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Using Analytic Hierarchy Process for Prioritising the Dimensions and Determinants of Internal Quality Assurance of Second Cycle Engineering Programmes

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Abstract:- Quality assurance in engineering education has a double aspect: the internal quality assurance process implemented by the institutions and the external quality assurance or accreditation undertaken by external independent bodies. The providers of engineering education have the primary responsibility for the quality of their provision and its assurance. Although several accreditation standards and guidelines have been established and implemented worldwide through various international, regional and national agencies; relevant literature searches show that frameworks for internal quality assurance have not been properly developed. The authors have developed a conceptual framework comprising of 24 determinants grouped under 6 dimensions (*Quality Enablers, Programme Design, Programme Resources, Programme Delivery, Programme Outcomes,* and *Quality Analysis*) for the internal quality assurance of second cycle engineering programmes. In this article, the authors elaborate on an Analytic Hierarchy Process (AHP) based study for the prioritisation of these dimensions and determinants. The results evolved from the study shows that all the 6 dimensions are significant in the internal quality assurance of second cycle engineering programmes. The study demonstrates that the most significant determinants of internal quality assurance are: *360^o Evaluation of Programme Dimensions; Programme Educational Objectives and Outcomes; Faculty: Adequacy, Competency and Development; Graduate Attributes and Professional Competencies; Institutional Leadership and Governance;* and *Support for Creativity and Innovation*.

Keywords:- Internal Quality Assurance, Multi-criteria Decision Making, Analytic Hierarchy Process, Programme Dimensions, Quality Determinants.

I. INTRODUCTION

Due to the rapid growth of engineering education and the introduction of free trade economy, the proper maintenance of academic quality in educational institutions has become mandatory for education providers in order to withstand the competitiveness of the global market. Liberalisation has been intervening into the education environment, and institutions have to adapt to the changes. The Master's (second cycle) engineering education forms the core for training of future teachers and researchers, and for building up international reputation through publications, patents and entrepreneurs. These professional leaders are capable of transforming the industry. Relevant literature searches show that there is no common agreement or criteria that can be used in the quality assurance of engineering education. What is quality, quality of education especially engineering education, and how it can be achieved are of great interest to the stakeholders of engineering education.

Quality assurance has a double aspect: the internal quality assurance and development at higher education institutions and the external quality assurance (accreditation) undertaken by independent bodies. The providers of engineering education have the primary responsibility for the quality of their provision and its assurance. Consistent with the principle of institutional autonomy, the primary responsibility for quality assurance lies with each institution itself and this provides the basis for real accountability of the academic system. Institutions should have a policy and associated procedures for the assurance of the quality and standards of their programmes and awards. They should also commit themselves explicitly to the development of a culture which recognises the importance of quality, and quality assurance, in their work. It is the institution's internal quality assurance or quality management system that is expected to provide key evidence that the goals for its degree programmes have been met.

The authors have developed a conceptual framework for the internal quality assurance of second cycle programmes in engineering. This paper provides a brief description of the framework developed, and focuses mainly on an Analytic Hierarchy Process (AHP) based study conducted by the authors to prioritise the factors influencing the internal quality assurance of second cycle engineering programmes.

II. QUALITY ASSURANCE FRAMEWORK

The authors identified the influencing factors of internal quality assurance of second cycle engineering programmes through analysis of the relevant literature, interviews and focus group discussions with experts from the fields of engineering education, engineering industry and engineering research as well as observation of procedures and processes in educational institutions and universities offering second cycle programmes in engineering. The data collected was analysed using the content analysis technique. Content analysis consists of analysing the contents of documentary materials (books, journals, reports, etc.) and verbal materials (interviews, group discussions, etc.) for the identification of certain characteristics that can be measured or counted.

The authors follow an integrated approach in developing a framework for the internal quality assurance of second cycle engineering programmes; and propose a multi-dimensional framework, taking into account all the dimensions of an engineering programme. From the content analysis, the authors have identified 24 factors (referred as 'determinants') which are absolutely necessary for the internal quality assurance of a second cycle programme in engineering, and have categorised these 24 determinants under 6 'dimensions'. The dimensions and determinants identified for the framework are shown in Table I.

Table I: Dimensions and Determinants of Internal Quality Assurance of Second Cycle Engineering Programmes

Dimension	Determinant
Quality Enablers	Institutional Leadership and Governance
	Institutional Strategic Planning and Development
	Autonomy, Accountability and Professional Learning
	Decentralisation, Delegation and Empowerment
Programme Design	Programme Educational Objectives and Outcomes
	Support and Participation of Industry and Society
	Global Linkages with National Labs and Institutions
	Industry Relevant, Flexible and Dynamic Curriculum
Programme Resources	Programme Budget and Financial Resources
	Programme Specific Learning Resources
	Faculty: Adequacy, Competency and Development
	Student Enrolment and Student Services Facilities
Programme Delivery	Learner-Centred Instructional Systems Design
	Knowledge Management System Intervention
	Support for Creativity and Innovation
	Academic Counselling, Guidance and Mentoring
Programme Outcomes	Course and Programme Learning Outcomes
	Research, Publications and Consultancy Services
	Graduate Attributes and Professional Competencies
	Development of Personal, Social and Ethical Values
Quality Analysis	Internal and Functional Benchmarking
	360^o Evaluation of Programme Dimensions
	Quality Circles and Internal Quality Audits
	Continual Review of PEOs and POs

The authors have identified that there are 4 major objectives for the internal quality assurance of second cycle engineering programmes. Referred as 'key performance results', they are:

- Defect avoidance in the educational system (Defect Avoidance)
- Alignment of the programme with the strategies of the institute (Strategic Alignment)
- Continuous improvement of the programme (Continuous Improvement)
- Development of trust among the stakeholders of the programme (Stakeholder Trust)

The dimensions and determinants are to be prioritised based on their significance in the internal quality assurance of second cycle programmes in engineering; and involve the theory of multi-criteria decision making.

III. MULTI-CRITERIA DECISION MAKING

Decision making, for which we gather most of our information, has become a mathematical science today [1]. Decision making problem is the process of finding the best option from all of the feasible alternatives. In almost all such problems the multiplicity of criteria for judging the alternatives is pervasive. That is, for many such problems, the decision maker wants to solve a multiple criteria decision making (MCDM) problem. Reference [2] provides a survey of the MCDM methods. Multi-Criterion Decision Analysis (MCDA) is a field of theory that analyses problems based on a number of criteria or attributes. A number of MCDA methods exist in the literature. While these methods differ in a number of ways, the primary difference is how each elicits preferences from decision makers. Weighting techniques range from fixed point scoring and rating to ordinal ranking and pairwise comparisons [3]. Techniques such as the ELCTRE methods produce a set of non-dominated alternatives through a process of outranking [4]. Reference [5] views that methods relying on ordinal judgments and outranking, however, will often not be able to produce a single best alternative.

A. Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) method which was developed by Thomas L. Saaty [6], has been used extensively in almost all the applications related to the multiple criteria decision making (MCDM) in the last 30 years. AHP was originally applied to uncertain decision problems with multiple criteria, and has been widely used in solving problems of ranking, selection, evaluation, optimization, and prediction decisions. The wide application of AHP is due to its simplicity, ease of use, and great flexibility. AHP is a comprehensive framework which is designed to cope with the intuitive, the rational, and the irrational when we make multi-objective, multi-criterion and multi-actor decisions with and without certainty for any number of alternatives [7]. The use of AHP does not involve cumbersome mathematics. AHP involves the principles of decomposition, pairwise comparisons, and priority vector generation and synthesis.

1) Hierarchical Structuring in AHP: The AHP is a multi-criteria decision support and evaluation approach that is used in finding optimal measures on the basis of hierarchical problem structure [8]. The hierarchy is a basic structure used intuitively by decision makers to decompose a complex problem into its most basic elements, a process referred to as hierarchical decomposition [9]. The advantages of using AHP in multi criteria decision making scenarios involves simplification of a complex problem into simple pair-wise comparisons, and construction of a hierarchy of goals, criteria and alternatives. It is very useful in complex decision making. The AHP separates complex decision problems into elements within a simplified hierarchical system. The AHP method is expressed by a unidirectional hierarchical relationship among decision levels. The top element of the hierarchy is the overall goal for the decision model. The hierarchy decomposes to a more specific criterion in which a level of manageable decision criteria is met. Under each criterion, sub-criteria elements related to the criterion can be constructed.

To make a decision in an organised way to generate priorities we need to decompose the decision into the following steps.

- Define the problem and determine the kind of knowledge sought.
- Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level (which usually is a set of the alternatives).
- Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it.
- Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained.

2) Pairwise Comparison: To make comparisons, we need a scale of numbers that indicates how many times more important or dominant one element is over another element with respect to the criterion or property with respect to which they are compared. The AHP methodology uses a fundamental scale of absolute numbers to compare criteria, or alternatives with respect to a criterion in a pair-wise mode. The fundamental scale (called the AHP standard scale), shown in Table II has been shown to be a scale that captures individual preferences with respect to quantitative and qualitative attributes just as well or better than other scales [10]. A classic psychological study conducted showed that the average individual has the capacity to keep only seven, plus or minus two, objects in mind at any one time without becoming confused [11]. Therefore Thomas L. Saaty recommends that for each branch at each level of the hierarchy, no more than seven items be compared [12]. For larger problems, this may mean that similar elements will need to be grouped and additional layers of hierarchy added in order to keep the problem formulation manageable. The eigenvector method was originally proposed by Saaty and is one of the most popular methods of calculating preferences from inconsistent matrices of pairwise comparisons. It is based on the well-defined mathematical structure of consistent matrices and their associated right eigenvector's ability to generate true or approximate weights [13].

Table II: The Saaty's Fundamental Scale of Absolute Numbers

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption

3) Group Decision Making: Two important issues in group decision making are: how to aggregate individual judgements in a group into a single representative judgement for the entire group and how to construct a group choice from individual choices. The reciprocal property plays an important role in combining the judgements of several individuals to obtain a single judgement for the group. Judgements must be combined so that the reciprocal of the synthesised judgements is equal to the syntheses of the reciprocals of these judgements. It has been proved that the geometric mean, not the frequently used arithmetic mean, is the only way to do that [14].

4) Consistency: Deviations from both ordinal and cardinal consistency are considered, and to a certain extent allowed, within AHP. Ordinal consistency requires that if *x* is greater than *y* and *y* is greater than *z*, then *x* should be greater than *z*. Cardinal consistency is a stronger requirement stipulating that if *x* is 2 times more important than *y* and *y* is 3 times more important than *z*, then *x* must be 6 times more important than *z*. Various methods have been devised to deal with inconsistency. Reference [12] suggests a consistency index,

$$CI = \frac{\lambda_{\max} - n}{n-1},$$

where n is the number of elements within a branch being compared, and λ_{max} is the largest eigen value of the pairwise comparison matrix, [A] of order (n x n). If [A] is perfectly consistent (cardinally), then λ_{max} will be at a minimum and equal to n, producing a CI equal to zero. As inconsistency increases, λ_{max} increases, producing a larger value of CI. This consistency index can be expressed as a consistency ratio (also referred as inconsistency ratio),

$$CR = \frac{CI}{CI_R},$$

where CI_R is the consistency index for a random square matrix of the same size. Saaty suggests that CR should be less than or equal to 0.1 [6], but the choice is arbitrary. If the value of CR is smaller or equal to 0.1 (10 %) the inconsistency is acceptable and that if that ratio exceeds 0.1 the set of judgments may be too inconsistent to be reliable. A CR of *zero* means that the judgements are perfectly consistent.

B. AHP in Research Studies in Higher Education

The use of AHP leads to both, more transparency of the quality of management decisions and an increase in the importance of AHP [15]. Reference [16] had identified that AHP was adopted in education, engineering, government, industry, management, manufacturing, personal, political, social, and sports for solving decision-making problems. Several researchers in higher education field have been using AHP as a decision making tool. Application of AHP can be seen in a wide range of areas like teaching quality appraisal [17], course evaluation [18], selection of university teachers [19], student understanding of the objectives of engineering exercise [20], curriculum design [21], improvement of the quality of teaching [22], selection of information systems in universities [23], improvement of education quality in industrial engineering [24], evaluation of university faculty for tenure and promotion [25], and university facilities planning [26].

IV. PRIORITISATION OF THE DIMENSIONS AND DETERMINANTS

The study is organised to systematically determine the priorities (importance) to be given to each of the dimension and determinant for internal quality assurance of second cycle engineering programmes. Before making a judgement, a clear understanding of the objectives of the internal quality assurance process is required. The study involves the collection of subjective opinions of experts and multilevel decision making. Hence, the study is planned as an Analytic Hierarchy Process. As the number of determinants to be prioritized is 24, which is a bigger number for one-shot pair wise comparison, a two stage decision making was done.

A. Prioritisation of the Dimensions

In the first stage of decision making, the dimensions for quality assurance are prioritised. The decision hierarchy, shown in Figure 1 is formulated by breaking down the problem into a hierarchy of decision elements.

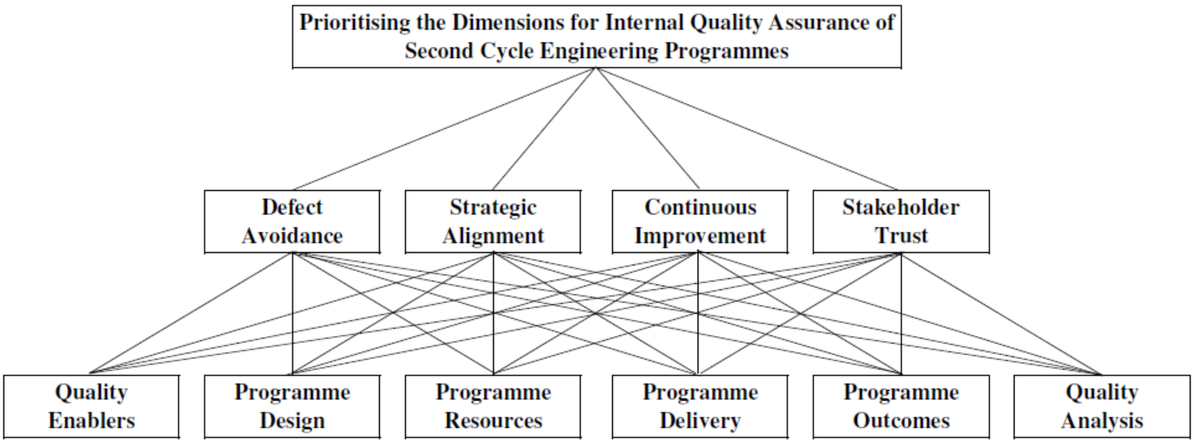

Fig. 1: AHP Model for Prioritizing the Dimensions of Internal Quality Assurance of Second Cycle Engineering Programmes

The topmost level of hierarchy specifies ‘goal’ of the study. Intermediate level corresponds to ‘criteria’, while the lowest level contains the ‘alternatives’. For the present study, the goal is ‘Prioritization of the dimensions for internal quality assurance of the second cycle engineering programmes’. The intermediate level represents the criteria, the four key performance results to be prioritised based on their importance in the achievement of internal quality assurance. The last level represents the alternatives, the six dimensions to be prioritised based on their importance in the achievement of the key performance results of internal quality assurance. Responses were collected using a developed AHP questionnaire from 20 experts, selected through purposive sampling. The details of experts are provided in Table III.

Table III: Details of Experts Participated in the Study

Field of Expertise (including former positions held)	No. of Experts
Directors of Technical Education department	2
Directors of All India Council for Technical Education (AICTE)	2
Members of AICTE accreditation teams	2
Governing Body members of engineering colleges	2
Directors / Principals of engineering colleges	2
Heads of the departments of engineering colleges	2
Coordinators of Technical Education Quality Improvement Programme (TEQIP)	2
Office bearers of professional institutions / societies	2
Senior scientists of National research labs	2
Senior executives of industrial organisations	2
Total	20

The individual responses are entered in the positive reciprocal matrix, and the geometric means of these responses are calculated to get the overall group response. The group response is entered to form the pairwise comparison matrix. The key performance result (criterion) listed on the left are one by one compared with each criterion listed on top as to which one is more important with respect to the internal quality assurance of second cycle engineering programmes. Local priorities of the key performance results of the internal quality assurance are determined from the pairwise comparison matrix shown in Table IV. The overall group response is found to be consistent.

Table IV: Pairwise Comparison Matrix of the Key Performance Results with Respect to Internal Quality Assurance

Key Performance Result	*Enhanced Quality*	*Strategic Alignment*	*Continuous Improvement*	*Stakeholder Trust*	*Priorities*
Defect Avoidance	1.00	2.13	1.27	1.63	0.3462
Strategic Alignment	0.47	1.00	0.55	0.68	0.1544
Continuous Improvement	0.79	1.82	1.00	1.44	0.2864
Stakeholder Trust	0.61	1.48	0.69	1.00	0.2130
Inconsistency Ratio:					*0.00142*

As the sum of priorities is unity, these priorities are called normalised priorities. The priorities may also be expressed in the idealised form by dividing each priority by the largest one, 0.3462 for *Defect Avoidance*, as given in Table V. The effect is to make this key performance result the ideal one with the others getting their proportionate value. One may then interpret the results to mean that *Continuous Improvement* is about 82.73% as significant as *Defect Avoidance* and so on.

Table V: Ranking of the Key Performance Results of Internal Quality Assurance

Rank	Key Performance Result	*Normalised Priorities*	*Idealised Priorities*
1	Defect Avoidance	0.3462	1.0000
2	Continuous Improvement	0.2864	0.8273
3	Stakeholder Trust	0.2130	0.6153
4	Strategic Alignment	0.1544	0.4460

After determining the priorities of the key performance results, the next step is to judge the importance of each of the 6 dimensions with respect to one key performance result at a time. Therefore 4 pairwise comparison matrices will be there in this step. The pairwise comparison matrices of the 6 dimensions with respect to each of the 4 key performance result are shown in tables VI to IX. The local priorities of each dimension are calculated and the decisions are found to be consistent.

Table VI: Pairwise Comparison Matrix of the Dimensions with Respect to Defect Avoidance

Dimension	*Quality Enablers*	*Programme Design*	*Programme Resources*	*Programme Delivery*	*Programme Outcomes*	*Quality Analysis*	*Priorities*
Quality Enablers	1.00	1.18	1.36	1.51	1.72	0.76	0.1948
Programme Design	0.85	1.00	1.32	1.59	1.72	0.70	0.1828
Programme Resources	0.74	0.76	1.00	1.33	1.53	0.61	0.1513
Programme Delivery	0.66	0.63	0.75	1.00	1.26	0.57	0.1257
Programme Outcomes	0.58	0.58	0.65	0.79	1.00	0.53	0.1086
Quality Analysis	1.32	1.43	1.64	1.74	1.87	1.00	0.2368
Inconsistency Ratio:							*0.00285*

Table VII: Pairwise Comparison Matrix of the Dimensions with Respect to Strategic Alignment

Dimension	*Quality Enablers*	*Programme Design*	*Programme Resources*	*Programme Delivery*	*Programme Outcomes*	*Quality Analysis*	*Priorities*
Quality Enablers	1.00	1.78	1.36	1.51	1.13	1.31	0.2154
Programme Design	0.56	1.00	0.62	0.69	0.65	0.79	0.1154
Programme Resources	0.74	1.61	1.00	1.35	0.72	1.23	0.1729
Programme Delivery	0.66	1.45	0.74	1.00	0.69	0.76	0.1386
Programme Outcomes	0.88	1.53	1.39	1.44	1.00	1.27	0.2003
Quality Analysis	0.76	1.26	0.81	1.32	0.79	1.00	0.1574
Inconsistency Ratio:							*0.00409*

Table VIII: Pairwise Comparison Matrix of the Dimensions with Respect to Continuous Improvement

Dimension	*Quality Enablers*	*Programme Design*	*Programme Resources*	*Programme Delivery*	*Programme Outcomes*	*Quality Analysis*	*Priorities*
Quality Enablers	1.00	0.78	0.75	0.63	0.68	0.76	0.1241
Programme Design	1.28	1.00	0.85	0.79	0.84	0.93	0.1531
Programme Resources	1.33	1.18	1.00	0.70	0.76	1.29	0.1660
Programme Delivery	1.59	1.27	1.42	1.00	1.26	1.57	0.2188
Programme Outcomes	1.48	1.19	1.32	0.79	1.00	1.41	0.1921
Quality Analysis	1.31	1.08	0.78	0.64	0.71	1.00	0.1459
Inconsistency Ratio:							*0.00323*

Table IX: Pairwise Comparison Matrix of the Dimensions with Respect to Stakeholder Trust

Dimension	*Quality Enablers*	*Programme Design*	*Programme Resources*	*Programme Delivery*	*Programme Outcomes*	*Quality Analysis*	*Priorities*
Quality Enablers	1.00	0.87	0.76	0.83	0.78	0.88	0.1405
Programme Design	1.15	1.00	0.89	0.95	0.90	0.96	0.1614
Programme Resources	1.32	1.12	1.00	1.09	1.18	1.19	0.1902
Programme Delivery	1.21	1.05	0.92	1.00	0.87	1.07	0.1682
Programme Outcomes	1.29	1.11	0.85	1.15	1.00	1.10	0.1784
Quality Analysis	1.14	1.04	0.84	0.93	0.91	1.00	0.1613
Inconsistency Ratio:							*0.00065*

The principle of hierarchic composition is utilised to calculate the overall priority of the dimensions.

Overall local priority of a dimension =
Σ_i *[(Local priority of the dimension with respect to the* i^{th} *key performance result) **
(Local priority of the i^{th} *key performance result with respect to internal quality assurance of second cycle engineering programmes)]*

The overall priorities of the dimensions are shown in Table X. Table XI provides a comparison of the ranking of the dimensions and the idealised overall priorities are as shown in Table XII.

Table X: Aggregation of the Priorities of the Dimensions for Internal Quality Assurance

Dimension	*Defect Avoidance*	*Strategic Alignment*	*Continuous Improvement*	*Stakeholder Trust*	*Overall Priorities*
	0.3462	*0.1544*	*0.2864*	*0.2130*	*1.0000*
Quality Enablers	0.1948	0.2154	0.1241	0.1405	0.1662
Programme Design	0.1828	0.1154	0.1531	0.1614	0.1593
Programme Resources	0.1513	0.1729	0.1660	0.1902	0.1672
Programme Delivery	0.1257	0.1386	0.2188	0.1682	0.1634
Programme Outcomes	0.1086	0.2003	0.1921	0.1784	0.1615
Quality Analysis	0.2368	0.1574	0.1459	0.1613	0.1824

Table XI: Comparison of the Ranking of the Dimensions for Internal Quality Assurance

Dimension	*Defect Avoidance*	*Strategic Alignment*	*Continuous Improvement*	*Stakeholder Trust*	*Overall Quality Assurance*
Quality Enablers	2	1	5	6	3
Programme Design	3	6	4	4	6
Programme Resources	4	3	3	1	2
Programme Delivery	5	5	1	3	4
Programme Outcomes	6	2	2	2	5
Quality Analysis	1	4	6	5	1

Table XII: Ranking of the Dimensions for Overall Internal Quality Assurance

Rank	Dimensions	*Normalised Priorities*	*Idealised Priorities*
1	Quality Analysis	0.1824	1.0000
2	Programme Resources	0.1672	0.9163
3	Quality Enablers	0.1662	0.9109
4	Programme Delivery	0.1634	0.8957
5	Programme Outcomes	0.1615	0.8854
6	Programme Design	0.1593	0.8732

From the idealised priorities, it is seen that even the dimension with the lowest idealised priority (*Programme Design* with a priority of 0.8732) is 87.32% as significant as the dimension with the highest priority. Therefore it is evident that all the 6 dimensions are very significant in the internal quality assurance of second cycle engineering programmes.

B. Prioritisation of the Determinants

The experts were also asked to judge the relative importance of each of the 4 determinants under one dimension, with respect to the particular dimension in the internal quality assurance of second cycle engineering programmes. The AHP model for this part of the study is illustrated in Figure 2.

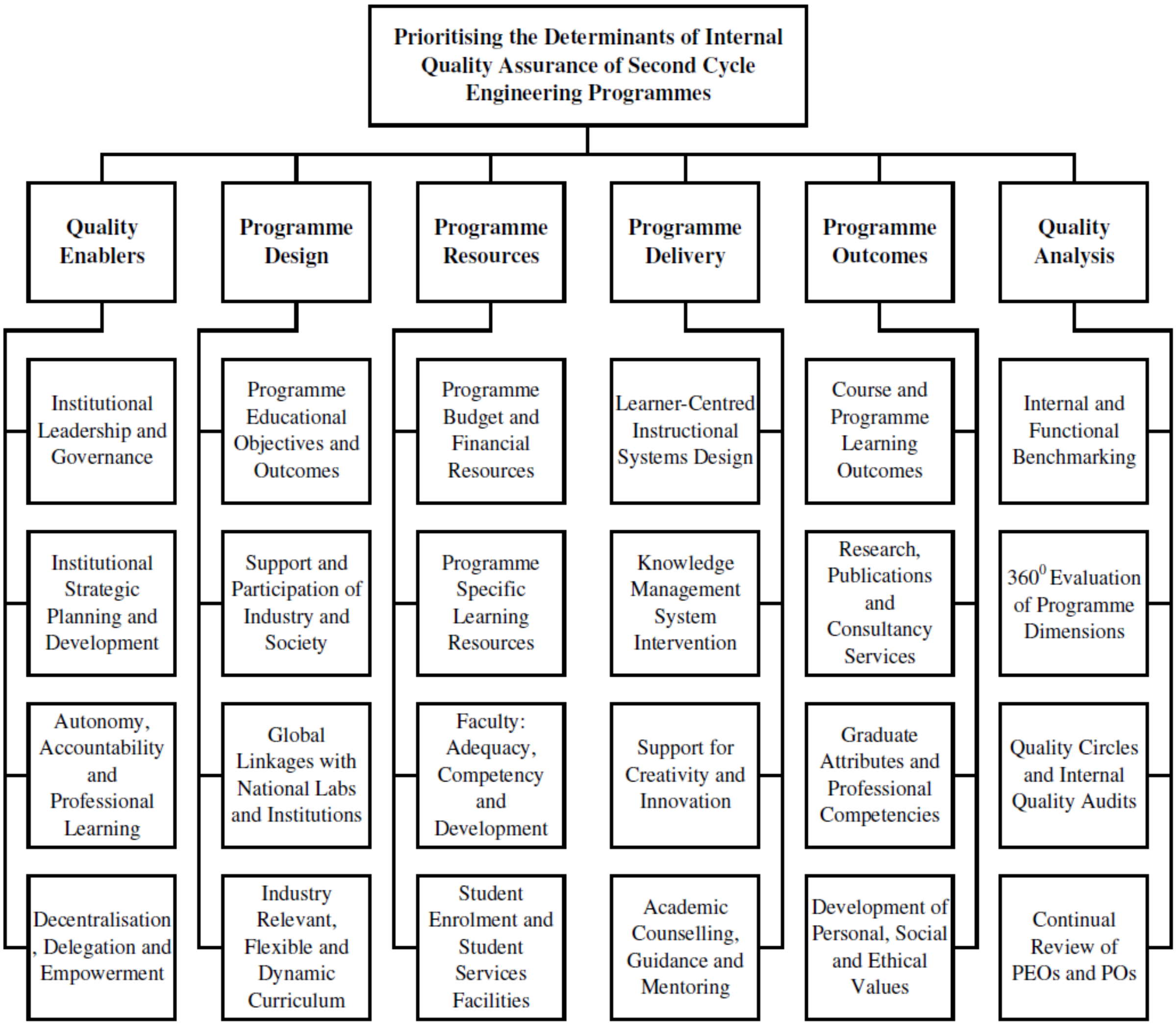

Fig. 2: AHP Model for Prioritizing the Determinants of Internal Quality Assurance of Second Cycle Engineering Programmes

The pairwise comparison matrices of the respective 4 determinants under each of the 6 dimensions are shown in tables XIII to XVIII.

Table XIII: Pairwise Comparison Matrix of the Determinants with Respect to Quality Enablers

Determinant	*ILG*	*ISPD*	*AAPL*	*DDE*	*Priorities*
Institutional Leadership and Governance	1.00	1.24	1.44	1.72	0.3245
Institutional Strategic Planning and Development	0.81	1.00	1.23	1.36	0.2641
Autonomy, Accountability and Professional Learning	0.69	0.81	1.00	1.15	0.2200
Decentralisation, Delegation and Empowerment	0.58	0.74	0.87	1.00	0.1914
Inconsistency Ratio:					*0.00016*

Table XIV: Pairwise Comparison Matrix of the Determinants with Respect to Programme Design

Determinant	*PEEO*	*SPIS*	*GLNLI*	*IRFDC*	*Priorities*
Programme Educational Objectives and Outcomes	1.00	1.93	2.18	1.36	0.3700
Support and Participation of Industry and Society	0.52	1.00	1.23	0.80	0.2021
Global Linkages with National Labs and Institutions	0.46	0.81	1.00	0.67	0.1691
Industry Relevant, Flexible and Dynamic Curriculum	0.74	1.25	1.49	1.00	0.2588
Inconsistency Ratio:					*0.00070*

Table XV: Pairwise Comparison Matrix of the Determinants with Respect to Programme Resources

Determinant	*PBFR*	*PSLR*	*FACD*	*SESSF*	*Priorities*
Programme Budget and Financial Resources	1.00	1.19	0.62	0.78	0.2117
Programme Specific Learning Resources	0.84	1.00	0.53	0.75	0.1850
Faculty: Adequacy, Competency and Development	1.61	1.88	1.00	1.24	0.3387
Student Enrolment and Student Services Facilities	1.29	1.34	0.81	1.00	0.2646
Inconsistency Ratio:					*0.00080*

Table XVI: Pairwise Comparison Matrix of the Determinants with Respect to Programme Delivery

Determinant	*LCISD*	*KMSI*	*SCI*	*ACGM*	*Priorities*
Learner-Centred Instructional Systems Design	1.00	1.45	0.74	0.81	0.2358
Knowledge Management System Intervention	0.69	1.00	0.58	0.70	0.1777
Support for Creativity and Innovation	1.36	1.72	1.00	1.34	0.3249
Academic Counselling, Guidance and Mentoring	1.23	1.43	0.75	1.00	0.2616
Inconsistency Ratio:					*0.00273*

Table XVII: Pairwise Comparison Matrix of the Determinants with Respect to Programme Outcomes

Determinant	*CPLO*	*RPCS*	*GAPC*	*DPSEV*	*Priorities*
Course and Programme Learning Outcomes	1.00	0.75	0.52	0.63	0.1697
Research, Publications and Consultancy Services	1.34	1.00	0.69	0.76	0.2213
Graduate Attributes and Professional Competencies	1.94	1.45	1.00	1.45	0.3439
Development of Personal, Social and Ethical Values	1.58	1.32	0.69	1.00	0.2651
Inconsistency Ratio:					*0.00277*

Table XVIII: Pairwise Comparison Matrix of the Determinants with Respect to Quality Analysis

Determinant	*IFB*	*EPD*	*QCIQA*	*CRPP*	*Priorities*
Internal and Functional Benchmarking	1.00	0.59	1.44	1.72	0.2619
360^o Evaluation of Programme Dimensions	1.69	1.00	1.84	2.01	0.3767
Quality Circles and Internal Quality Audits	0.69	0.54	1.00	1.24	0.1962
Continual Review of PEOs and POs	0.58	0.50	0.81	1.00	0.1652
Inconsistency Ratio:					*0.00546*

From the analysis of the pairwise comparison matrices, the most significant determinant under each dimension can be listed as shown in Table XIX.

Table XIX: Most Significant Determinant under each Dimension

Dimension	Determinant	*Priority of the Dimension*	*Priority of the Determinant*
Quality Enablers	Institutional Leadership and Governance	0.1662	0.3245
Programme Design	Programme Educational Objectives and Outcomes	0.1593	0.3700
Programme Resources	Faculty: Adequacy, Competency and Development	0.1672	0.3387
Programme Delivery	Support for Creativity and Innovation	0.1634	0.3249
Programme Outcomes	Graduate Attributes and Professional Competencies	0.1615	0.3439
Quality Analysis	360^o Evaluation of Programme Dimensions	0.1824	0.3767

The principle of hierarchic composition is again utilised to calculate the overall priority (global priority) of the determinants with respect to internal quality assurance of second cycle programmes in engineering.

Global priority of a determinant =
*(Local priority of the determinant with respect to the dimension to which it belong) **
(Overall local priority of the corresponding dimension with respect to internal quality assurance of second cycle engineering programmes)

The global priorities of all the 24 determinants evolved from the study are displayed in Table XX. The overall ranking of the determinants along with their idealised global priorities are indicated in Table XXI.

Table XX: Global Priorities of the Determinants of Internal Quality Assurance

Dimension	Determinant	*Overall Priorities of the Dimension*	*Local Priorities of the Determinant*	*Global Priorities of the Determinant*
Quality Enablers	Institutional Leadership and Governance	0.1662	0.3245	0.0539
	Institutional Strategic Planning and Development	0.1662	0.2641	0.0439
	Autonomy, Accountability and Professional Learning	0.1662	0.2200	0.0366
	Decentralisation, Delegation and Empowerment	0.1662	0.1914	0.0318
Programme Design	Programme Educational Objectives and Outcomes	0.1593	0.3700	0.0589
	Support and Participation of Industry and Society	0.1593	0.2021	0.0322
	Global Linkages with National Labs and Institutions	0.1593	0.1691	0.0269
	Industry Relevant, Flexible and Dynamic Curriculum	0.1593	0.2588	0.0412
Programme Resources	Programme Budget and Financial Resources	0.1672	0.2117	0.0354
	Programme Specific Learning Resources	0.1672	0.1850	0.0309
	Faculty: Adequacy, Competency and Development	0.1672	0.3387	0.0566
	Student Enrolment and Student Services Facilities	0.1672	0.2646	0.0442
Programme Delivery	Learner-Centred Instructional Systems Design	0.1634	0.2358	0.0385
	Knowledge Management System Intervention	0.1634	0.1777	0.0290
	Support for Creativity and Innovation	0.1634	0.3249	0.0531
	Academic Counselling, Guidance and Mentoring	0.1634	0.2616	0.0427
Programme Outcomes	Course and Programme Learning Outcomes	0.1615	0.1697	0.0274
	Research, Publications and Consultancy Services	0.1615	0.2213	0.0357
	Graduate Attributes and Professional Competencies	0.1615	0.3439	0.0555
	Development of Personal, Social and Ethical Values	0.1615	0.2651	0.0428
Quality Analysis	Internal and Functional Benchmarking	0.1824	0.2619	0.0478
	360^o Evaluation of Programme Dimensions	0.1824	0.3767	0.0687
	Quality Circles and Internal Quality Audits	0.1824	0.1962	0.0358
	Continual Review of PEOs and POs	0.1824	0.1652	0.0301

Table XXI: Ranking of the Determinants for Internal Quality Assurance

Rank	Dimensions	*Normalised Priorities*	*Idealised Priorities*
1	360^o Evaluation of Programme Dimensions	0.0687	1.0000
2	Programme Educational Objectives and Outcomes	0.0589	0.8574
3	Faculty: Adequacy, Competency and Development	0.0566	0.8239
4	Graduate Attributes and Professional Competencies	0.0555	0.8079
5	Institutional Leadership and Governance	0.0539	0.7846
6	Support for Creativity and Innovation	0.0531	0.7729
7	Internal and Functional Benchmarking	0.0478	0.6958
8	Student Enrolment and Student Services Facilities	0.0442	0.6434
9	Institutional Strategic Planning and Development	0.0439	0.6390
10	Development of Personal, Social and Ethical Values	0.0428	0.6230
11	Academic Counselling, Guidance and Mentoring	0.0427	0.6215
12	Industry Relevant, Flexible and Dynamic Curriculum	0.0412	0.6000
13	Learner-Centred Instructional Systems Design	0.0385	0.5604
14	Autonomy, Accountability and Professional Learning	0.0366	0.5328
15	Quality Circles and Internal Quality Audits	0.0358	0.5211
16	Research, Publications and Consultancy Services	0.0357	0.5197
17	Programme Budget and Financial Resources	0.0354	0.5153
18	Support and Participation of Industry and Society	0.0322	0.4687
19	Decentralisation, Delegation and Empowerment	0.0318	0.4629
20	Programme Specific Learning Resources	0.0309	0.4498
21	Continual Review of PEOs and POs	0.0301	0.4381
22	Knowledge Management System Intervention	0.0290	0.4221
23	Course and Programme Learning Outcomes	0.0274	0.3988
24	Global Linkages with National Labs and Institutions	0.0269	0.3916

The results of the study show that the normalised global weightages of the top 6 determinants are more than 5% and their idealised global weightages are more than 75%. Therefore these 6 determinants can be considered as the most significant determinants of internal quality assurance of second cycle engineering programmes. These 6 determinants are:

- 360^o Evaluation of Programme Dimensions
- Programme Educational Objectives and Outcomes
- Faculty: Adequacy, Competency and Development
- Graduate Attributes and Professional Competencies
- Institutional Leadership and Governance
- Support for Creativity and Innovation

V. CONCLUSIONS

Improving the quality of engineering programmes is of high interest to researchers, policy makers and leaders of engineering institutions as it is considered as one of the key requirements for sustainability. The importance of various factors influencing the quality assurance process is to be assessed properly before implementing an internal quality assurance system. Prioritising the factors influencing quality assurance is a problem of multi-criteria decision making. The decision making problem is the process of finding the best option from all of the feasible alternatives. The analytic hierarchy process (AHP) is one of the extensively used multi-criteria decision making methods. One of the main advantages of this method is the relative ease with which it handles multiple criteria. The use of AHP does not involve cumbersome mathematics. AHP involves the principles of decomposition, pairwise comparisons, and priority vector generation and synthesis. In this study, AHP was applied to structure a multi-criteria prioritisation problem with the overall objective of enhancing the effectiveness of the internal quality assurance of second cycle engineering programmes. The results of the study shows that internal quality assurance process will be effective only if quality is assured in all the dimensions of the programme: Quality Enablers, Programme Design, Programme Resources, Programme Delivery, Programme Outcomes and Quality Analysis.

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