Adama Science and Technology University

School of Electrical Engineering and Computing

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MASTER'S THESIS

ON

An Intelligent Fuzzy Rule-Based System for Teachers' Performance Evaluation in Higher Educations

(In Case: Adama Science and Technology University)

Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Information Systems

By

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This Research Thesis entitled "**AN INTELLIGENT FUZZY RULE-BASED System FOR TEACHERS' PERFORMANCE EVALUATION IN HIGHER EDUCATIONS (In Case of: ASTU)**" has been read and approved as meeting the preliminary research requirements of the Department of Computing in partial fulfillment for the award of the degree of Master Science in Information System, Adama Science and Technology University, Adama, Ethiopia.

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Abstract

Evaluation of teachers' performance is an important element in enhancing the quality of education and improves teachers' motivation to perform well. It also presents a basis for upgrading and enhancing of an educational institution. This paper represents adaptation of expert systems technology using fuzzy logic to handle qualitative and uncertain facts in the decision-making process of teachers' performance evaluation. Human behaviors are mostly based upon qualitative facts, which cannot be numerically measured and hard to decide. This approach is an attempt to cope with such problems in the scenario of teachers' performance evaluation. Through Fuzzy Logic we numerically weighted the linguistic terms, like; *very poor, poor, good, very good, excellent, low or satisfied, unsatisfied* by assigning priorities to these qualitative facts. One of the challenging problems facing decision makers in educational institutions is the evaluation of teachers' knowledge and skills in delivering a given course. According to the standard methods of teachers' evaluation, a mark, expressed either with a numerical value within a given scale (e.g., from 1 to 5) or with a linguistic value (e.g., Very Low to Very High) corresponding to the percentage of a teacher's success, is assigned in order to characterize his/her performance. Finally, this study found that the use of fuzzy logic approach has a great flexibility and reliability in decision-making process of teachers' performance evaluation.

Key Words: - Performance Evaluation, Fuzzy Logic, Fuzzification, Membership Functions, Crisp data, Defuzzification, Rule-base, Fuzzy Inference System.

Declaration

I declare that this thesis is my original work and has not been presented for a degree in any other Universities, and all sources of material used for the study have been accordingly acknowledged.

Mereke Mohammed Lambebo

December, 2016

This Thesis work has been submitted for examination with my approval as a University advisor.

Mohammed Wazih (Ass. Prof.)

December, 2016

Table of Contents

List of Tables

List of Figures

Abbreviations

ASTU	Adama Science and Technology University
COA	Center of Area
COG	Center of Gravity
FL	Fuzzy Logic
FLR	Fuzzy Logic Reasoning
FIS	Fuzzy Inference System
FRBSs	Fuzzy Rule-Based Systems
FST	Fuzzy Set Theory
KB	Knowledge-Base
MATLAB	Matrix Laboratory
MFs	Membership Functions
MFIS	Mamdani Fuzzy Inference System
RB	Rule-Base
SFIS	Sugeno Fuzzy Inference System
SOEEC	School of Electrical Engineering and Computing
TPES	Teachers’ Performance Evaluation System

CHAPTER ONE

1 INTRODUCTION

Evaluation of teachers' performance in educational institutions is an important element in enhancing the quality of the education and in improving teachers' motivation to best their performance.

The most important and complicated task in every organization is the proper evaluation of employee's performance. It also presents a basis for upgrading and enhancing of an organization. Periodical teachers' performance evaluation in an educational institution assists management to recognize its strengths and weaknesses. Performance evaluations require and often involve different types of information that are vague, incomplete, objective, and subjective. (Shaout & Yousif, 2014).

Educational institutions strongly need to have a good performance evaluation system to supply good quality students to the competitive environment. Thus, evaluation of a teacher's performance is important for both students and institution, and must be measured and evaluated for positive reinforcement to teachers. Evaluation of a faculty is a difficult and sensitive issue which has quantitative and qualitative aspects, complexity and imprecision (Neogi, Mondal, & Mandal, 2008).

An organization's performance management system helps the organization to meet its short-term goals, long term goals as well as the objectives by helping the management and employees to do their jobs more efficiently and effectively, and performance appraisal is one part of performance management system (Bacal, 1999).

Performance evaluations require and often involve different types of information that are vague, incomplete, objective, and subjective. This study proposes a performance evaluation system of teachers considering various performance evaluation criteria using fuzzy logic. The main task in the proposed approach involves determining the performance indices of teachers considering their respective performance in various qualitative and quantitative evaluation criteria.

1.1 Background of Study

In artificial intelligence, an expert system is a computer system that emulates the decision-making ability of a human expert. Expert systems are designed to solve complex problems by reasoning about knowledge, represented primarily as if–then rules rather than through conventional procedural code. The concept of expert systems was first developed in the 1970s by Edward Feigenbaum, professor and founder of the Knowledge Systems Laboratory at Stanford University. Feigenbaum explained that the world was moving from data processing to "knowledge processing," a transition which was being enabled by new processor technology and computer architectures (TechTarget, 2014).

Fuzzy logic is branch of logic specially designed for representing knowledge and human reasoning in such a way that it is amenable to process by a computer. Thus, it is applicable to artificial intelligence, control engineering, and expert systems (Padhy, 2005). The more traditional propositional and predicate logic do not allow for degrees of imprecision, indicated by words or phrases such as poor, average and good. Instead of truth values such as true or false, it is possible to introduce a multivalued logic consisting of *Unsatisfactory, Satisfactory, Average, Good, and Excellent*. Fuzzy systems implement fuzzy logic, which uses sets and predicates of this kind. As the classic logic is the basic of ordinary expert logic, fuzzy logic is also the basic of fuzzy expert system. Fuzzy expert systems, in addition to dealing with uncertainty, are able to model common sense reasoning which is very difficult for general systems.

One of the basic limitations of classic logic is that it is restricted to two values, true or false and its advantage is that it is easy to model the two-value logic systems and also we can have a precise deduction. The major shortcoming of this logic is that, the number of the two-value subjects in the real world is few. The real world is an analogical world not a numerical one, i.e. it is full of uncertainties and difficult to express things in discreet manner. Fuzzy logic is a logical system, which is an extension of multivalued logic. However, in a wider sense fuzzy logic is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with unsharp boundaries in which membership is a matter of degree. In general, approximation or fuzzy reasoning is the deduction of a possible and imprecise conclusion out of a possible and imprecise initial set (Ramjeet & Vijendra, 2011).

In 1965, Lotfi Zadeh introduced fuzzy logic as means to model and handle uncertainty in natural language (Zadeh, 1965). Fuzzy logic describes the qualitative nature aspects of the object while conventional logic systems focus on their quantitative aspects. Two fuzzy approaches can be used to construct performance appraisal. The first one is conventional fuzzy approach, which evaluates overall rating from many linguistic fuzzy input variables without any intermediate fuzzy reasoning using if-then rules. The conventional approach generates too many rules and it is difficult for the expert to take into account all aspects and formulates rules with accurate weight. Organization may need to weight some factor such as employee safety observation over quantity and employee attitude or any other critical element. In this situation, the whole process will become extremely complicated. Moreover, the functions of designing inference rules needs to use customize high level language instead of using the simple fuzzy toolbox. The second approach defines the relationship between the performance critical elements and accordingly specifies new large groups (Adnan & Jaldip, 2013).

1.1.1 Background of ASTU

Adama Science and Technology University (ASTU) was first established in 1993 as Nazareth Technical College (NTC), offering degree and diploma level education in technology fields. Later, the institution was renamed as Nazareth College of Technical Teacher Education (NCTTE), a self-explanatory label that describes what the institution used to train back then: candidates who would become technical teachers for TVET colleges/Schools across the country. In 2003, a new addition to NCTTE came about introduction of business education. Nonetheless, the new entries were solely meant for similar purposes: these graduates were also expected to help overcome the existing dearth of educators in vocational institutions. Although it is an institution with a history of only two decades, ASTU is known for its dynamic past. It has always been responsive to the realization of national policies: training of technologists at its infant stage, and later shifting to training of technical trainers, as well as business educators, to fill the gap in TVETs. Following its inauguration in May 2006 as Adama University, the full-fledged university started opening other academic programs in other areas an extension to its original mission.

However, it was not until it was nominated by the Ministry of Education as Center of Excellence in Technology in 2008 that it opened various programs in applied engineering and technology. For its realization, it became a university modeled after the German paradigm: it not only became the only technical university in the nation, but also the only one led by a German professor.

Notwithstanding closure of some disciplines as per the new vision and mission, the ensuing three years saw flourishing of graduate programs, of which some (like a few in the undergraduate program) were exceptional to our university. Before 2008, the university was divided into faculties, and ASTU's reach was limited to its only campus in Adama town. The university has now extended its reach to Asella, where two of the seven schools are located. The faculties at the main campus include: School of Business, School of Engineering and Information Technologies, School of Humanities and Law, School of Natural Sciences, and School of Educational Science and Technology Teachers Education. On the other hand, the two schools in Asella are the School of Agriculture and School of Health and Hospital.

In addition to its main concern (academics), ASTU also hosts research Institutes and enterprises. In the main campus, apart from the Institute of Continuing and Distance Education (ICDE), there exist two others: the Further Training Institute (better known as FTI) and Adama Institute of Sustainable Energy. The sister town where the two schools are located, Asella, is also host to the Artificial Insemination Institute and Asella model Agricultural Enterprise.

Following its renaming by the Council of Ministers as Adama Science and Technology University in May 2011, the university has started working towards the attainment of becoming a center of excellence in science and technology, thereby allowing for the realization of goals set in the Growth and Transformation Plan (GTP). To this end, a South Korean has been appointed as President of the University. Currently, ASTU is setting up a Research Park, in collaboration with stakeholders and other concerned bodies: one of a kind in the Ethiopian context. The university is also venturing out to the wider community and is currently engaged in various joint undertakings (ASTU, 2016).

1.2 Statement of the Problem

One of the challenging problems facing decision makers in educational institutions is the evaluation of teachers' performance. According to the standard methods of teachers' evaluation, a mark, expressed either with a numerical value within a given scale (e.g., from 1 to 5) or with a linguistic value (e.g., Poor to Excellent) corresponding to the percentage of a teacher's success, is assigned in order to characterize his/her performance. However, this classical crisp characterization, based on principles of the bivalent logic (i.e. yes or no), although it is the one most of the time applied in practice, it is not probably the most appropriate to determine a teacher's performance.

In fact, the decision maker can be never absolutely sure about a particular numerical value characterizing the teacher's abilities and skills, because in bivalent logic it is difficult to represent degree of truth and uncertainties. In contrast, fuzzy logic, due to its nature of including multiple values, offers a wider and richer field of resources for evaluating the teachers' performance than the classical crisp characterization.

Therefore, the application of fuzzy logic that we shall attempt in this study seems to be a suitable tool for developing teachers' performance evaluation in Higher Education Institutions.

1.3 Purpose of the Study

The basic purpose of this study is to propose an intelligent fuzzy rule-based teachers' performance evaluation system for Adama Science and Technology University. It is aimed to reduce the current problems of decision makers as discussed above.

1.4 The Objectives of the Study

1.4.1 General Objective

The main objective of this study is to model fuzzy rule-based system for evaluation of teachers' performance in Higher Education Institutions.

1.4.2 Specific Objectives

In line with the general objective, the researcher is aimed at dealing with the following specific objectives.

- To review related literatures and previous work in the area to have better understanding about the study
- To see the difference between rank list of teachers by classical approach and fuzzy approach
- To differentiate performance evaluation results of teachers between classical approach and with fuzzy logic approach

1.5 Research Specific Questions

The aim of this study is to determine teachers' performance using a fuzzy logic model in place of the classical assessment methods. The most important question that are focused in this study is how to accurately compute the overall rating of teachers' performance using the fuzzy logic approach. Also, the study aimed to address the following research questions:

1. To what extent the rank of teachers in classical and fuzzy approach would be the same?
2. How can we quantify the improvement achieved through fuzzy logic as compared to traditional approach?
3. What are the major benefits of using fuzzy logic for teachers' performance evaluation?

1.6 Conceptual Framework

Fuzzy Inference System is an optimization technique that considers different inputs and relates those inputs with some rules to get the output. Rules indicate the relationship between inputs and outputs. The output is optimized based on relationship between inputs. The final output is obtained from the aggregated optimized result of individual rule. Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned (Ahmed & Azeem, 2013).

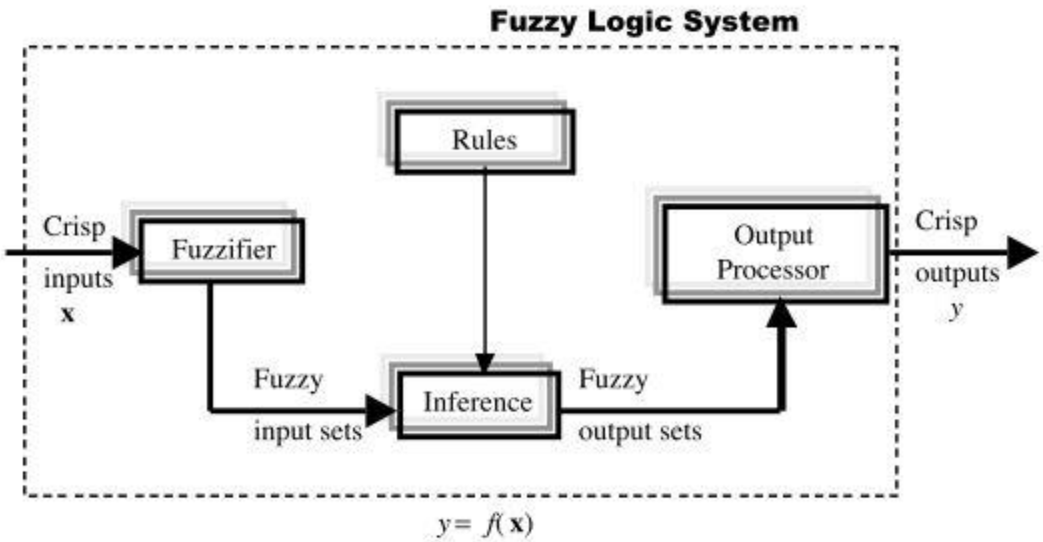

Figure 1. 1. Fuzzy Logic System *(Lotfi, 1995)*

As shown in *figure 1.1* the process of fuzzy logic can be explained in four main steps. Firstly, a crisp set of input data are gathered and converted to a fuzzy set using fuzzy linguistic variables, fuzzy linguistic terms and membership functions. This step is known as fuzzification. Afterwards, an inference is made based on a set of rules. Lastly, the resulting fuzzy output is mapped to a crisp output using the membership functions, in the defuzzification step (Mendel, 1995). In this study, we follow Fuzzy Logic Approach to develop the system for teachers' performance evaluation.

1.7 Scope and Limitation of the Study

Generally, there are two types of higher education institutions: public and private. However, the main focus of this study is Ethiopian Public Higher Education Institutions, specifically, Adama Science and Technology University (ASTU). Fuzzy logic approach can be applied in Educational Institutions to various areas, such as: risk forecasting, decision making, performance evaluation, and so on. In this study, we focus on performance evaluation of ASTU teachers.

1.8 Significance of the Study

The availability of a good performance evaluation of teachers in educational institutions is a vital task which signifies students, institution and teachers. With this study, student in the selected institution indirectly will get an abundant benefit from the study. A teacher who has a high-performance grade in a specific course shows that he/she has a good knowledge in that course and the students can gain a good skill from that teacher.

The main aim of Educational Institutions is to supply good quality education in today's competitive environment. So, to produce good quality students to the competitive environment the availability of a good performance evaluation of teachers is very vital in Educational Institutions.

The availability of performance evaluation benefits teachers in several ways, such as a teacher who has a low performance grade will try to upgrade himself in that subject area. And those who get high performance grade will have a good chance to be promoted.

1.9 Research Methods

1.9.1 Research Design

According to (Singh, 2006), research design is essentially a statement of the object of the inquiry and the strategies for collecting the evidences, analyzing the evidences and reporting the findings. In this study, we used experimental research design, because we have done different experiments and the results are presented.

1.9.2 Data and Data Sources

The main source of the data used to undertake this research was teachers' real data taken from Adama Science and Technology University (ASTU). ASTU is one of the two public University which is under Ministry of Science and Technology and it is found in Oromia region Adama town. In ASTU there are 515 (Five hundred and Fifteen) foreign and local teachers with different academic rank. However, we use 24 teachers' data as a sample. The main reason to select this University for the study is that, we can get important data easily concerning the problem domain. This can help for the learner to learn more and to give a better performance model. The collected data was both in a hard copy and some soft copy format.

1.9.3 Developmental Tools used

To implement the framework, we used MATLAB 7.6.0.324 (R2008a). It is a product of the Math Works, Inc. and is an advanced interactive software package specially designed for scientific and engineering computation. The reason for selecting MATLAB is, it has a built-in fuzzy logic toolbox that helps the researcher to implement the framework easily.

1.9.4 Evaluation Methods

For the purpose of measuring the similarity between ranks of classical and fuzzy logic approach we used Kendall’s tau method. In statistics, the Kendall rank correlation coefficient, commonly referred to as Kendall's tau coefficient (after the Greek letter τ), is a statistic used to measure the ordinal association between two measured quantities. A tau test is a non-parametric hypothesis test for statistical dependence based on the tau coefficient. It is a measure of rank correlation: the similarity of the orderings of the data when ranked by each of the quantities.

1.10 Organization of the Thesis

The thesis is organized into six chapters. The first chapter is an introductory chapter which gives a brief introduction about the study. It also describes the problem that constitutes the basis of the paper, objectives of the study, significance and scope of the study. Chapter two focuses on reviewing relevant related literatures on fuzzy logic and fuzzy ranking that are necessary to understand the methods and terms that are introduced in the parts of the thesis. Finally, a few researches which address problems similar to this study are reviewed. The third chapter of this thesis is devoted on methodology which describes the proposed approach and intended steps and methods of the study. Chapter four is all about the design and implementation of the proposed prototype. And chapter five gives the evaluation of the prototype. Finally, in chapter six, conclusions and recommendations are forwarded and ideas for future work are presented.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Overview of Fuzzy Logic and Fuzzy Inference Systems

2.1.1 Classical Sets

In classical set theory, a subset A of a set X is induced by its characteristic function χ_A mapping the elements of X with the elements of the set {0, 1},

$$x_A : X \to \{0,1\} \qquad (Eq.\ 2.1)$$

In classical set an answer to question "does x belong to A" is given by the ordered pair $\left(x, X_A(x)\right)$ where x is an element of X. The answer is either true when the second element of the pair is equal to 1 or false when the second element is equal to 0. Therefore, the set of ordered pairs {x, χA (x)}, where for each x ∈ X there is exactly one pair, is another way of representation of classical subsets (Starczewski, 2013). The following figure shows the graphical representation of classical set.

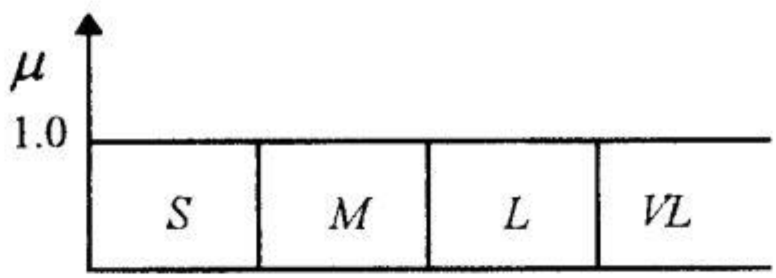

Figure 2. 1. Classical Logic *(Zhang, 1999)*

2.1.2 Fuzzy Sets

In contrast to classical set, fuzzy set theory defines a fuzzy subset A of a set X by its membership function μ_A as a mapping from the elements of X to the unity interval [0, 1]. Let X be a non-empty set. A fuzzy set A in X is characterized by its membership function as shown in equation 2.2.

$$\mu_A : X \rightarrow [0,1] \qquad (Eq.\ 2.2)$$

Whether x belong to A, is given by the ordered pair (x, μA (x)). The answer for this question is not only true or false, but it could be also partially true when the second element is between 0 and 1. The set of ordered pairs {x, μA (x)}, with exactly one pair present for each x, represents a fuzzy subset (Starczewski, 2013).

A fuzzy set is a set with fuzzy boundaries as shown *figure 2.2* below. Defined fuzzy sets or classes for each variable allows intermediate grades of membership in them, which means each set could have elements that belongs partially to it; the degree of belonging is called membership functions ranging from 0 to 1. Fuzzy sets are found whenever there is some ambiguity or subjectivity, and thus imprecisely worded conditions to belong to the set (Jaiswal & Sarode, 2015).

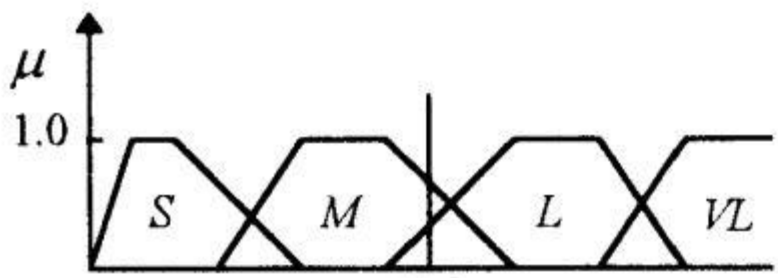

Figure 2. 2. Fuzzy Logic *(Zhang, 1999)*

Fuzzy logic is the extension of classical logic that has been extended to handle the concept of partial truth- truth values between "completely true" and "completely false". As we can understand from its name, it is the logic underlying modes of reasoning which are rough rather than exact. The use of fuzzy logic originates from the fact that most methods of human reasoning and especially common sense reasoning are approximate in nature (AbdulAziz, 2016). According to (Zadeh, 1965) "words" or "sentences" used in our day to day conversation can be observed upon as the "linguistic variables" and can be assigned with "linguistic values". These variables represent the gradual transition from HIGH to LOW, TRUE to FALS and are called "fuzzy variables". A set containing such variables is known as "Fuzzy Set". It has been argued that one of most appropriate ways of handling multiple variables that contain imprecise and vague data is to use Fuzzy Logic Reasoning (FLR) which reflects the way of human-thinking. Fuzzy Logic can be incorporated into

Expert System to enhance the performance and reliability of Expert System in decision making even in the midst of uncertainty (Suvitha & Nirmala, 2016).

2.1.3 Fuzzy Operators

As in classical logic, in fuzzy logic there are three basic operations on fuzzy sets: union, intersection and complement (Alonso, 2016).

- **Union**: Let μ_A and μ_B be membership functions that define the fuzzy sets A and B, respectively, on the universe X. The union of fuzzy sets A and B is a fuzzy set defined by the membership function:

$$\mu_{(A\cup B)}(x) = max\left(\mu_A(x),\ \mu_B(x)\right) \qquad \text{(Eq. 2.4)}$$

- **Intersection**: Let μ_A and μ_B be membership functions that define the fuzzy sets A and B, respectively, on the universe X. The intersection of fuzzy sets A and B is a fuzzy set defined by the membership function:

$$\mu_{(A\cap B)}(x) = min\left(\mu_A(x),\ \mu_B(x)\right) \qquad \text{(Eq. 2.5)}$$

- **Complement:** Let μ_A be a membership function that defines the fuzzy set A, on the universe X. The complement of A is a fuzzy set defined by the membership function:

$$\mu_{(A)c}(x) = 1 - \mu_{(A)}(x) \qquad \text{(Eq. 2.6)}$$

2.1.4 Fuzzy Inference System

The process of drawing conclusion from existing data is called inference. Fuzzy Inference Process combine membership functions with the control rules to derive the fuzzy output. The fuzzy inference engine uses the rules in the knowledge-base and derives conclusion based on the rules. By using linguistic variable, fuzzy if-then rules would be set up: generally presented in the form of: if x is A then y is B where x and y are linguistic variables and A and B are linguistic values, determined by their fuzzy sets. The first part of the rule is called the antecedent, and can consist of multiple parts with the operators AND or OR between them. The latter part is called the consequent, and can also include several outputs (Jaiswal & Sarode, 2015).

2.1.5 Components of Fuzzy Inference Systems

The basic configuration of a fuzzy inference system consists of four conceptual components: fuzzification, rule base, inference process and defuzzification. The fuzzification is a mapping from the observed input universe of discourse to the fuzzy sets. Note that the basic fuzzy inference system can take either fuzzy inputs or crisp inputs, but the outputs it produces are almost always fuzzy sets. Sometimes it is necessary to have a crisp output, especially in a situation where a fuzzy inference system is used as a controller. Therefore, we need a method of defuzzification to extract a crisp value that best represents a fuzzy set (Chen, 2013).

2.1.6 Types of Fuzzy Rule-Based Systems

There are two types of fuzzy rule-based systems that can be implemented in the Fuzzy Logic: Mamdani-type and Sugeno-type. These two types of rule-based systems vary somewhat in the way outputs are determined. Because of its multidisciplinary nature, FRBSs are associated with a number of names, such as fuzzy inference systems, fuzzy expert systems, fuzzy modeling, fuzzy associative memory, fuzzy logic controllers, and simply (and ambiguously) fuzzy systems. Mamdani's fuzzy inference method is the most commonly seen fuzzy methodology. Mamdani's method was among the first control systems built using fuzzy set theory (MathWorks, 2015).

2.1.6.1 Mamdani-Type Fuzzy Rule-Based System

Mamdani's fuzzy inference method is the most commonly used fuzzy methodology. Mamdani's method was among the first control systems built using fuzzy set theory. It was proposed in 1975 by Ebrahim Mamdani as an attempt to control a steam engine and boiler combination by synthesizing a set of linguistic control rules obtained from experienced human operators. Mamdani's effort was based on Lotfi Zadeh's 1973 paper on fuzzy algorithm for complex systems and decision processes (Mamdani & Assilian, 1975), (Lotif, 1975).

Mamdani-type inference, as defined for Fuzzy Logic Toolbox, expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification. It is possible, and in many cases, much more efficient, to use a single spike as the output membership functions rather than a distributed fuzzy set. This type of output is sometimes known as a singleton output membership function, and it can be thought of as a pre-defuzzified fuzzy set (Mamdani & Assilian, 1975).

2.1.6.2 Sugeno-Type Fuzzy Rule-Based System

In Sugeno-type, rather than integrating across the two-dimensional function to find the centroid, the weighted average of a few data points is used. In general, Sugeno-type systems can be used to model any inference system in which the output membership functions are either linear or constant (Mamdani & Assilian, 1975).

A typical rule in a Sugeno fuzzy model has the form:

$$If\ Input\ 1\ =\ x\ and\ Input\ 2\ =\ y,\ then\ Output\ is\ z\ =\ ax\ +\ by\ +\ c$$

2.2 Fuzzy Numbers

A fuzzy number is a generalization of a regular, real number in the sense that it does not refer to one single value but rather to a connected set of possible values, where each possible value has its own weight between 0 and 1 (Hanss, 2005). Fuzzy number and possibility theories are used for problems where uncertainties in the definition of input data do not allow for a treatment by means of probabilistic methods. Starting from a scarce/uncertain body of information, fuzzy numbers are used to define possibility distributions as well as upper and lower bounds for a wide class of probability distributions compatible with available data (Ferrari & Savoia, 1999).

2.2.1 Ranking Fuzzy Numbers

Ranking fuzzy numbers plays a very important role in linguistic decision making and some other fuzzy application systems. Several strategies have been proposed for ranking of fuzzy numbers. Each of these techniques have been shown to produce non-intuitive results in certain cases. In many applications, ranking of fuzzy numbers is an important component of the decision process. In practice, many real-world problems require handling and evaluation of fuzzy data for making decision. To evaluate and compare different alternatives, it is necessary to rank fuzzy numbers. In addition, the concept of optimum or best choice is completely based on ranking, rating or comparison (Abbasbandy, 2006).

2.3 Related Works

Recently, many researchers have reported a work on the applications of Fuzzy Logic in Educational systems on performance evaluation of teachers as well as students' evaluation. Some of these researchers' works are presented below.

Ramjeet and Vijendra (2011) have done their work on students' academic performance evaluation by the help of fuzzy logic technique. The system was known as fuzzy expert system. To implement the proposed system, they have used fuzzy logic toolbox in Matlab (version 7.8). The testing of the system was done by taking 20 students' mark obtained by examination results of semester-I and semester-II. For the sake of fuzzification both semester examination results were converted to linguistic values by the help of triangular membership functions. To calculate active membership function according to the rule table, Mamdani-type fuzzy inference system was used. The calculated output was done by using most common defuzzification method, known as center of gravity (centroid). Finally, when the results are evaluated by fuzzy expert system, the have found that evaluation with the classical method obeys to a mathematical rule, but evaluation with fuzzy logic technique has a great flexibility and reliability (Ramjeet & Vijendra, 2011).

Similarly, Gokmen proposed Student performance evaluation method for laboratory courses in Marmara University Technical Education Faculty, Electricity Education Department based on fuzzy logic systems. This study was carried out with fuzzy logic technique and it was compared with classical evaluating method. The study is done by taking two exam results of twenty students, exam1 and exam2, and the membership function used is triangular for both inputs and output. Defuzzification technique used in this study is center of area (centroid). Study samples are notes which twenty students took the control technique laboratory course. Evaluation of the results showed variations between the classical and fuzzy logic methods. He found that fuzzy logic evaluation is flexible and provides many evaluation options, while the classical method adheres to constant mathematical calculation (Gokmen, 2010).

In addition, Jamsandekar and Mudholkar (2013) have proposed an approach that perform fuzzification of the input data (students' marks) by creating fuzzy inference system(FIS) subject wise, next each FIS output is passed to next level FIS with two inputs, outputs of the final FIS are performance value calculated based on all subject marks with/without lab marks. In this proposed approach, two membership function trapezoidal and triangular are used in combination. As they compared experimental results with traditional evaluation method, it helps in identifying students lying at overlapping section of two class distribution the results also could help educators to monitor the progress and provide timely guidance to students to achieve better performance score. In addition to evaluating students' performance, they perform classification of students' score according to the level of their performance (Jamsandekar & Mudholkar, 2013).

The use of fuzzy logic approach for academic performance evaluation is in general fairly new. However, it has reached a wide range of application areas in different fields in addition to academic performance in educational systems, including engineering field for the performance evaluation of buildings. A new approach is presented in (Pakdamar & Guler, 2008) for the performance evaluation of existing or new design buildings. In this study a fuzzy logic system used that gives more realistic results to determine the performance level of reinforced concrete buildings under earthquake effect by considering the sections having plastic deformations and the level of deformation on the structural elements by using the displacement based design technique and analysis.

In the above section literatures are reviewed in the area of fuzzy logic. As the papers reviewed, all the authors argued that the use of fuzzy logic has a great flexibility and reliability over classical set. All the papers deal with only fuzzy logic; however, fuzzy number ranking is also an important task in the decision making (performance evaluation). In this study, we integrate fuzzy logic with ranking fuzzy numbers.

CHAPTER THREE

3 METHODOLOGY

This section describes the overall strategy that we choose to integrate the different components of the study in a coherent and logical way, thereby, ensuring we have effectively address the research problem; it constitutes the blueprint for the method of data collection, measurement, and analysis of data; and practical methods used in order to answer the research questions and meet the objectives of this research are presented.

3.1 Research Design

According to (Singh, 2006), research design is essentially a statement of the object of the inquiry and the strategies for collecting the evidences, analyzing the evidences and reporting the findings. The purpose of this research is to study the practice and problems of teachers' performance evaluation in Higher Education Institutions of Ethiopia: the case of Adama Science and Technology University. In this study, we used experimental research design, it is blueprint of the procedure that enables the researcher to test his hypothesis by reaching valid conclusions about relationships between independent and dependent variables.

3.2 Data Source

The main source of the data used to undertake this research was teachers' real data taken from Adama Science and Technology University (ASTU). ASTU is one of the two public University which is under Ministry of Science and Technology and it is found in Oromia region Adama town. In ASTU there are 515 (Five hundred and Fifteen) foreign and local teachers with different academic rank. However, the study is concerned on only teachers, we use 24 teachers' data as a sample. The main reason to select this University for the study is that, we can get important data easily concerning the problem domain. This can help for the learner to learn more and to give a better performance model. The collected data was both in a hard copy and some soft copy format.

3.3 Data Collection Techniques

For the purpose of this study we collected data by using different data collection techniques: such as interview, document analysis, and evaluation forms. These are most common methods used by different researchers and they are very crucial in developing various types of frameworks.

3.3.1 Evaluation Forms

These are forms in which the teachers are evaluated by students, colleagues and their department heads. The feedbacks from those forms are submitted to the department and then will be transferred to the school. We used the average results which are found from the evaluation forms.

3.3.2 Interview

An interview is a conversation where questions are asked and answers are given. We have used this method to have a better understanding about the current approach of teachers' performance evaluation system.

3.4 Modeling Fuzzy Rule-Based Systems

In 1965 Zadeh introduced the theory of fuzzy sets (Zadeh, 1965). This theory proposes making the membership function operations over the range of real numbers [0, 1]. New operations for the calculation of logic membership functions were proposed and showed to be a reasonable tool to generalize classic logic. The use of linguistic variables and mathematical relationships in this technique, gives the decision-making process more adequacy. Fuzzy logic systems are particularly suited to model the relationship between variables in environments that are either ill-defined or very complex. Fuzzy systems provide the means of representing the expert knowledge of humans about the process in terms of fuzzy (IF–THEN) rules. A fuzzy rule is the basic unit for capturing knowledge in fuzzy systems. A fuzzy rule, like a conventional rule in artificial intelligence, has two components: an 'if' part and a 'then' part which are also referred to as antecedent and consequent, respectively (Alavi, 2013).

3.5 How Fuzzy Logic Systems Work?

A fuzzy logic system (FLS) can be defined as the nonlinear mapping of an input data set to a scalar output data. A FLS consists of four main components: fuzzifier, rules, inference engine, and defuzzifier. The general process of fuzzy logic is explained in the *table 3.1*. Firstly, a crisp set of input data are gathered and converted to a fuzzy set using fuzzy linguistic variables, fuzzy linguistic terms and membership functions. This step is called fuzzification. After that, an inference is made based on a set of rules. Lastly, the resulting fuzzy output is mapped to a crisp output using the membership functions, in the defuzzification step (Mendel, 1995).

Table 3. 1. Fuzzy Logic Algorithm *(James, 1995)*

Steps	**Fuzzy logic algorithm**
1	Define the linguistic variables and terms (initialization)
2	Construct the membership functions (initialization)
3	Construct the rule base (initialization)
4	Convert crisp input data to fuzzy values using the membership functions (fuzzification)
5	Evaluate the rules in the rule base (inference)
6	Combine the results of each rule (inference)
7	Convert the output data to non-fuzzy values (defuzzification)

The detailed discussion on the phases of fuzzy inference system is presented below:

3.5.1 Fuzzification of Inputs

Fuzzification is the first step to define the inputs and determine the degree to which they belong to each of the appropriate fuzzy sets by means of membership functions. In Fuzzy Logic Toolbox, the input is always a crisp numerical value limited to the universe of discourse of the input variable and the output is a fuzzy degree of membership in the qualifying linguistic set. Fuzzification of the input amounts to either a table lookup or a function evaluation. Each input is fuzzified over all the qualifying membership functions required by the rules (MathWorks, 2015).

3.5.2 Application of Fuzzy Operator

After the crisp inputs are converted to fuzzy sets, the degree to which each part of the antecedent is satisfied for each rule is known. If the antecedent of a given rule has more than one part, the fuzzy operator is applied to obtain one number that represents the result of the antecedent for that rule. This number is then applied to the output function. The input to the fuzzy operator is two or more membership values from fuzzified input variables. The output is a single truth value. Any number of well-defined methods can fill in for the AND operation or the OR operation. In Fuzzy Logic Toolbox, two built-in AND methods are supported: min (minimum) and prod (product). Two built-in OR methods are also supported: max (maximum), and probor (probabilistic OR) method (MathWorks, 2015).

3.5.3 Implication Method

Before applying the implication method, the rule's weight is determined. Every rule has a weight between 0 and 1, which is applied to the number given by the antecedent. Generally, this weight is 1 and thus has no effect at all on the implication process. From time to time you may want to weight one rule relative to the others by changing its weight value to something other than 1. After proper weighting, has been assigned to each rule, the implication method is implemented. A consequent is a fuzzy set represented by a membership function, which weights appropriately the linguistic characteristics that are attributed to it. The consequent is reshaped using a function associated with the antecedent (a single number). The input for the implication process is a single number given by the antecedent, and the output is a fuzzy set. Implication is implemented for each rule. Two built-in methods are supported, and they are the same functions that are used by the AND method: min (minimum), which truncates the output fuzzy set and prod (product), which scales the output fuzzy set (MathWorks, 2015).

3.5.4 Aggregation of All Outputs

Because decisions are based on the testing of all of the rules in a FIS, the rules must be combined in some manner in order to make a decision. Aggregation is the process by which the fuzzy sets that represent the outputs of each rule are combined into a single fuzzy set. Aggregation only occurs once for each output variable, just prior to the fifth and final step, defuzzification. The input of the aggregation process is the list of truncated output functions returned by the implication process for each rule. The output of the aggregation process is one fuzzy set for each output variable. As long as the aggregation method is commutative (which it always should be), then the order in which the rules are executed is unimportant. Totally, three built-in methods are supported: max (maximum), PROB-OR (probabilistic OR) and sum (simply the sum of each rule's output set) (MathWorks, 2015).

3.5.5 Defuzzification

The input to the defuzzification process is a fuzzy set while the output of the defuzzification process is a single number (crisp output) (Jaiswal & Sarode, 2015). The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single number. As much as fuzziness helps the rule evaluation during the intermediate steps, the final desired output for each variable is generally a single number. However, the aggregate of a fuzzy set encompasses a range of output values, and so must be defuzzified in order to resolve a single output value from the set. Perhaps the most popular defuzzification method is the centroid calculation, which returns the center of area under the curve. There are five built-in methods supported: centroid, bisector, middle of maximum (the average of the maximum value of the output set), largest of maximum, and smallest of maximum. The fuzzy inference diagram is the composite of all the smaller diagrams presented so far in this section. It simultaneously displays all parts of the fuzzy inference process. This compact flow shows everything at once, from linguistic variable fuzzification all the way through defuzzification of the aggregate output (James, 1995).

Finally, to conclude this chapter it presents the whole methodology used to develop the framework, source of data, data collection techniques and research design. The next chapter discusses about the design and implementation of the proposed system.

CHAPTER FOUR

4 DESIGN AND IMPLEMENTATION

4.1 Architecture of Proposed Fuzzy Rule-Based System

The architecture of proposed Fuzzy rule-based framework for teachers' performance evaluation passes the basic steps of fuzzy logic systems as shown in *figure 4.1*.

- **Crisp Value:** Crisp value is a calculated feedback value of teachers from students, colleagues and department head.
- **Fuzzification**: Fuzzification means crisp value (feedback) is converted into Fuzzy input value with help of suitable membership function (triangular and trapezoidal membership functions).
- **Inference Mechanism**: Define different type fuzzy rule ("If Then" Rule) for teachers' performance evaluation.
- **Fuzzy Output**: Determines an output membership function value for each active rule ("If Then" rule).
- **Defuzzification (Performances):** Defuzzification means calculate the final output (Performance Value) with the help suitable defuzzification method. In this study, we have used Centre of Area (COA) for Defuzzification (performance evaluation).

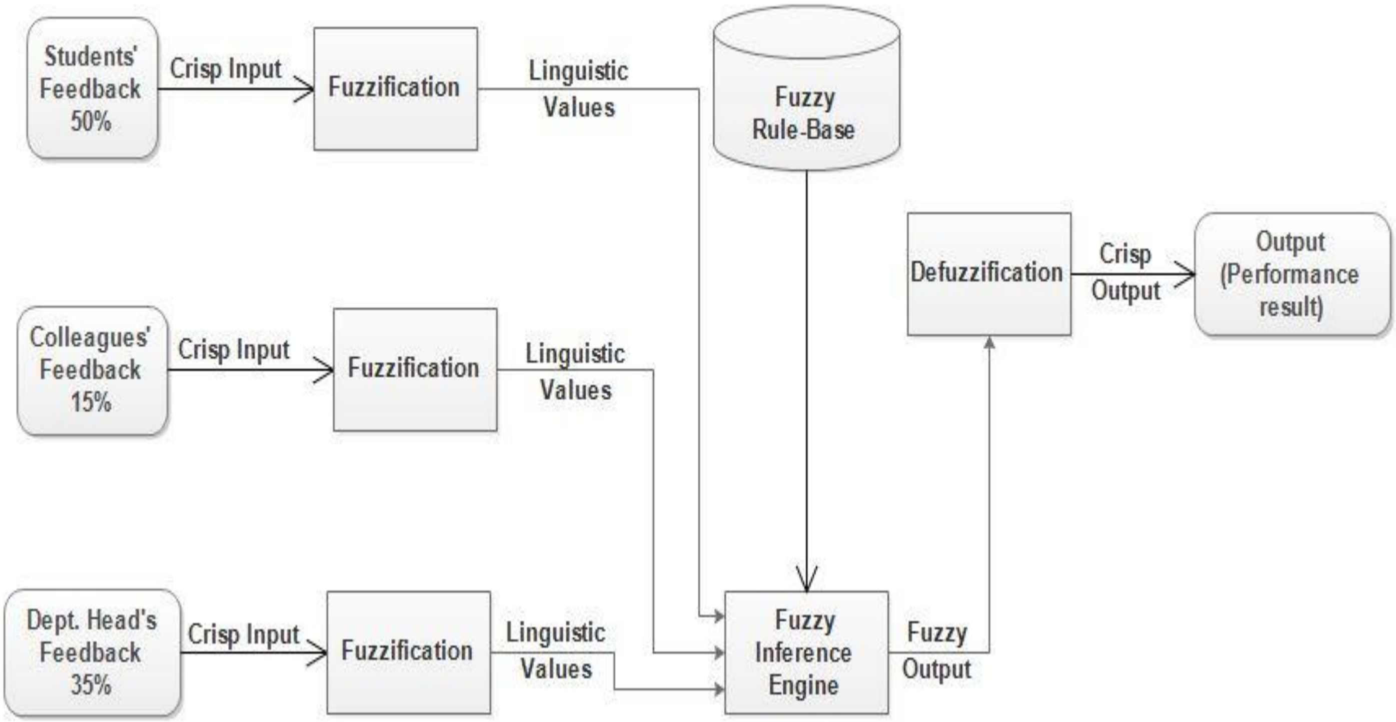

Figure 4. 1 Architecture of Proposed Fuzzy Rule-Based System

4.2 System Developmental Tool Overview

To implement the framework, we used MATLAB 7.6.0.324 (R2008a). It is a product of the Math Works, Inc. and is an advanced interactive software package specially designed for scientific and engineering computation. The Matlab environment integrates graphic illustrations with precise numerical calculations, and is a powerful, easy-to-use, and comprehensive tool for performing all kinds of computations and scientific data visualization. Matlab has proven to be a very flexible and usable tool for solving problems in many areas. It is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation (Sivanandam, Sumathi, & Deepa, 2007). Typical use includes:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping

- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building

4.2.1 Fuzzy Logic Toolbox in Matlab

Fuzzy Logic Toolbox™ provides MATLAB® functions, apps, and a Simulink® block for analyzing, designing, and simulating systems based on fuzzy logic. The product guides us through the steps of designing fuzzy inference systems. Functions are provided for many common methods, including fuzzy clustering and adaptive neuro-fuzzy learning. The toolbox lets us to model complex system behaviors using simple logic rules, and then implement these rules in a fuzzy inference system. We can use it as a stand-alone fuzzy inference engine. Alternatively, we can use fuzzy inference blocks in Simulink and simulate the fuzzy systems within a comprehensive model of the entire dynamic system (MathWorks, 2016).

4.2.1.1 Key Features of Fuzzy Logic Toolbox

- Fuzzy Logic Design application for building fuzzy inference systems and viewing and analyzing results
- Membership functions for creating fuzzy inference systems
- Support for AND, OR, and NOT logic in user-defined rules
- Standard Mamdani and Sugeno-type fuzzy inference systems
- Automated membership function shaping through neuro adaptive and fuzzy clustering learning techniques
- Ability to embed a fuzzy inference system in a Simulink model

4.2.2 Membership Function

A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is sometimes referred to as the universe of discourse. Or, the membership function is a graphical representation of the magnitude of participation of each input. The rules use the input membership values as weighting factors to determine their influence on the fuzzy output sets of the final output conclusion. Once the functions are inferred, scaled, and combined, they are defuzzified into a crisp output which drives the system (Omar, 2015).

For any set X, a membership function on X is any function from X to the real unit interval [0, 1]. The membership function which represents a fuzzy set is usually denoted by μA. For an element x of X, the value μA(x) is called the membership degree of x in the fuzzy set. The membership degree μA(x) quantifies the grade of membership of the element x to the fuzzy set. The value '0' means that x is not a member of the fuzzy set; the value '1' means that *x* is fully a member of the fuzzy set. The values between 0 and 1 characterize fuzzy members, which belong to the fuzzy set only partially.

A fuzzy set is fully characterized by its membership function (MF). Since most fuzzy sets in use have a universe of discourse X consisting of the real line R, it would be impractical to list all the pair defining a membership function. A more convenient and concise way to define an MF is to express it as a mathematical formula.

The definition of the membership functions is a very delicate point in the design of the FC, because the only restriction that a membership function has to satisfy is that its values must be in the [0,1] range. Therefore, unlike a crisp one, a fuzzy set can be represented by an infinite number of membership functions (Omar, 2015).

4.2.2.1 Types of Membership Functions

The simplest membership functions are formed using straight lines. Due to their simple formulas and computational efficiency, both triangular MFs and trapezoidal MFs have been used extensively, especially in real-time implementations (Alonso, 2016). The most common types of MF are discussed below.

- **Triangular and Trapezoidal MFs**

From strait line membership functions, the simplest is the *triangular* membership function, and it has the function name *trimf* in fuzzy logic toolbox. It is nothing more than a collection of three points forming a triangle. The *trapezoidal* membership function, has the function name *trapmf*, has a flat top and really is just a truncated triangle curve. These straight-line membership functions have the advantage of simplicity (eMathTeacher, 2016).

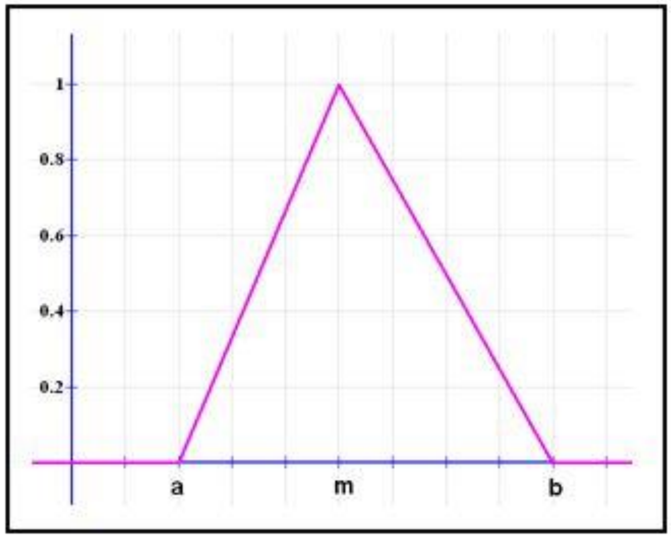

Figure 4. 2. Triangular Membership Function

$$\mu_A(x)=\begin{cases}0, & x\le a\\ \frac{x-a}{m-a}, & a<x\le m\\ \frac{b-x}{b-m}, & m<x\le b\\ 0, & x\ge b\end{cases} \qquad \text{(Eq. 4.1)}$$

Triangular function: defined by a lower limit *a*, an upper limit *b*, and a value *m*, where *a* < *m* < *b*.

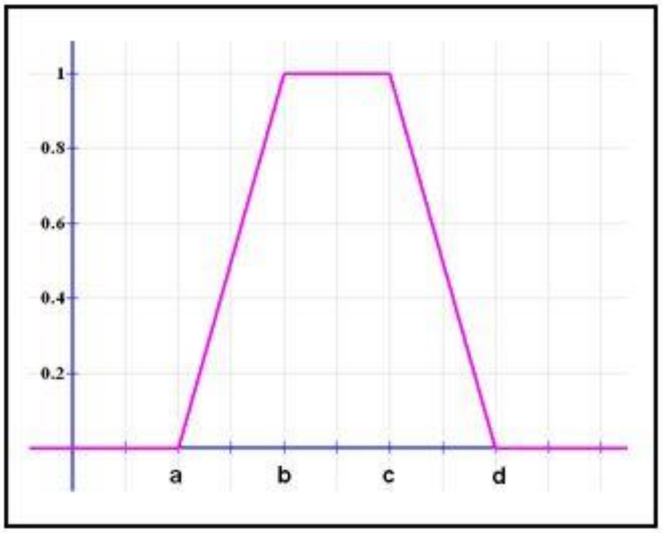

Figure 4. 3. Trapezoidal Membership Function

$$\mu_A(x) = \begin{cases} 0, & (x<a) \text{ or } (x>d) \\ \frac{x-a}{b-a}, & a \le x \le b \\ 1, & \text{b} \le x \le c \\ \frac{d-x}{d-c} & x \ge b \end{cases} \qquad \text{(Eq. 4.2)}$$

Trapezoidal function: defined by a lower limit *a*, an upper limit *d*, a lower support limit *b*, and an upper support limit *c*, where $a < b < c < d$. According to (eMathTeacher, 2016) there are two special cases of a trapezoidal function, which are called R-functions and L-functions.

L-Functions: with parameters c = d = + ∞

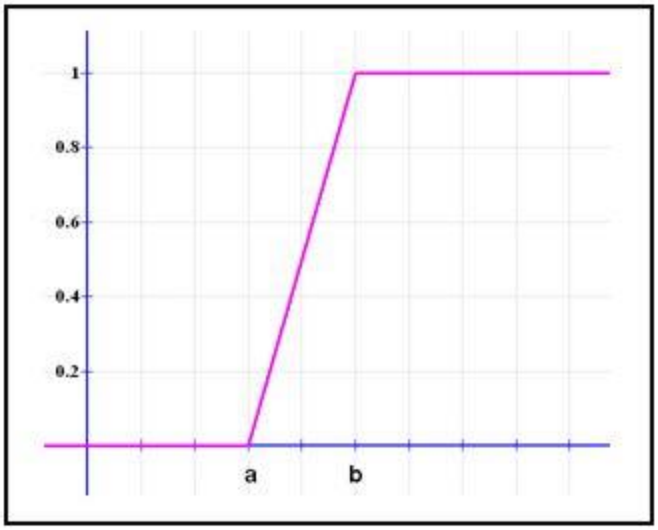

Figure 4. 4. L-Trapezoidal Membership Function

$$\mu_A(x) = \begin{cases} 0, & x < a \\ \frac{x-a}{b-a}, & a \le x \le b \\ 1, & x > b \end{cases} \qquad \text{(Eq. 4.3)}$$

R-functions: with parameters, a = b = - ∞

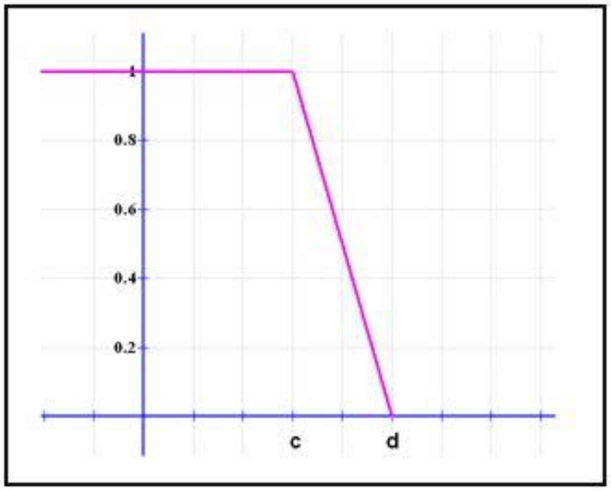

Figure 4. 5. R-Trapezoidal Membership Function

$$\mu_A(x) = \begin{cases} 0, & x<d \\ \frac{d-x}{d-c}, & c \le x \le d \\ 1, & x<c \end{cases} \qquad \text{(Eq. 4.4)}$$

- **Gaussian Membership Function**

It is another type membership function and defined by a central value ***m*** and a standard deviation ***k* > *0***. The smaller *k* is, the narrower the "bell" is.

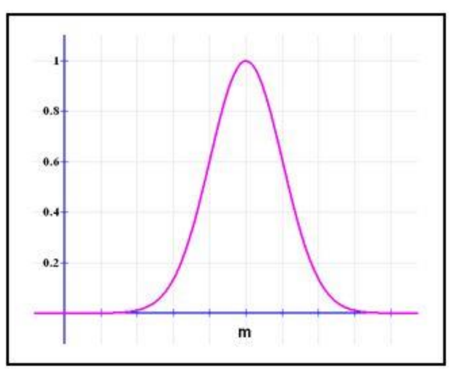

Figure 4. 6. Gaussian Membership Function

$$e^{-\frac{(x-m)^2}{2k^2}} \quad \text{(Eq. 4.5)}$$

Where: m and k are the center and width of the fuzzy set A, respectively.

- **Generalized bell Membership Function**

The generalized bell membership function is specified by three parameters and has the function name "gbellmf" in MATLAB. The bell membership function has one more parameter than the Gaussian membership function, so it can approach a non-fuzzy set if the free parameter is tuned. Because of their smoothness and concise notation, Gaussian and bell membership functions are popular methods for specifying fuzzy sets. Both of these curves have the advantage of being smooth and nonzero at all points. Figure 4.7 shows the graphical representation of the generalized bell-shaped membership function. The generalized bell function depends on three parameters a, b, and c as given by:

$$f(x;a,b,c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}} \quad \text{(Eq. 4.6)}$$

where the parameter b is usually positive. The parameter c locates the center of the curve. Enter the parameter vector parameters, the second argument for gbellmf, as the vector whose entries are a, b, and c, respectively.

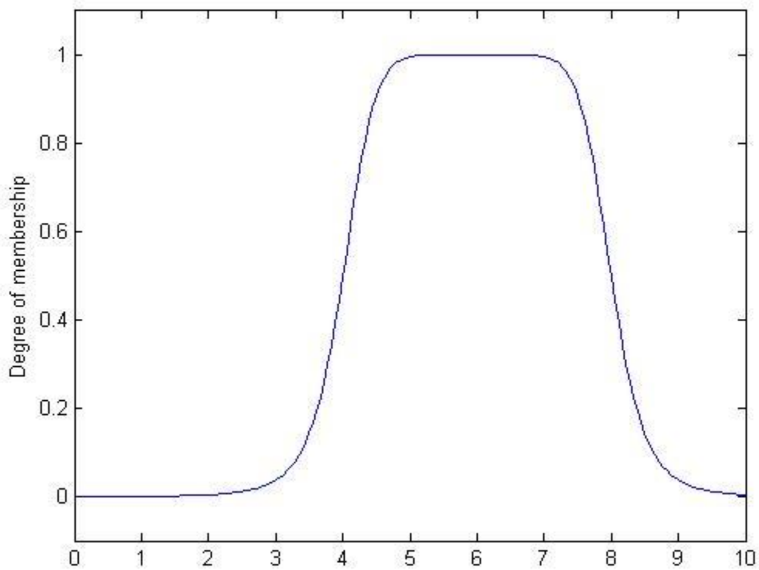

Figure 4. 7. Generalized-Bell Membership Function, P = [2 4 6]

Due to their simple formula and computational efficiency, the triangular membership function and trapezoidal membership function have been used.

4.3 Experimentation

All the experimentations presented here are done by using fuzzy logic toolbox in Matlab software. As discussed in the earlier chapters using fuzzy logic approach passes five stages, namely: crisp data preparation, fuzzification (crisp-to-fuzzy), rule-base, aggregation of output, and defuzzification.

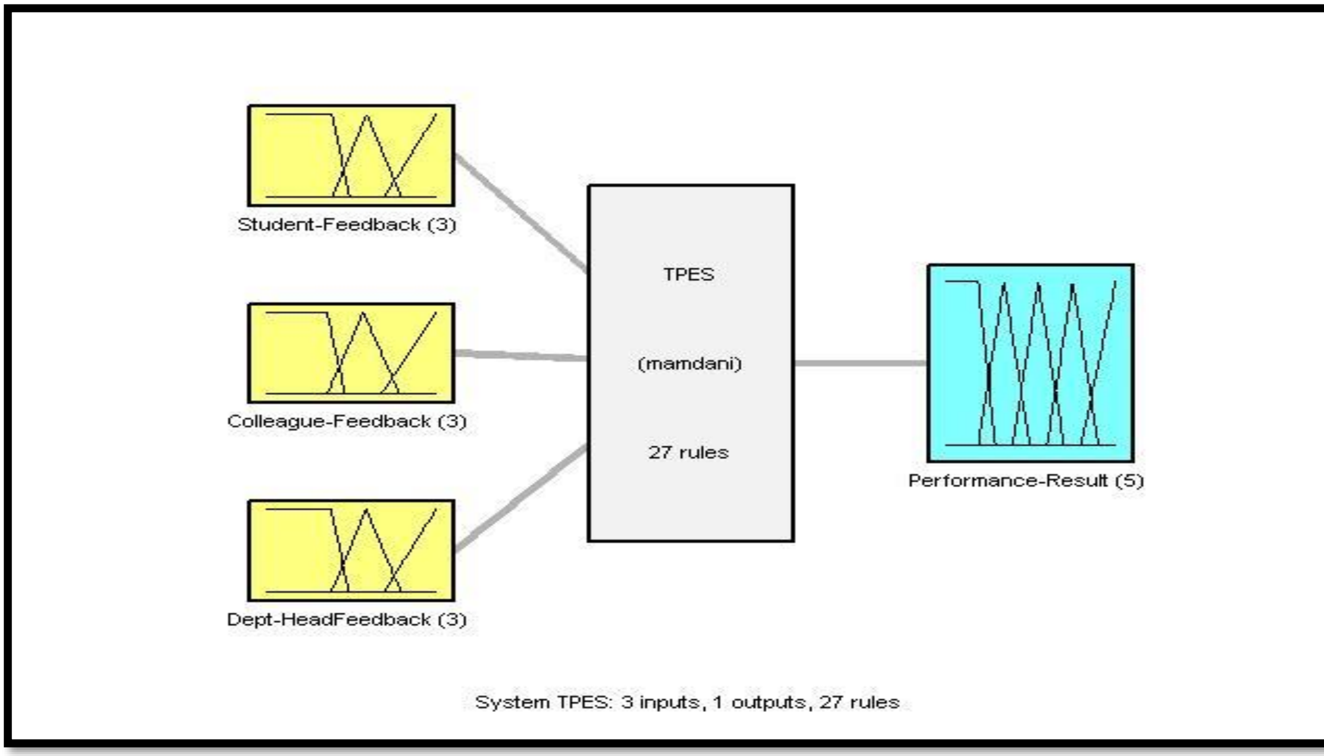

Figure 4. 8. Fuzzy Inference System of TPES

Figure 4.8 shows that the selected three parameters namely: Student_Feedback with three membership function, Colleague_Feedback with three membership function and Dept-Head_Feedback with three membership function are integrated together by Mamdani type FIS to give the final output named Performance_result with five membership function.

4.3.1 Crisp Data Preparation

In this study, the crisp data is the average feedback result that is collected from students, colleagues and department head. The feedback results we used for this study are the average result. And the average feedback results are converted linguistic values for the sake of *if-then* rule generation and development of fuzzy inference system. The following are the major reasons that press us to use the average feedback results.

- Performance evaluation of teachers' involvers more than twenty different criteria, so that this extremely increases the number of rule.
- If the number of rules increase, the complexity of the system also increase.

So, to make the system manageable and easy to develop we have used the average feedback result. The following tables shows the procedure of assigning linguistic values for the average feedback intervals.

Table 4. 1. Crisp data of Performance result

Performance Result	
Linguistic Values	**Numeric Intervals**
Excellent	(80, 100, 100)
Very Good	(60, 75, 90)
Good	(40, 55, 70)
Poor	(20, 35, 50)
Very Poor	(0, 0, 20, 30)

Table 4.1 shows the linguistic values of final performance result and the intervals assigned to each linguistic value. The output performance result has five membership function namely, *"Very poor", "Poor", "Good", "Very good" and "Excellent"* each with its own numeric interval as shown in the table.

Table 4. 2.Crisp data of Student's Feedback

Student's Feedback	
Linguistic Value	**Intervals**
Good	(35, 50, 50)
Average	(20, 30, 40)
Low	(1, 1, 20, 25)

Table 4. 3. Crisp data of Colleague's Feedback

Colleague's Feedback	
Linguistic Value	**Intervals**
Good	(10.5, 15, 15)
Average	(6, 9, 12)
Low	(1, 1, 6, 7.5)

Table 4. 4. Crisp data of Department Head's Feedback

Department Head's Feedback	
Linguistic Value	**Intervals**
Good	(24.5, 35, 35)
Average	(14, 21, 28)
Low	(1, 1, 14, 17.5)

For the teachers' performance evaluation, initially there are five linguistic values, namely *"Poor", "Fair", "Good", "Very Good"* and *"Excellent"* with numeric values 1, 2, 3, 4 and 5 respectively. After collecting and calculating the feedback results from the students, colleagues and department head, we got average feedback result, this value is used to perform the final performance result.

Table 4.2, 4.3 and 4.4 shows the crisp data of student feedback, colleague feedback and department head feedback respectively. Each average feedback results are grouped into three membership functions, namely *"Low", "Average"* and *"Good"*. For the three feedback results the intervals for each membership function is different, because the percentage assigned for student feedback, colleague feedback and department head feedback is different, i.e. 50% from student feedback, 15% from colleague feedback and 35% from department head feedback.

4.3.2 Fuzzification

Fuzzification means the crisp value (teachers' feedback result) is converted into Fuzzy input value with help of suitable membership function (In the present work the combination of triangular and trapezoidal membership functions has been employed). The following figures show that the conversion of crisp data to fuzzy data. The figures are the graphical representations of the fuzzification process, and the graphs are plotted by "*plot"* command in MATLAB.

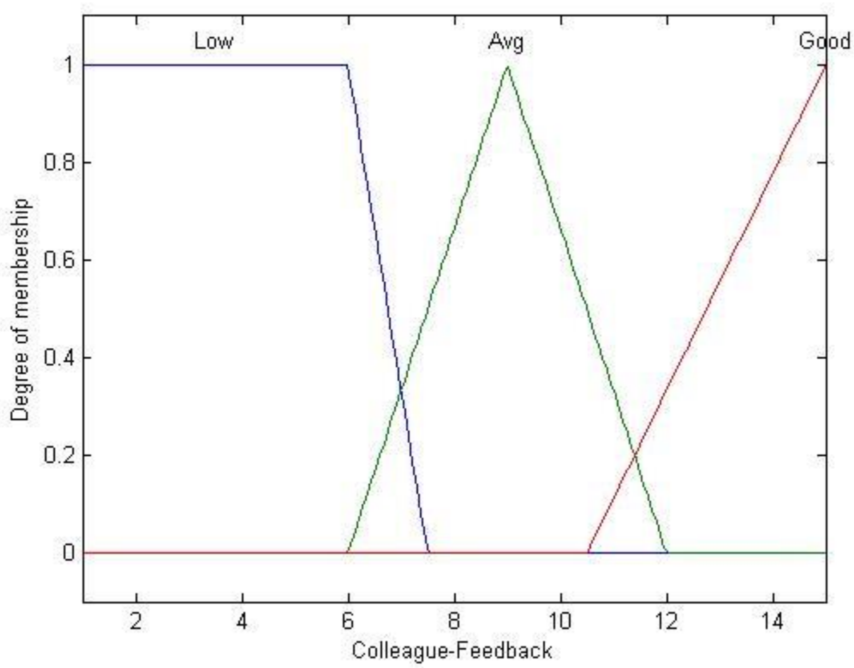

Figure 4. 9.Membership Functions for Colleague Feedback

Figure 4.9 shows the graphical representation of fuzzification of input parameter "Colleague Feedback" with three membership functions and its corresponding range as explain in Table 4.3, the membership functions are overlapping with each other for achieving better results.

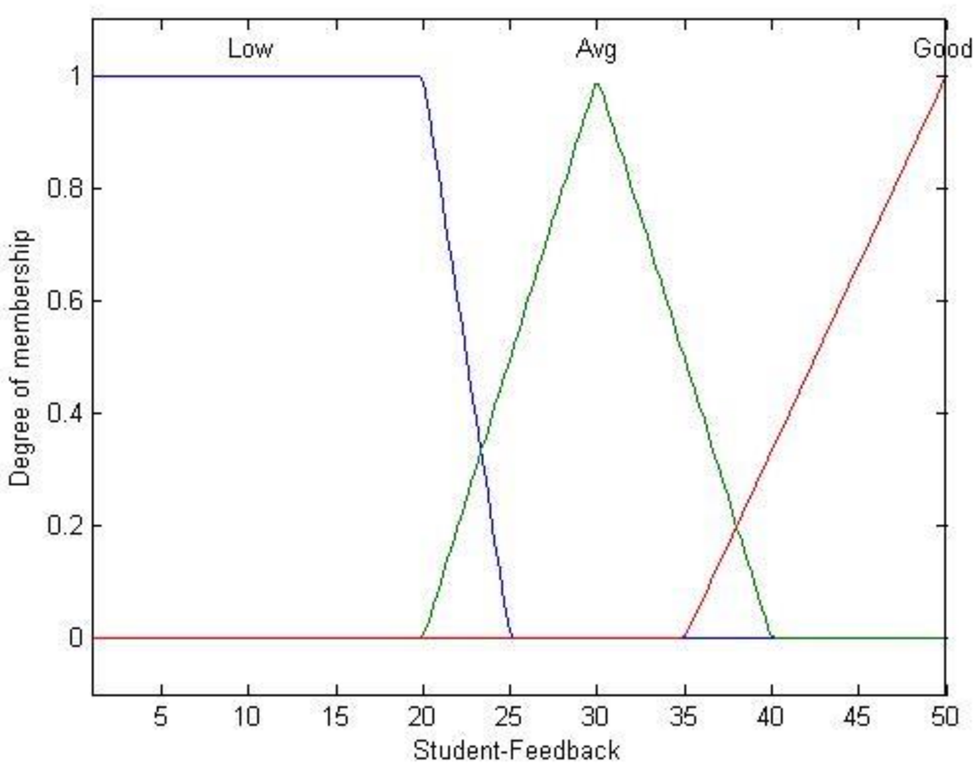

Figure 4. 10. Membership Functions for Students Feedback

Figure 4.10 shows the graphical representation of fuzzification of input parameter "Students Feedback" with three membership functions namely *low, average and good,* and its corresponding range is as explain in Table 4.2, the membership functions are overlapping with each other for achieving better results.

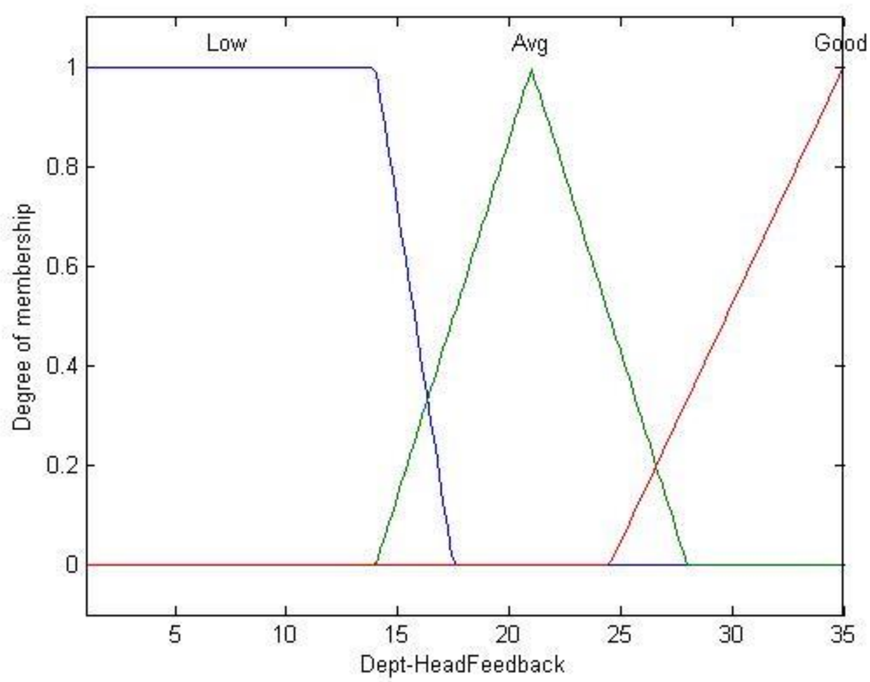

Figure 4. 11. Membership Functions for Dept. Head Feedback

Figure 4.11 shows the graphical representation of fuzzification of input parameter "Dept. Head Feedback" with three membership functions and its corresponding range as explain in Table 4.4, the membership functions are overlapping with each other for achieving better results.

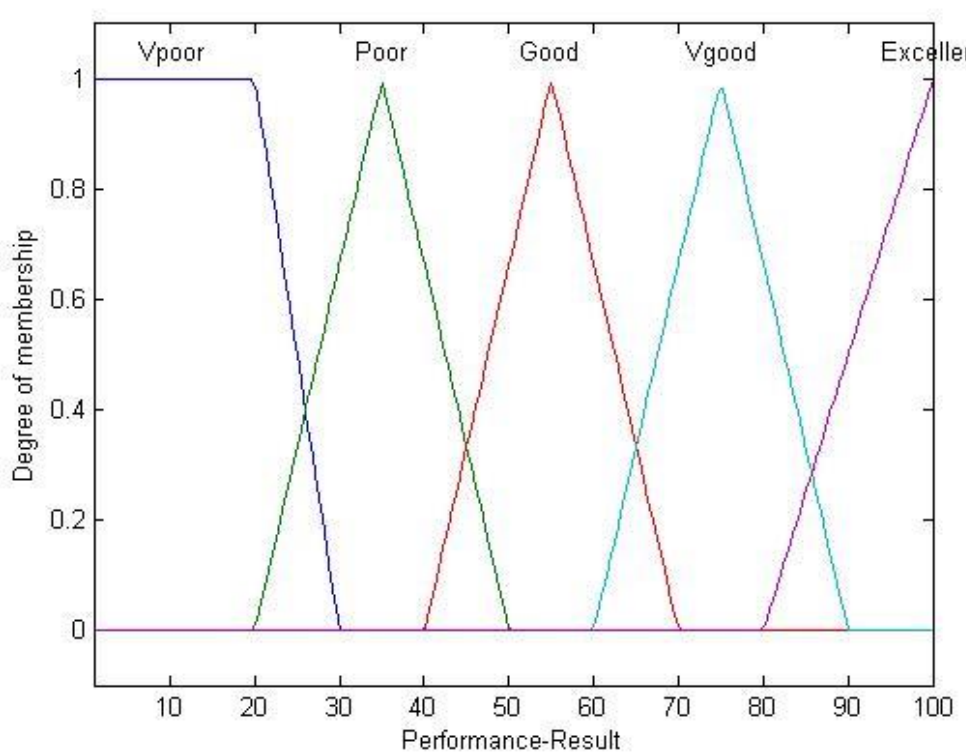

Figure 4. 12. Membership Functions for Performance Result

Figure 4.12 shows the graphical representation of fuzzification of output parameter "Performance-Result" with five membership functions namely "*Very Poor, Poor, Good, Very Good and Excellent"* and its corresponding range as explain in Table 4.1, the membership functions are overlapping with each other for achieving better results.

4.3.3 Rule-Base

Rules form the basis for the fuzzy logic to obtain the fuzzy output. The rule-based form uses linguistic variables as its antecedents and consequents. The antecedents express an inference or the inequality, which should be satisfied. The consequents are those, which we can infer, and is the output if the antecedent inequality is satisfied. The fuzzy rule- based system uses IF–THEN rule-based system, given by, IF antecedent, THEN consequent (Deepa, 2007).

The rule-base defines different types Fuzzy Rules in the form of If-Then for teachers' performance evaluation have been devised based on the criteria approved by University bodies (see appendix IV). That means a particular teacher should be evaluated out of 100%, from this 50% is evaluated by students, 15% is evaluated by colleagues and the rest of 35% is evaluated by the department head. For the purpose of experimentation, we build twenty-seven different if-then rules by using linguistic values. We use the following rules to evaluate the performance of teachers.

Rule1 . IF student_feedback is low AND colleague_feedback is low AND dept_head_feedback is low THEN performance is Very_Poor.

Rule2 . IF student_feedback is low AND colleague_feedback is low AND dept_head_feedback is average THEN performance is Very_Poor.

Rule3 . IF student_feedback is low AND colleague_feedback is average AND dept_head_feedback is low THEN performance is Very_Poor.

Rule4 . IF student_feedback is average AND colleague_feedback is low AND dept_head_feedback is low THEN performance is Poor.

Rule5 . IF student_feedback is low AND colleague_feedback is low AND dept_head_feedback is good THEN performance is Poor.

Rule6 . IF student_feedback is low AND colleague_feedback is good AND dept_head_feedback is low THEN performance is Poor.

Rule7 . IF student_feedback is good AND colleague_feedback is low AND dept_head_feedback is low THEN performance is good.

Rule8 . IF student_feedback is average AND colleague_feedback is average AND dept_head_feedback is low THEN performance is Poor.

Rule9 . IF student_feedback is average AND colleague_feedback is low AND dept_head_feedback is average THEN performance is Poor.

Rule10 . IF student_feedback is low AND colleague_feedback is average AND dept_head_feedback is average THEN performance is Poor.

Rule11 . IF student_feedback is average AND colleague_feedback is average AND dept_head_feedback is average THEN performance is good.

Rule12 . IF student_feedback is low AND colleague_feedback is average AND dept_head_feedback is good THEN performance is Poor.

Rule13 . IF student_feedback is average AND colleague_feedback is low AND dept_head_feedback is good THEN performance is good.

Rule14 . IF student_feedback is good AND colleague_feedback is low AND dept_head_feedback is average THEN performance is good.

Rule15 . IF student_feedback is low AND colleague_feedback is good AND dept_head_feedback is average THEN performance is Poor.

Rule16 . IF student_feedback is good AND colleague_feedback is average AND dept_head_feedback is low THEN performance is good.

Rule17 . IF student_feedback is average AND colleague_feedback is low AND dept_head_feedback is good THEN performance is good.

Rule18 . IF student_feedback is low AND colleague_feedback is good AND dept_head_feedback is good THEN performance is good.

Rule19 . IF student_feedback is good AND colleague_feedback is low AND dept_head_feedback is good THEN performance is very_good.

Rule20 . IF student_feedback is good AND colleague_feedback is good AND dept_head_feedback is low THEN performance is very_good.

Rule21 . IF student_feedback is good AND colleague_feedback is average AND dept_head_feedback is average THEN performance is very_good.

Rule22 . IF student_feedback is average AND colleague_feedback is good AND dept_head_feedback is average THEN performance is good.

Rule23 . IF student_feedback is average AND colleague_feedback is average AND dept_head_feedback is good THEN performance is good.

Rule24 . IF student_feedback is average AND colleague_feedback is good AND dept_head_feedback is good THEN performance is very_good.

Rule25 . IF student_feedback is good AND colleague_feedback is good AND dept_head_feedback is average THEN performance is very_good.

Rule26 . IF student_feedback is good AND colleague_feedback is average AND dept_head_feedback is good THEN performance is very_good.

Rule27 . IF student_feedback is good AND colleague_feedback is good AND dept_head_feedback is good THEN performance is excellent.

In case of several rules are active for the same output membership function, it is necessary that only one membership value is chosen. This process is entitled “fuzzy decision” or “fuzzy inference”. Several authors, including Mamdani, Takagi-Surgeno and Zadeh have developed a range of techniques for fuzzy decision-making and fuzzy inference. The present study uses the method proposed by Mamdani, shown in *Equation 4.6* (Semerci, 2004), (Zadeh, 1965) *and* (Rutkowski, 2004).

$$\mu_c(y) = \max_k \left[\min \left[\mu_{A_1}(input(i)) . \mu_{B_1}(input(j)) \right] \right] \ \mathrm{k} = 1, 2, \ \ldots, r \qquad (Eq.\ 4.6)$$

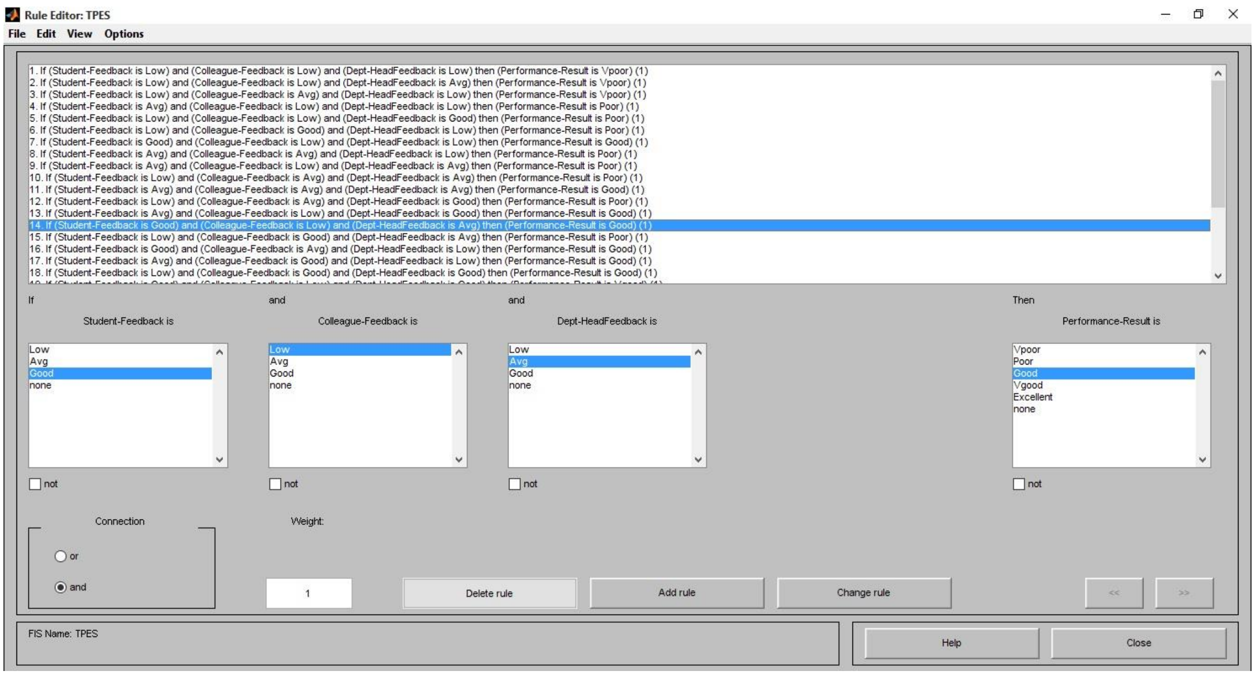

Figure 4. 13. IF-THEN Rule Editor

Figure 4. 14. Active Rules and Performance Value for feedback results (25, 7.5, 17.5) of Students, Colleagues and Department head, respectively.

Figure 4.14 shows the performance result of a particular teacher, If student_feedback is 25 AND colleague_feedback is 7.5 AND dept-head_feedback is 17.5 THEN the performance result become 55. i.e. this particular teacher get a "Good" performance result with membership value 1 (complete membership).

4.3.4 Aggregation of the Rule

The fuzzy rule-based system may involve more than one rule. The process of obtaining the overall conclusion from the individually mentioned consequents contributed by each rule in the fuzzy rule-based system is known as aggregation of rule (Deepa, 2007). There are two methods for determining the aggregation of rules:

4.3.4.1 Conjunctive System of Rules

The rules that are connected by "AND" connectives satisfy the connective system of rules. In this case, the aggregated output may be found by the fuzzy intersection of all individual rule consequents.

4.3.4.2 Disjunctive System of Rules

The rules that are connected by “OR” connectives satisfy the disjunctive system of rules. In this case, the aggregated output may be found by the fuzzy union of all individual rule consequents.

4.3.5 Defuzzification

The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single number. As much as fuzziness helps the rule evaluation during the intermediate steps, the final desired output for each variable is generally a single number. However, the aggregate of a fuzzy set encompasses a range of output values, and so must be defuzzified in order to resolve a single output value from the set (MathWorks, 2015).

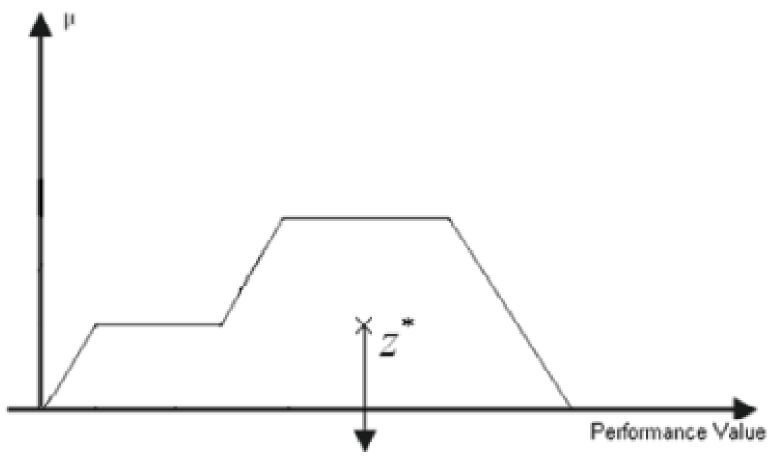

Figure 4. 15. Defuzzification with Centroid Method

After completing the fuzzy decision process, the fuzzy number obtained must be converted to a crisp value. This process is known as Defuzzification. Many methods have been developed for Defuzzification. In this paper, a center of area (Centroid) technique was applied, which is one of the most common methods (Padhy, 2005). The crisp value is calculated by the formula given below:

$$z_{COA} = \frac{\int \mu_A(z).\, zdz}{\int \mu_A(z)} \quad \text{(Eq. 4.7)}$$

where *z* is the output variable, and $\mu_A(z)$ is the membership function of the aggregated fuzzy set *A* with respect to *z*. So, this method determines the center of the area below the combined membership function. *Figure 4.15* shows the graphical representation of centroid defuzzification method.

CHAPTER FIVE

5 EVALUATION OF THE PROTOTYPE

In this chapter, we present the evaluation of the prototype and the comparison between current classical approach and the proposed fuzzy logic approach. In this study, the proposed Fuzzy Rule-Based System for Teachers' Performance Evaluation has been implemented in MATLAB 7.6.0.324 (R2008a). The proposed Fuzzy Rule-Based Framework was tested with 24 teachers' results obtained from students' feedback, colleagues' feedback and dept. head's feedback.

Table 5.1 shows the results achieved from 24 teachers of School of Electrical Engineering and Computing (SOEEC) at Adama Science and Technology University in academic year of 2015/2016 Semester-I, and the comparison of classical approach and fuzzy logic approach.

The table has six major columns and twenty-five rows. The first column shows the list of twenty-four sample teachers of SOEEC. The second major column shows the students feedback about the teacher performance, and the column has two other minor columns namely "5 and 50%", these numbers represent that the student feedback covers 50% from the total 100%, the number "5" shows that the total calculated result of student feedback converted to out of 5. In the same manner, the third and the fourth major columns show the feedback result of colleague and department head respectively.

The fifth major column of *table 5.1* shows the total calculated result of teachers with the current approach (i.e. classical approach) of teachers' performance evaluation system. It is presented in three separate minor columns namely "*5, 100% and Rank*". The "*100%*" column shows the total sum of the feedback results, and the "*Rank*" column shows the rank of teachers out of twenty-four selected sample teachers. The following equation can show this statement.

$$\mathrm{Re}\,sult\ with\ CA = student\_feedback + colleague\_feedback + dept\_head\_feedback$$

Where CA = Classical Approach

Table 5. 1. Comparison of Classical Approach with Fuzzy Logic Approach

Teachers List	**Student Feedback**		**Colleague Feedback**		**Dept. Head Feedback**		**Classical Approach**			**Fuzzy Approach**		
	5	**50%**	**5**	**15%**	**5**	**35%**	**5**	**100%**	**C_Rank**	**5**	**100%**	**F_Rank**
1	4.92	49.2	5	15	4.94	34.58	4.94	98.78	1	4.74	93.6	1
2	4.68	46.8	4.97	14.91	4.79	33.53	4.76	95.24	2	4.73	93.4	2
3	4.76	47.6	4.36	13.08	4.71	32.97	4.68	93.65	3	4.71	92.7	6
4	4.41	44.1	4.64	13.92	4.91	34.37	4.62	92.39	4	4.71	92.9	3
5	4.73	47.3	5	15	4.24	29.68	4.6	91.98	5	4.7	92.5	8
6	4.39	43.9	4.82	14.46	4.79	33.53	4.59	91.89	6	4.71	92.8	5
7	4.12	41.2	4.97	14.91	5	35	4.56	91.11	7	4.68	92.1	12
8	4.51	45.1	5	15	4.41	30.87	4.55	90.97	8	4.71	92.9	3
9	4.17	41.7	5	15	4.88	34.16	4.54	90.86	9	4.69	92.3	10
10	4.63	46.3	4.67	14.01	4.29	30.03	4.52	90.34	10	4.7	92.6	7
11	4.17	41.7	4.94	14.82	4.76	33.32	4.49	89.84	11	4.69	92.3	10
12	4.62	46.2	4.91	14.73	4.12	28.84	4.49	89.77	12	4.68	92.1	12
13	4.21	42.1	4.06	12.18	5	35	4.46	89.28	13	4.68	92	14
14	3.86	38.6	5	15	4.94	34.58	4.41	88.18	14	4.11	83	16
15	3.8	38	4.97	14.91	5	35	4.4	87.91	15	4.23	81	17
16	4.79	47.9	4.06	12.18	3.97	27.79	4.39	87.87	16	4.58	89.5	15
17	4.27	42.7	4.97	14.91	4.26	29.82	4.37	87.43	17	4.7	92.5	8
18	3.75	37.5	4.88	14.64	5	35	4.36	87.14	18	4.17	79.5	18
19	3.73	37.3	5	15	4.56	31.92	4.21	84.22	19	4.15	79	19
20	3.67	36.7	5	15	4.44	31.08	4.14	82.78	20	4.1	77.7	21
21	3.52	35.2	5	15	4.5	31.5	4.09	81.7	21	4	75.3	22
22	3.68	36.8	5	15	4.26	29.82	4.08	81.62	22	4.11	77.9	20
23	2.98	29.8	5	15	4.94	34.58	3.97	79.38	23	3.99	75	23
24	2.49	24.9	5	15	4.24	29.68	3.48	69.58	24	3.95	74.1	24

The sixth and the last major column shows the results of performance evaluation of teachers found by the proposed fuzzy rule-based approach. It shows the final performance result out of 5, out of 100%, and the ranked list. The performance result here is came by the experiment.

5.1 Comparison of the Two Ranked Lists

Table 5.2 shows the two ranks found with classical and fuzzy logic approaches. We used Kendall's tau-b correlation coefficient method to compare the two ranked lists. Kendall's Tau-a is a non-parametric correlation which is an alternative to the Spearman correlation.

5.1.1 Kendall's Tau Basic Concepts

In statistics, the Kendall rank correlation coefficient, commonly referred to as Kendall's tau coefficient (after the Greek letter τ), is a statistic used to measure the ordinal association between two measured quantities. A tau test is a non-parametric hypothesis test for statistical dependence based on the tau coefficient. It is a measure of rank correlation: the similarity of the orderings of the data when ranked by each of the quantities.

Definition: Let $x_1, \ldots, x_n$ be a sample for random variable x (in our case "x" is classical method) and let $y_1, \ldots, y_n$ be a sample for random variable y (in our case "y" is fuzzy method) of the same size n. There are $C(n,2)$ possible ways of selecting distinct pairs (x_i, y_i) and (x_j, y_j) (Zaiontz, 2016). For any such assignment of pairs, define each pair as concordant, discordant or neither as follows:

- Concordant if ($xi > xj$ and $yi > yj$) or ($xi < xj$ and $yi < yj$)
- Discordant if ($xi > xj$ and $yi < yj$) or ($xi < xj$ and $yi > yj$)
- neither if $xi = xj$ or $yi = yj$ (i.e. ties are not counted).

Now let C = the number of concordant pairs and D = the number of discordant pairs. Then define the Kendall's tau as:

$$\tau = \frac{(C-D)}{(C+D)} \qquad \text{(Eq. 5.1)}$$

Table 5. 2. Comparison of Classical and Fuzzy Ranked Lists

Teachers' List	**Classical Approach** (x)		**Fuzzy Approach** (y)	
	Performance Result (100%)	**C_Rank**	**Performance Result (100%)**	**F_Rank**
1	98.78	1	93.6	1
2	95.24	2	93.4	2
3	93.65	3	92.7	6
4	92.39	4	92.9	3
5	91.98	5	92.5	8
6	91.89	6	92.8	5
7	91.11	7	92.1	12
8	90.97	8	92.9	3
9	90.86	9	92.3	10
10	90.34	10	92.6	7
11	89.84	11	92.3	10
12	89.77	12	92.1	12
13	89.28	13	92	14
14	88.18	14	83	16
15	87.91	15	81	17
16	87.87	16	89.5	15
17	87.43	17	92.5	8
18	87.14	18	79.5	18
19	84.22	19	79	19
20	82.78	20	77.7	21
21	81.7	21	75.3	22
22	81.62	22	77.9	20
23	79.38	23	75	23
24	69.58	24	74.1	24

The above table shows that the list of teachers evaluated by the two approaches and their ranks by both approaches. The correlation between the two ranked lists is discussed below.

Correlation Coefficients of the two ranked lists (C_Rank and F_Rank) has done with the help of *Kendall's tau-b* method.

Table 5. 3. Correlation Coefficients of variables "Classical (x)" and "Fuzzy (y)"

Correlation Coefficient		Classical	Fuzzy
Kendall's tau_b (τ)	Classical	1.000	0.818
	Fuzzy	0.818	1.000

The τ value *0.818* shows that there is a positive correlation between the two variables (Classical approach and Fuzzy approach).

This means 81.8% of the two ranked lists is the same, in other words if we use fuzzy logic approach in place of classical approach we lose only 18.2%.

In another word, by considering the ability of handling uncertainties in performance evaluation system, we can prefer fuzzy logic approach to teachers' performance evaluation. The following are the major benefits of using fuzzy logic approach for teachers' performance evaluation:

- Most of the time teachers' performance evaluation involves qualitative data, so that fuzzy logic is a suitable tool to compute with qualitative data.
- The availability of membership function in fuzzy logic is very important to represent the degree of truthiness of the input and output variables.
- Fuzzy logic approach uses simple *if then* rule based system, so that it is easy to develop the rule, because, it uses linguistic values.

CHAPTER SIX

6 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

With the change toward knowledge-based capitalism, maintaining talented, knowledgeable and competitive teachers is critical. To maintain this, performance evaluation of teachers is to be performed by human resource management of an organization. In this research, an intelligent fuzzy rule-based system for performance evaluation of teachers is applied. Here, three input variables (students' feedback, colleagues' feedback and dept. heads' feedback) for twenty-four teachers are considered to determine the final performance result. For each input and output variable triangular and trapezoidal membership functions are considered to design the system. As based on the performance index obtained by the system, selecting teachers for promotion, training, performance bonus, and performance-based pay awards could be accomplished through a transparent process; naturally it could become a great supportive tool for the managers.

Moreover, managers do not have to know the technical details for using this model as it works like a black box, what they need is to give the input values for the selected variables only and in turn they will get the output results and according to those they could rate their teachers. So, it is a user-friendly process.

The complex middle calculation of fuzzy logic is done entirely by MATLAB software. Input, output values have been provided and found from the fuzzy toolbox in MATLAB which could be operated very easily by concerned human resource personnel who usually handle the performance evaluation system and determine the performance index of the teachers. The proposed approach is flexible compared to other methods as it allows the decision maker to introduce vagueness, uncertainty, and subjectivity into the evaluation system. Again, it allows the decision maker to use a broad range of linguistic variables and modifiers for finer discrimination or to make changes to membership values and/or performance categories which clearly turns it into a superior method.

The limitations lying in this approach are in developing the rule as with the increase of input variables or performance criteria the variations of rule also increase. Very apparently if we use more rules, the result becomes more appropriate, but developing the rule in various combinations is some while troublesome and tiresome. But the good thing is once the rules are set, it could be used onward. Again, it is to be mentioned too that the result found considering a good number of rules that are quite easy to set is also handy and more appropriate compared to other traditional quantitative methods.

6.2 Recommendations

The results of our work indicate the possibility of designing and developing efficient performance evaluation of teachers by using fuzzy rule-based approach. However, a number of efforts are remained as a future work.

- Testing the sensitivity of membership values as well as their impact on the outcome.
- Development of this model might be done by programming the fuzzy logic along with the rule set up technique in any basic programming language so that the rule development may become easier.
- Extending the model to all type of employee performance evaluation in educational institutions as well as in others government & private organizations.
- Combining techniques of Fuzzy Logic and Artificial Neural Networks called Neuro-Fuzzy Systems to evaluate teachers' performance.
- Ranking the teachers by pair-wise comparison method.

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Appendix I

ASTU Academic Staff Performance Evaluation Form, to be filled by Colleague.

Adama Science and Technology University
Academic staff Performance Evaluation Form
To be filled in by Colleague

Name________________________________ Academic Rank ________________
School________________________ Program/division ________________
Academic Year_______________ Semester______ Date____________

Performance Standards

Performance Standard 1: Professional Knowledge and skill
Performance Standard 2: Instructional Planning
Performance Standard 3: Instructional Delivery
Performance Standard 4: Assessment of/for Learning
Performance Standard 5: Professionalism and Communication

KEY 5= Excellent, 4= Very good, 3=Good 2= Fair, 1= Poor

No	Activities	Scale					Remark
		1	2	3	4	5	
1	Is willing to take part in the meeting/discussions made for the improvements of the program/division						
2	Shares knowledge, skills and experiences with colleagues						
3	Works with minimum supervision.						
4	Effectively performs job-related tasks.						
5	Works to realize technology transfer						
6	Generates innovative ideas to improve the teaching-learning situation						
7	Demonstrates time-management skills.						
8	Uses a variety of problem-solving techniques.						
9	Uses available resources appropriately.						
10	Communicates specific performance expectations to students.						
11	Provide appropriate feedback for the tasks accomplished by the students						
12	Follows through with instructional directives.						
13	Works with colleague (s) to differentiate instruction to meet students' diverse needs.						
14	Supports colleague(s) in assessing student performance.						
15	Promotes and maintains positive relationships with diverse groups in the school and the university community.						
16	Demonstrates effective communications skills.						
17	Demonstrates teamwork.						
18	Contributes towards the accomplishment of program goals.						
19	Demonstrates knowledge of ASTU's policies and procedures.						
20	Maintains confidentiality and integrity.						

Appendix II

ASTU Academic Performance Evaluation Form, to be filled by the program division/ department head.

Adama Science and Technology University
Academic staff Performance Evaluation Form
To be filled in by the program/division/unit chair

Name____________________ Academic Rank ____________
School________________ Program/division/unit ____________
Academic Year__________ Semester______ Date________

Performance Standards

Performance Standard 1: Professional Knowledge and skill
Performance Standard 2: Instructional Planning
Performance Standard 3: Instructional Delivery
Performance Standard 4: Assessment of/for Learning
Performance Standard 5: Professionalism and Communication

KEY 5= Excellent, 4= Very good, 3=Good 2= Fair, 1= Poor

No	Activities	Scale					Remark
		1	2	3	4	5	
1	Is willing to take part in the meeting/discussions made for the improvements of the program/division						
2	Shares knowledge, skills and experiences with colleagues						
3	Works with minimum supervision.						
4	Effectively performs job-related tasks.						
5	Works to realize technology transfer						
6	Generates innovative ideas to improve the teaching-learning situation						
7	Demonstrates time-management skills.						
8	Participates in research activities						
9	Uses available resources appropriately.						
10	Submits students' grade (s) on time.						
11	Participates in committee works						
12	Follows through with instructional directives.						
13	Works with colleague (s) to differentiate instruction to meet students' diverse needs.						
14	Supports colleague(s) in assessing student performance.						
15	Promotes and maintains positive relationships with diverse groups in the school and the university community.						
16	Demonstrates effective communications skills.						
17	Demonstrates teamwork.						
18	Contributes towards the accomplishment of program goals.						
19	Demonstrates knowledge of ASTU's policies and procedures.						
20	Maintains confidentiality and integrity.						

Adama Science and Technology University
School of Electrical Engineering and Computing

Appendix III

ASTU Academic Performance Evaluation Form, to be filled by Students

Adama Science and Technology University

Academic Staff Performance Evaluation Form,

To be filled in by students

Name________________________ **Academic rank** __________________
School________________________ **Program/ division** __________________
Academic Year_______ **Semester**______ **Date**____________

Performance Standards

Performance Standard 1: Professional Knowledge and skill
Performance Standard 2: Instructional Planning
Performance Standard 3: Instructional Delivery
Performance Standard 4: Assessment of/for Learning
Performance Standard 5: Professionalism and Communication

KEY 5= Excellent, 4= Very good, 3= Good, 2= Fair, 1= Poor

No	Activities	Scale					Remark
		1	2	3	4	5	
1	Demonstrates the knowledge of the subject matter and transmits the knowledge in an interesting manner to the students using a Varity of techniques and/or materials to accomplish the objectives of the course						
2	Maximizes the use of time for instructional purpose.						
3	Possesses the ability to adapt to different tasks as needed.						
4	Demonstrates a working knowledge of the students.						
5	Focuses on team learning						
6	Implement continuous assessment in the classroom						
7	Demonstrates time-management skills.						
8	Identify strong and weak points of his/her students and provides the necessary support to the students. Uses a variety of problem-solving techniques.						
9	Uses available resources appropriately.						
10	Communicates specific performance expectations to students.						
11	Provide appropriate feedback for the tasks accomplished by the students						
12	Update students with the current information of the courses he/she offers.						
13	Ensures good student behavior and an overall sense of respect in the classroom.						
14	Is willing to support and advise students at his/her free time.						
15	Promotes and maintains positive relationships with diverse groups of students in the classroom.						
16	Demonstrates effective communications skills.						
17	Exhibits the skills required to execute specific tasks/activities successfully.						
18	Contributes toward the accomplishment of the objectives of the course.						
19	Provide supplementary and reference materials to the students						
20	Follow students' progresses in the course						

Adama Science and Technology University
School of Electrical Engineering and Computing

Appendix IV

The sample performance result of a particular four teachers.

Adama Science and Technology University

Techers' Evaluation Result

No	Performance Result						Total	5
	Student		Colleague		Department Head			
	5	50%	5	15%	5	35%	100%	
1	**3.68**	36.80	**5.00**	15.00	**4.26**	29.82	81.62	**4.08**
2	**4.41**	44.10	**4.64**	13.92	**4.91**	34.37	92.39	**4.62**
3	**2.49**	24.90	**5.00**	15.00	**4.24**	29.68	69.58	**3.48**
4	**4.51**	45.10	**5.00**	15.00	**4.41**	30.87	90.97	**4.55**