# Use of Analytical Hierarchy Process for Selection of Elective Subjects by Pre-Final Year Students of Computer Science

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***Abstract*** **-** An eternally updating and enhancing nature of Information Technology and Communication leads to frequent revise of the curriculum syllabus in computer science courses, specifically in framing elective subjects for the courses of master degree. Choosing of preeminent elective subject by students depends on numerous parameters or criteria. This paper highlights the results of analysis of criteria which students considered for deciding on selection of elective subjects. The study assessed 12 subjects which are divided into two main heads - elective I and elective II. For this Analytical Hierarchy Process (AHP) technique was applied to evaluate the preference of students towards elective subjects. A list of five criteria was prepared to select the best elective subjects. These criteria are student interest, subject content, future application, factor of ease and peer's choice. The outcome of the proposed research experiment shows that student gave more significance to 'Future Application' in selecting any of the elective subjects. Considering future application, 'Data Mining' and 'Android Programming – I' are the subjects which gained maximum preferences considering the stated criteria.

***Keywords:*** *Analytical Hierarchy Process (AHP), Criteria, Elective Subject, Student*

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## I. Introduction

Every sphere of environment is facing a rapid change due to digitalization and frenziedly advancement in technology. Considering this factor a continuous revolutionize is to be done in academic subjects taught to students especially of post graduate computer science courses. These courses consist of core subjects which are also known as compulsory subjects as well as elective. Pre final year students are given opportunity to select their most favourable subject from the list of elective subjects. So, selecting the most appropriate elective subject by student's considering their own preference is not an easy task. This selection approach is entirely based on making choices, choosing the best decision, as well as choosing the best elective subject. This means decision making is to be done on the basis of several criteria and alternatives. The decision regarding which elective subject is best out of many is considered to be the most critical and important in academic context.

To help as well as guide the students in determining the elective subjects to be selected requires a lot of technical focus. The proposed research supports this type of decision making for the selection of elective subjects. To implement this strategy Analytical Hierarchical Process (AHP) plays an important role. The research work delineates the goal of AHP technique and presents the relative importance of elective subject selection parameters. The rest of this paper is organized as follow. In section II, literature review related to AHP and its implementation in various applications is represented, followed by a brief explanation of AHP technique. Section IV represents problem formulation followed by results and at last concluding section.

## II. Related Literature Review

In this section we present the findings from the literature reviewed in Table 1 about the relevant importance of Analytical Hierarchical Process in decision making.

Table 1. Summarization of Literature Review

| Sr. No. | Author(s) | Contributions |
|---|---|---|
| 1. | Juhartini and Suyanto [8] | In their study, they studied five types of programming language by using the approach of AHP to obtain information on the programming language that has the quality or better rating in comparison with 5 other programming languages. |
| 2. | Kaur and Bhatia [1] | The authors used AHP which consists of various parameters for the management of software projects, for this they conducted a survey in well known software developing company. |
| 3. | Chaudhary and Mishra [21] | In their work they represented the comparative performance analysis of Linux, Mac and Windows operating systems and selection of best operating system on basis of different criteria. |

| | | |
|---|---|---|
| 4. | Kaur and Bhatia [2] | In their further study, the authors also used AHP technique to prioritize parameters for software project selection. |
| 5. | Kamal [10] | Author presented a group decision-making using the AHP. |
| 6. | Vaidya and Kumar [15] | They used AHP method to categorize research papers as well as articles according to identified themes, areas of application, year wise and so on. |
| 7. | Young et al. [11] | They identified the need of the development of a software aided approach based on the Analytic Hierarchy Process (AHP) as a decision-making tool for selecting Storm water management. |
| 8. | Kutlu [3] | Their study focuses on the selection of project management software using Analytic Hierarchy Process (AHP) method. |
| 9. | Muhisn [22] | They used AHP to select suitable team leader based on four criteria - personality type, academic achievement, teamwork experience, and previous programming grade. |
| 10. | Bakshi and Sarkar[20] | They proposed how additive ratio assessment method along with AHP can be used in decision making. |
| 11. | Reddy [17] | In their examination they proposed an Integrated approach of AHP and Goal Model (AHP-GP Model) for Selection of Software Architecture. |
| 12. | Triantaphyllou and Mann [5] | They examined practical and computational issues involved when the AHP method is used in engineering applications. |
| 13. | Trudel and Zaras [4] | In their work they compared two multi-criteria analysis methods, Analytic Hierarchy Process (AHP) and Dominance- based Rough Set Approach (DRSA) to rank ten investment projects based on evaluation of the overall risk associated with each. |
| 14. | Drake [16] | The author used AHP to reveal the extent to which the student understands the objectives of the engineering exercise. |
| 15. | Goepel [12] | In their research work the author describes the development of a general, freely available AHP Excel template for decision making. |
| 16. | Omar et al. [13] | They proposed and constructed a model that can be used to form a software team leader using AHP technique. |
| 17. | Kendrick and Saaty [7] | According to authors, analytic hierarchy process (AHP) method is good technique in Six Sigma. Also proves beneficial for other business process improvement. |
| 18. | Alexander [14] | The author wrap that, AHP has broad applications in operations research, quality engineering, and design-for-six-sigma situations. |
| 19. | Huizingh and Vrolijk [9] | They analyzed various project selection criteria which are helpful in decision making by using AHP |
| 20. | Shahroodi et al. [18] | Their research deals with a brief review of the literature regarding AHP technique and its application in supplier selection process. |

## III. Analytical Hierarchy Process

Thomas Saaty introduced Analytic Hierarchy Process (AHP). It can be used as an effective decision making tool and assists the decision maker to set priorities and make the best decision. The AHP can be implemented in three simple consecutive steps:

1) First step is to develop and prepare a hierarchy and list of criteria which is important for decision making [6], [19].
2) Next, pair wise comparison are done using weights on the basis of relative level importance that and are assigned to each criterion. The comparison is done based on a simple ratio scale of one to nine as defined in Table 2.

Table 2. Saaty's scale for pair wise comparison [19]

| Definition | Intensity |
|---|---|
| Equal importance/quality | 1 |
| Moderately more important/ better | 3 |
| Strongly more important / better | 5 |
| Very strongly more important / better | 7 |
| Extremely more important / better | 9 |
| Intermediate values | 2,4,6,8 |

3) After performing pair wise comparisons of various criteria in step 2 then generated data are organised into a square matrix. The diagonal elements of the matrix are 1. Following rules indicates which helps to fill up the upper triangular matrix is using the following rules:
- The actual judgment value is inserted if the judgment value is on the left side of 1
- In other case, reciprocal value is inserted if the judgment value is on the right side of 1

4) From that matrix, a normalized matrix has been obtained by dividing each column element by column sum. After priority vectors have been obtained by averaging each row of matrix. This method of obtaining priority vector is known as Approximation method.
5) Further, consistency index (CI) is calculated as specified by Saaty [14]. Consistency Index (CI) is related to Eigen value method. In proposed research, consistency check is also taken into consideration and calculated. The consistency ratio (CR) is the ratio of CI and RI, which is given by:

$$CR = \frac{CI}{RI} \quad (1)$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (2)$$

Where λmax = maximum Eigen value, n=order of matrix and RI= Random index (the average CI of 500 randomly filled matrices).If CR is less than 0.1 0r 10% then, the matrix is said to be having acceptable consistency.

Table 3. Value of Random Index [19]

| N | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

## IV. Problem Formulation

For the analysis of proposed problem, study has been done considering the elective subjects provided by Gujarat Technological University to pre final year students of Master of Computer Applications semester III. Students are given freedom to select any one subject from each of the two lists of electives. The electives are classified as: Elective – I which consist of subjects – Network Security (NS), R Programming Language (RPL), Data Mining (DM), IOT Programming (IOT), Image Processing (IP), and Operations Research (OR). Similarly, Elective - II, includes – Web Data Management (WDM), Cyber Security & Forensic (CSF), Language Processing (LP), Function Programming in Java (FPJ), Advance Python (AP), and Android Programming I (AP-I). Further, a list of five criteria was prepared which are listed in Table 4. The selection of elective subjects entirely depends on these criteria. Before the selection, first students must focus on these basic criteria or parameters, then on sub - criteria and after on alternatives. In Figure 1 block diagram of the problem formulation is presented.

Table 4. Criteria Description

| Sr. No. | Criteria | Description |
|---|---|---|
| 1. | Student Interest (SI) | Student's own interest in learning the particular subject. |
| 2. | Subject Content (SC) | The teaching structure/in-depth syllabus of the subject. |
| 3. | Future Application (FA) | Implies job opportunity, market demand of the given subject. |
| 4. | Factor of Ease (FOE) | How easy as well as scoring is the given subject? |
| 5. | Peer's Choice (PC) | Dependability of student on his/her friend's choice of selection. |

 ISSN: 2321-8169
1196 – 1202

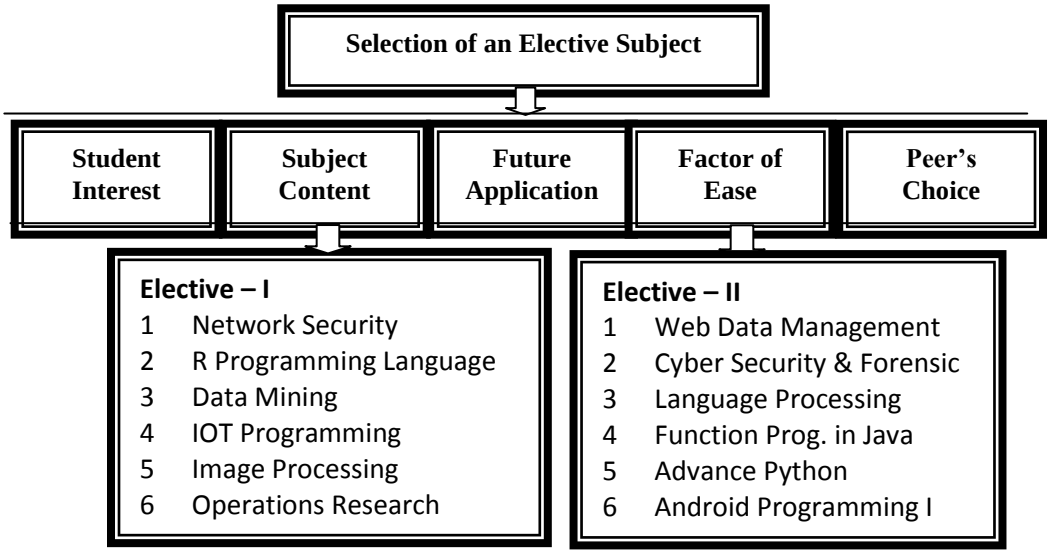


Fig 1: Diagram of Problem Formulation

This type of effort has not been done for prioritizing elective subject's criteria or parameters. Initially starting with pair wise comparison is done as to determine the relative importance of each criterion. All the five criteria are written in a row and in a column so as to form the matrix. Further a survey was conducted to get values of criteria comparisons. The total numbers of respondents were sixty three and all are students of fourth semester of master of computer application. First the pair wise comparison has been done, for the parameters involved in the study and a reciprocal matrix has been developed presented in Table 5.

Table 5. AHP for Criteria

| Criteria | SI | SC | FA | PC | FOE |
|---|---|---|---|---|---|
| **SI** | 1 | 3 | 1/5 | 5 | 3 |
| **SC** | 1/5 | 1 | 1/5 | 5 | 3 |
| **FA** | 3 | 5 | 1 | 7 | 5 |
| **FOE** | 1/5 | 1/5 | 1/7 | 1 | 1/3 |
| **PC** | 1/3 | 1/3 | 1/5 | 3 | 1 |

The fractional values shown in Table 5 depict the relative significance of each criterion over another. Subsequently the same methodology was followed for comparing matrix between different alternatives considering the criteria.

## V. Results

In this section result of experimentation is presented. In Table 6, fractional values that are converted into decimal form and column sum are specified.

Table 6. Pair wise Comparison of Criteria

| Criteria | SI | SC | FA | PC | FOE |
|---|---|---|---|---|---|
| **SI** | 1.0000 | 3.0000 | 0.2000 | 5.0000 | 3.0000 |
| **SC** | 0.2000 | 1.0000 | 0.2000 | 5.0000 | 3.0000 |
| **FA** | 3.0000 | 5.0000 | 1.0000 | 7.0000 | 5.0000 |
| **FOE** | 0.2000 | 0.2000 | 0.1429 | 1.0000 | 0.3333 |
| **PC** | 0.3333 | 0.3333 | 0.2000 | 3.0000 | 1.0000 |
| | **4.7333** | **9.5333** | **1.7429** | **21.0000** | **12.3333** |

Proceeding further, now columns are normalized as shown in Table 7. For normalization of column, each column element is divided by column sum, and then average of each row is calculated. The resulted average of each row gives that gives the priority values. Higher the

 ISSN: 2321-8169
1196 – 1202

priority value more will be the importance of criteria in decision making.

Table 7. Normalized Column

| Criteria | SI | SC | FA | PC | FOE | SI | Rank |
|---|---|---|---|---|---|---|---|
| **SI** | 0.2113 | 0.3147 | 0.1148 | 0.2381 | 0.2432 | 0.2244 | 2 |
| **SC** | 0.0423 | 0.1049 | 0.1148 | 0.2381 | 0.2432 | 0.1486 | 3 |
| **FA** | **0.6338** | **0.5245** | **0.5738** | **0.3333** | **0.4054** | **0.4942** | **1** |
| **FOE** | 0.0423 | 0.0210 | 0.0820 | 0.0476 | 0.0270 | 0.0440 | 5 |
| **PC** | 0.0704 | 0.0350 | 0.1148 | 0.1429 | 0.0811 | 0.0888 | 4 |
| | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | |

From Table 7, it can be understood that 'Future Application' is the most important criteria. Further, 'Student Interest' is the second most important whereas 'Factor of Ease' is least relative important. Now consistency ratio is calculated by applying formula where value of $\lambda_{max}$ = 5.3593, Consistency Index (CI) = 0.089825 and Consistency Ratio (CR) = 0.0802 which is less than 0.1. Means in this matrix inconsistency is less than 10%, which is acceptable.

Comparison matrix between different elective subjects as Network Security, R Programming Language, Data Mining, IOT Programming, Image Processing and Operations Research of elective I as well as subjects like Web Data Management, Cyber Security & Forensic, Language Processing, Function Programming in Java, Advance Python and Android Programming I of elective II according to Student Interest, Subject Content, Future Application, Factor of Ease and Peer's Choice and their priority/ Eigen Vector and Consistency Ratio are determined.

Table 8. AHP for Factor of Ease (Elective I)

| Criteria | NS | RPL | DM | IOT | IP | OR |
|---|---|---|---|---|---|---|
| **NS** | 1 | 3 | 1/3 | 3 | 3 | 3 |
| **RPL** | 1/5 | 1 | 1/7 | 1/3 | 1/3 | 3 |
| **DM** | 3 | 7 | 1 | 3 | 5 | 5 |
| **IOT** | 1/3 | 3 | 1/3 | 1 | 5 | 3 |
| **IP** | 1/3 | 3 | 1/5 | 1/5 | 1 | 3 |
| **OR** | 1/3 | 1/3 | 1/5 | 1/3 | 1/5 | 1 |

Table 9. Pair wise Comparison of Alternatives

| Criteria | NS | RPL | DM | IOT | IP | OR |
|---|---|---|---|---|---|---|
| **NS** | 1.0000 | 3.0000 | 0.3333 | 3.0000 | 3.0000 | 3.0000 |
| **RPL** | 0.2000 | 1.0000 | 0.1429 | 0.3333 | 0.3333 | 3.0000 |
| **DM** | 3.0000 | 7.0000 | 1.0000 | 3.0000 | 5.0000 | 5.0000 |
| **IOT** | 0.3333 | 3.0000 | 0.3333 | 1.0000 | 5.0000 | 3.0000 |
| **IP** | 0.3333 | 3.0000 | 0.2000 | 0.2000 | 1.0000 | 3.0000 |
| **OR** | 0.2000 | 0.3333 | 0.2000 | 0.2000 | 0.2000 | 1.0000 |
| | **5.0667** | **17.3333** | **2.2095** | **7.7333** | **14.5333** | **18.0000** |

Table 10. Normalized Column

| Criteria | NS | RPL | DM | IOT | IP | OR | Priority Vector | Rank |
|---|---|---|---|---|---|---|---|---|
| **NS** | 0.1974 | 0.1731 | 0.1509 | 0.3879 | 0.2064 | 0.1667 | 0.2137 | 2 |
| **RPL** | 0.0395 | 0.0577 | 0.0647 | 0.0431 | 0.0229 | 0.1667 | 0.0658 | 5 |
| **DM** | **0.5921** | **0.4038** | **0.4526** | **0.3879** | **0.3440** | **0.2778** | **0.4097** | **1** |
| **IOT** | 0.0658 | 0.1731 | 0.1509 | 0.1293 | 0.3440 | 0.1667 | 0.1716 | 3 |
| **IP** | 0.0658 | 0.1731 | 0.0905 | 0.0259 | 0.0688 | 0.1667 | 0.0985 | 4 |
| **OR** | 0.0395 | 0.0192 | 0.0905 | 0.0259 | 0.0138 | 0.0556 | 0.0407 | 6 |
| | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | | |

In Table 8 AHP for criteria 'Factor of Ease' is presented for subjects of elective I, similarly in Table 9 pair wise comparison and in Table 10 column normalization is done. Same procedure was repeated for four more times for each of the criterion. On completion of comparison for each criterion, we found that students' highest preference was for 'Data Mining' whereas 'Network Security' stood second while 'IOT Programming' third. The value of Consistency Ratio was determined which came to 0.0998 that is less than 0.1. Further, the same strategy is implied for subjects of elective II which are presented in Table 11, Table 12 and Table 13.

Table 11. AHP for Factor of Ease (Elective II)

| Criteria | WDM | CSF | LP | FPJ | AP | AP-I |
|---|---|---|---|---|---|---|
| **WDM** | 1 | 3 | 3 | 1/5 | 3 | 1/3 |
| **CSF** | 1/7 | 1 | 5 | 1/3 | 1/3 | 1/5 |
| **LP** | 1/5 | 1/5 | 1 | 1/5 | 1/3 | 1/7 |
| **FPJ** | 5 | 3 | 5 | 1 | 5 | 1/5 |
| **AP** | 1/3 | 3 | 1/5 | 1/7 | 1 | 1/7 |
| **AP - I** | 3 | 3 | 7 | 5 | 5 | 1 |

Table 12. Pair wise Comparison of Alternatives

| Criteria | WDM | CSF | LP | FPJ | AP | AP-I |
|---|---|---|---|---|---|---|
| **WDM** | 1.0000 | 3.0000 | 0.2000 | 0.2000 | 3.0000 | 0.3333 |
| **CSF** | 0.1429 | 1.0000 | 0.1429 | 0.3333 | 0.3333 | 0.3333 |
| **LP** | 0.3333 | 0.3333 | 1.0000 | 0.2000 | 0.3333 | 0.1429 |
| **FPJ** | 5.0000 | 3.0000 | 5.0000 | 1.0000 | 5.0000 | 0.2000 |
| **AP** | 0.3333 | 3.0000 | 0.2000 | 0.1429 | 1.0000 | 0.1429 |
| **AP - I** | 3.0000 | 3.0000 | 7.0000 | 5.0000 | 5.0000 | 1.0000 |
| | **9.8095** | **13.3333** | **13.5429** | **6.8762** | **14.6667** | **2.1524** |

Table 13. Normalized Column

| Criteria | WDM | CSF | LP | FPJ | AP | AP-I | Priority Vector | Rank |
|---|---|---|---|---|---|---|---|---|
| **WDM** | 0.1019 | 0.2250 | 0.0148 | 0.0291 | 0.2045 | 0.1549 | 0.12170138 | 3 |
| **CSF** | 0.0146 | 0.0750 | 0.0105 | 0.0485 | 0.0227 | 0.1549 | 0.05436377 | 5 |
| **LP** | 0.0340 | 0.0250 | 0.0738 | 0.0291 | 0.0227 | 0.0664 | 0.04183418 | 6 |
| **FPJ** | 0.5097 | 0.2250 | 0.3692 | 0.1454 | 0.3409 | 0.0929 | 0.28052764 | 2 |
| **AP** | 0.0340 | 0.2250 | 0.0148 | 0.0208 | 0.0682 | 0.0664 | 0.07151294 | 4 |
| **AP - I** | **0.3058** | **0.2250** | **0.5169** | **0.7271** | **0.3409** | **0.4646** | **0.43006009** | **1** |
| | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | |

Again the procedure was done for each criterion and the experimental results shows that students highest preference for subjects in elective II was for 'Android Programming I' whereas 'Function Programming in Java' stood second while 'Web Data Management' third and the value of Consistency Ratio was 0.0626 which is less than 0.1.

## VII. Conclusion

In present experiment, AHP technique was applied so that effective decision can be done by students in selecting best and appropriate elective subjects according to Student interest, Subject Content, Future Application, Factor of Ease and Peer's Choice. We conclude that while selecting any of the elective subjects, students first consider future application of subject and then their own interest. Further, 'Data Mining' and 'Android Programming - I' are the subjects that got maximum preference from students considering subject future application and student interest. We do not claim that the lists of these five criteria are exhaustive listing. Further, more criteria can also be discovered in this field.

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