System (C_{65})	30
	Total	**100**
VII. Innovations and Best Practices (C_7)	7.1 Environment Consciousness (C_{71})	30
	7.2 Innovations (C_{72})	30
	7.3 Best Practices (C_{73})	40
	Total	**100**
TOTAL		**1000**

To meet international standard in terms of students, academic staff, programs, institutions and professionalism, mutual recognition of quality assurance among HEIs across country needs to be ascertained [6]. The NAAC accredited Higher Educational Institutions are producing better quality output as compared to non-accredited institutions [7].

NAAC has based University accreditation process on seven criteria. These seven criteria further consist of key aspects to define the essence of given criteria. These key aspects consist of questions based on which the NAAC team consolidates its marks. The total marks allocated are 1000. Table I shows the marking system used by NAAC for Universities [8].

III. METHODOLOGY

Quantification of criteria and concerned key aspects need to be based on students' score. This depends upon the degree of inheritance of key aspects and the amount of interactions present between them. The quantification of inheritances and interactions is not possible by using Delphi, AHP (Analytic Hierarchy Process), ANP (Analytic Network Process) or SEM (Structural Equation Modeling). While using graph theory and matrix method, the interactions among the key aspects can be easily analyzed and they can even be transformed into mathematical equations. This would enable educational institutions' management team to understand the contribution of different key aspects towards implementation of concerned processes to achieve educational quality.

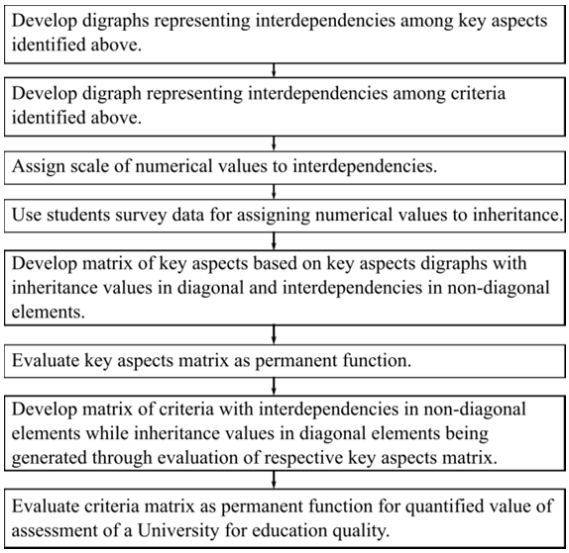

Fig. 1 Block Diagram of methodology for quantification of University education system quality

Fig. 1 represents Block Diagram of methodology employed for quantification of University education system quality. The graph theory and matrix methods consist of the digraph representation, the matrix representation and the permanent function representation. The digraph is the visual representation of the variables and their interdependencies. The matrix converts the digraph into mathematical form and the permanent function is a mathematical representation that helps to determine the numerical index. This paper aims to

extend this approach for the analysis, quantification and comparison of criteria and their key aspects of University education system quality.

NAAC advises institutions for regular conduct of Academic and Administrative Audits (AAA) in order to continuously strive for excellence [9]. The criterion and key aspects help in preparing the institution for the purpose.

IV. Development of Graph Theoretic Model

As suggested by the NAAC, key aspects regarding university education system quality is broadly classified under seven major criteria viz. (i) Curricular Aspects, (ii) Teaching-Learning and Evaluation, (iii) Research, Consultancy and Extension, (iv) Infrastructure and Learning Resources, (v) Student Support and Progression, (vi) Governance, Leadership and Management, (vii) Innovations and Best Practices. Each criterion depends on their key aspects which may be shown in the form of equations. Thus,

UESQ = *f* {University education system quality} = *f* {f (Curricular Aspects), *f* (Teaching-Learning and Evaluation), *f* (Research, Consultancy and Extension), *f* (Infrastructure and Learning Resources), *f* (Student Support and Progression), *f* (Governance, Leadership and Management), *f* (Innovations and Best Practices)}

where,

f (Curricular Aspects) = *f* (Curriculum Design and Development, Academic Flexibility, Curriculum Enrichment, Feedback System)

f (Teaching-Learning and Evaluation) = *f* (Student Enrolment and Profile, Catering to Student Diversity, Teaching-Learning Process, Teacher Quality, Evaluation Process and Reforms, Student Performance and Learning Outcomes)

f (Research, Consultancy and Extension) = *f* (Promotion of Research, Resource Mobilization for Research, Research Facilities, Research Publications and Awards, Consultancy, Extension Activities and Institutional Social Responsibility, Collaborations)

f (Infrastructure and Learning Resources) = *f* (Physical Facilities, Library as a Learning Resource, IT Infrastructure, Maintenance of Campus Facilities)

f (Student Support and Progression) = *f* (Student Mentoring and Support, Student Progression, Student Participation and Activities)

f (Governance, Leadership and Management) = *f* (Institutional Vision and Leadership, Strategy Development and Deployment, Faculty Empowerment Strategies, Financial Management and Resource Mobilization, Internal Quality Assurance System)

f (Innovations and Best Practices) = *f* (Environment Consciousness, Innovations, Best Practices)

The above dimensions can be represented in the form of cause and effect diagram for University education system quality as shown in Fig. 2.

A. University Education System Quality Digraph

A digraph consists of a set of nodes N = [C_i], with i = 1, 2, …, m and a set of directed edges D = [c_{ij}], where C represents a criteria/key aspect. The direction of edge c_{12} from node C_1 to node C_2 indicates the dependency of C_2 on C_1 that is, C_1 impacts C_2. It is possible that any two criteria/key aspect (C_i and C_j) of a digraph are interdependent on one another. This is represented by joining two nodes (C_i and C_j) by two directed edges (c_{ij} and c_{ji}) in the opposite directions forming a close loop. University education system quality digraph represents 7 criteria and their key aspects as identified in Fig. 2.

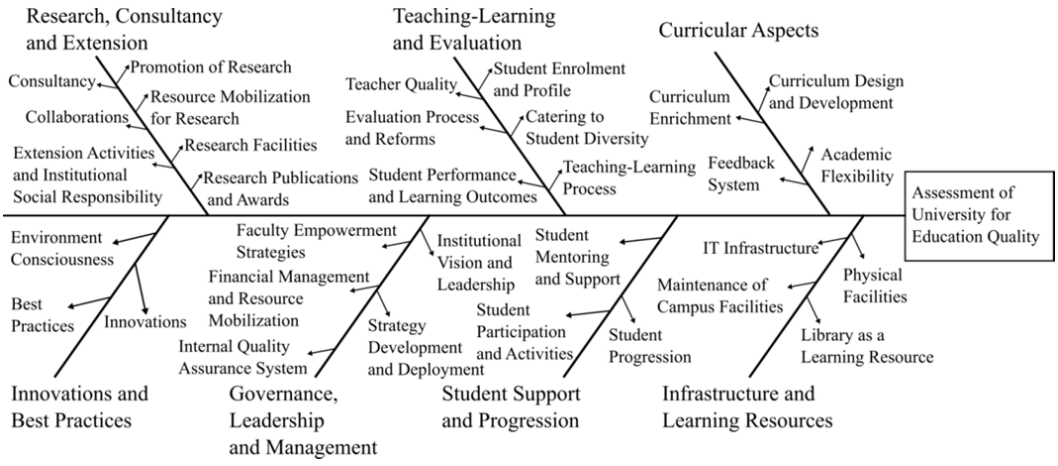

Fig. 2 Cause and effect diagram for University education system quality

The interdependencies among criteria/key aspects are developed with the help of expert opinion. A small workshop was conducted where experts from the field and academia participated. The relationships among these criteria/key aspects are then expressed through digraph representation as shown in Fig. 3.

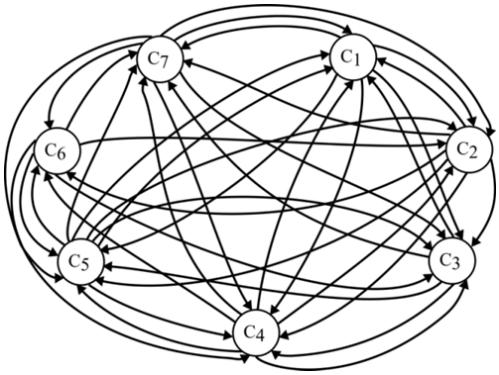

Fig. 3 Digraph for University education system quality

B. University Education System Quality Matrix Representation

Consider a matrix A with off-diagonal elements c_{ij} representing interactions between UESQ criteria. Other matrix B is taken with diagonal elements C_i, i = 1, 2, 3, 4, 5, 6, 7 where C_i represents the effect of individual criteria. The permanent matrix for University education system quality (VPM-UESQ) corresponding to the seven criteria digraph (Fig. 3) is given by sum of matrix A and B as shown in (1):

$$PM-UESQ=\begin{bmatrix} C_1 & c_{12} & c_{13} & c_{14} & c_{15} & 0 & c_{17} \\ c_{21} & C_2 & c_{23} & c_{24} & c_{25} & c_{26} & c_{27} \\ c_{31} & 0 & C_3 & c_{34} & c_{35} & 0 & c_{37} \\ c_{41} & c_{42} & c_{43} & C_4 & c_{45} & c_{46} & c_{47} \\ c_{51} & c_{52} & c_{53} & c_{54} & C_5 & c_{56} & c_{57} \\ 0 & c_{62} & c_{63} & c_{64} & c_{65} & C_6 & c_{67} \\ c_{71} & c_{72} & c_{73} & c_{74} & c_{75} & c_{76} & C_7 \end{bmatrix} \quad (1)$$

The permanent is a standard matrix function and it is used in combinatorial mathematics. The permanent function is similar to the determinant function except that all negative sign of a determinant function is replaced by positive sign in the permanent function. Quantitative value of University education system quality is obtained by substituting numerical values of the C_i's and c_{ij}'s. This single numerical index is the representation of a typical University education system quality in quantitative terms.

C. Quantification of University Education System Quality

The diagonal elements in PM-UESQ (1) representing interactions of criteria of University education system quality need to be assigned its importance weight. Similarly, the interaction of key aspects of University education system quality also needs to be assigned its importance weight. For this purpose, a questionnaire was prepared based on key aspects of NAAC marking system for a University. The survey data were collected from the students based on Likert scale of five.

As the data collected were fuzzy in nature, necessity was felt for conversion of vague data into a crisp score. Mean value of each key aspect was calculated. The mean value was suitably assigned crisp score based on fuzzy scale. This crisp score was used to assign weights to concerned diagonal element. The fuzzy scale used for the purpose has been shown in Table II. Method proposed by Chen and Hwang has been used to convert fuzzy data into crisp scores [10].

TABLE II
INHERITANCE OF WEB QUALITY ENVIRONMENT VARIABLES

S. No.	Qualitative measure of University education quality factor	Fuzzy number M_i (Mean Value)	Crisp score	Assigned value of University education quality factor (C_i)
1	Low	$0 < M_i \leq 1$	0.115	0.575
2	Below average	$1 < M_i \leq 2$	0.295	1.475
3	Average	$2 < M_i \leq 3$	0.495	2.475
4	Above average	$3 < M_i \leq 4$	0.695	3.475
5	High	$4 < M_i \leq 5$	0.895	4.475

TABLE III
INTERDEPENDENCE SCALE FOR UNIVERSITY EDUCATION SYSTEM QUALITY

S.No.	Qualitative measure of interdependencies	C_{ij}
1	Very weak	1
2	Weak	2
3	Medium	3
4	Strong	4
5	Very strong	5

For off-diagonal elements importance weights has been assigned as detailed in Table III.

V. DEMONSTRATION OF 'UNIVERSITY EDUCATION SYSTEM QUALITY' QUANTIFICATION

A. Digraph of Key Aspects

The proposed methodology for quantification of University education system quality has been applied on a University and is demonstrated here. It is proposed to find the value of University education system quality index. For determining the index, we require numerical values of inheritances and interdependencies of criteria and the key aspects as identified for University education system. Digraph for group of key aspects for all seven criteria has been formed with the help of experts (Figs. 4-10).

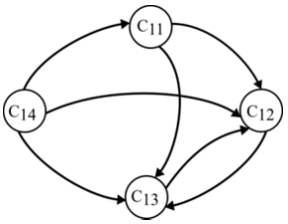

Fig. 4 Digraph for key aspects under 'curricula aspects'

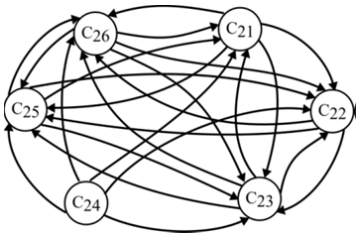

Fig. 5 Digraph for key aspects under 'Teaching-Learning and Evaluation'

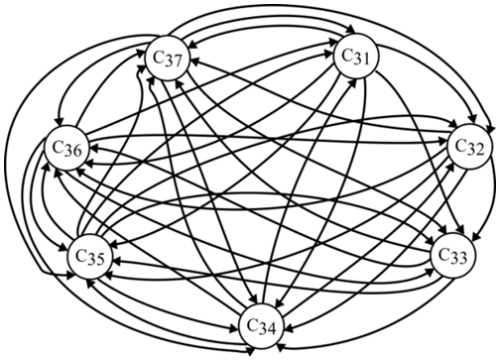

Fig. 6 Digraph for key aspects under 'Research, Consultancy and Extension'

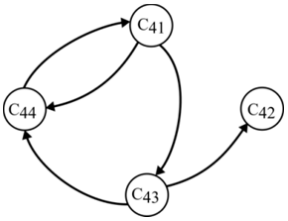

Fig. 7 Digraph for key aspects under 'Infrastructure and Learning Resources'

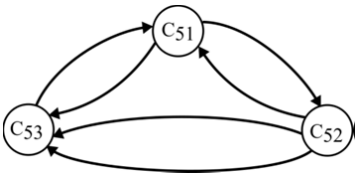

Fig. 8 Digraph for key aspects under 'Student Support and Progression'

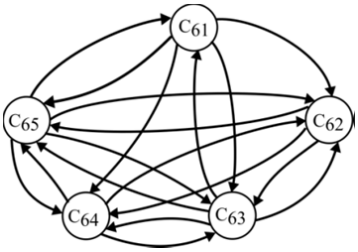

Fig. 9 Digraph for key aspects under 'Governance, Leadership and Management'

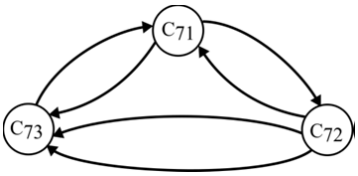

Fig. 10 Digraph for key aspects under 'Innovations and Best Practices'

B. Permanent Matrix of Key Aspects

Figs. 4-10 can be converted into permanent matrix. The value of interdependencies can be filled with the help of Table III using experts' opinion. Inheritance values can be filled with the help of Table II by using mean value of key aspects obtained through students' data.

$$PM-UESQ_1=\begin{array}{c} \\ C_{11}\\ C_{12}\\ C_{13}\\ C_{14}\end{array}\begin{array}{c}\begin{array}{cccc} C_{11} & C_{12} & C_{13} & C_{14}\end{array}\\ \begin{bmatrix} 3.475 & 4 & 4 & 0\\ 0 & 2.475 & 4 & 0\\ 0 & 1 & 3.475 & 0\\ 3 & 3 & 3 & 4.475\end{bmatrix}\end{array} \quad (2)$$

$$PM-UESQ_2=\begin{array}{c} \\ C_{21}\\ C_{22}\\ C_{23}\\ C_{24}\\ C_{25}\\ C_{26}\end{array}\begin{array}{c}\begin{array}{cccccc} C_{21} & C_{22} & C_{23} & C_{24} & C_{25} & C_{26}\end{array}\\ \begin{bmatrix} 4.475 & 4 & 2 & 0 & 2 & 3\\ 0 & 4.475 & 1 & 0 & 1 & 2\\ 3 & 2 & 3.475 & 0 & 3 & 4\\ 4 & 3 & 4 & 2.475 & 3 & 5\\ 2 & 1 & 3 & 0 & 3.475 & 3\\ 5 & 1 & 2 & 0 & 3 & 3.475\end{bmatrix}\end{array} \quad (3)$$

$$PM-UESQ_3=\begin{array}{c} \\ C_{31}\\ C_{32}\\ C_{33}\\ C_{34}\\ C_{35}\\ C_{36}\\ C_{37}\end{array}\begin{array}{c}\begin{array}{ccccccc} C_{31} & C_{32} & C_{33} & C_{34} & C_{35} & C_{36} & C_{37}\end{array}\\ \begin{bmatrix} 2.475 & 3 & 3 & 3 & 2 & 2 & 3\\ 0 & 2.475 & 3 & 2 & 3 & 3 & 2\\ 0 & 0 & 2.475 & 2 & 2 & 3 & 4\\ 2 & 2 & 0 & 2.475 & 2 & 2 & 3\\ 2 & 3 & 3 & 3 & 2.475 & 4 & 4\\ 2 & 4 & 3 & 3 & 3 & 3.475 & 4\\ 2 & 3 & 2 & 2 & 2 & 3 & 3.475\end{bmatrix}\end{array} \quad (4)$$

$$PM-UESQ_4=\begin{array}{c} \\ C_{41}\\ C_{42}\\ C_{43}\\ C_{44}\end{array}\begin{array}{c}\begin{array}{cccc} C_{41} & C_{42} & C_{43} & C_{44}\end{array}\\ \begin{bmatrix} 4.475 & 0 & 3 & 4\\ 0 & 3.475 & 0 & 0\\ 0 & 3 & 3.475 & 2\\ 2 & 0 & 0 & 3.475\end{bmatrix}\end{array} \quad (5)$$

$$PM-UESQ_5=\begin{array}{c} \\ C_{51}\\ C_{52}\\ C_{53}\end{array}\begin{array}{c}\begin{array}{ccc} C_{51} & C_{52} & C_{53}\end{array}\\ \begin{bmatrix} 3.475 & 4 & 4\\ 3 & 2.475 & 3\\ 3 & 3 & 3.475\end{bmatrix}\end{array} \quad (6)$$

$$PM-UESQ_6=\begin{array}{c} \\ C_{61}\\ C_{62}\\ C_{63}\\ C_{64}\\ C_{65}\end{array}\begin{array}{c}\begin{array}{ccccc} C_{61} & C_{62} & C_{63} & C_{64} & C_{65}\end{array}\\ \begin{bmatrix} 3.475 & 4 & 3 & 3 & 4\\ 0 & 3.475 & 2 & 3 & 4\\ 1 & 2 & 3.475 & 2 & 4\\ 0 & 3 & 1 & 3.475 & 3\\ 2 & 3 & 2 & 1 & 2.475\end{bmatrix}\end{array} \quad (7)$$

$$PM-UESQ_7=\begin{array}{c} \\ C_{71}\\ C_{72}\\ C_{73}\end{array}\begin{array}{c}\begin{array}{ccc} C_{71} & C_{72} & C_{73}\end{array}\\ \begin{bmatrix} 3.475 & 2 & 2\\ 1 & 1.475 & 4\\ 3 & 4 & 3.475\end{bmatrix}\end{array} \quad (8)$$

Permanent matrix of key aspects under seven criteria are shown in (2)-(8). Evaluating permanent matrix, the current value obtained for each may be summarized as:

- PM-UESQ$_1$ = 195.9476
- PM-UESQ$_2$ = 3.99790 x 10^4
- PM-UESQ$_3$ = 2.3473 x 10^6
- PM-UESQ$_4$ = 326.0885
- PM-UESQ$_5$ = 204.5622
- PM-UESQ$_6$ = 9.3537 x 10^3
- PM-UESQ$_7$ = 121.2115

For the scope of further improvement, it is suggested to find hypothetical best and hypothetical worst value of University education system quality. This can be done by substituting highest assigned value for inheritance (i.e. 4.475) from Table II at subsystem level to obtain maximum value. Similarly substitute lowest value from Table II for inheritance (i.e.

0.575) at subsystem level to obtain minimum value. The values thus obtained have been summarized in Table IV.

TABLE IV
VALUES FOR CURRENT, MAXIMUM AND MINIMUM FOR UNIVERSITY EDUCATION SYSTEM QUALITY INDEX

System/ Subsystem	Current value	Maximum value	Minimum value
$UESQ_1$	195.9476	481.1282	1.4318
$UESQ_2$	3.99790×10^4	9.0855×10^4	1.8269×10^3
$UESQ_3$	2.3473×10^6	5.2333×10^6	9.2795×10^5
$UESQ_4$	326.0885	614.9307	9.6543
$UESQ_5$	204.5622	309.2897	91.1651
$UESQ_6$	9.3537×10^3	1.6047×10^4	2.2569×10^3
$UESQ_7$	121.2115	229.0147	45.9901
UESQ	1.3852×10^{24}	1.5993×10^{26}	3.6075×10^{17}

VI. CONCLUSION

The quantification of University education system quality by single numerical index is an effective aid in improving the understanding of various criteria and underlying key aspects. The use of permanent concept helps in better appreciation of the criteria as it contains all possible structural components in the form of key aspects and their relative importance. The current values of University education system quality index as compared to the maximum value suggest overall scope for improvement.

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