Reducing uncertainty in decision making through fuzzy logic: A model and prototype for monitoring and evaluation of IFMG higher courses

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Abstract: The existence of uncertainty in decision making processes generates a substantial demand for techniques to handle such uncertainty and promote a favorable environment for decision making. The decision support systems allow the exploration and conversion of experts knowledge to govern decision-making processes. In the educational environment, the uncertainty that surrounding the assessment indicators courses, the resistance to the processes of performance evaluation generate an environment with the presence of uncertain and vague aspects and high degree of complexity in decision making. There is a need for methods of education assessment that consider vague in order to govern decision-making aspects part of enterprise governance. This paper, through a qualitative applied research, develops a decision support system called Fuzzy Model and Prototype (FMP) in two phases: the first phase, the FMP is developed abstractly using the classic cycle of software development and in the second phase, the FMP is validated through the case study of the Federal Institute of Minas Gerais (IFMG), in the problem of educational programs evaluation with Process indicators. The business process align with Enterprise Resource Planning using information and knowledge management provides the enterprise engineering environment ideal for decision making and knowledge conversion. The Enterprise Governance`s concept of control and assessment possibility organizational measures on a continuous basis. FMP was created to help companies establish a way to systematically measure performance and make decisions. In this work, to obtain the results, the technique of content analysis by the method of categorical analysis was used. The results show that the fuzzy logic, through the concept of approximate reasoning, improves decision making by allowing a more aligned with vague analysis aspects inherent to the problem.

Keywords: information management, enterprise engineering, expert systems, decision support systems, decision making, fuzzy logic, higher education evaluation, enterprise governance.

1. INTRODUCTION

The expansion of the Federal Network of Technological Education (Federal Network – ECPT) in Brazil promoted a question to society and educational institutions: How can we consider progress, citizens who hold more educational options with contested quality? The question is configured as a reason for the development of this work and reflects the thinking of much of Brazilian society. The courses offered must undergo processes of internal and external evaluation. The evaluation of internal courses, or self-assessment should be conducted by the institution itself as regulation of Ministry of Education (MEC).Based on such evaluation processes, institution managers shall take corrective and preventative decisions. The managers of these institutions are faced with a scenario with lack of information, redundant information, and uncertainty in decision making. At the Federal Institute of Minas Gerais (IFMG), a member of the Federal Education Network, the process of evaluation higher education courses conducted by MEC does not provide the necessary support for the management of the institution. Through internal evaluation, creating custom indicators, setting goals, the IFMG will be able to monitor results and get a more efficient decision making. It is noted that in this process the lack of standards, uncertainty about indicators and lack of consensus regarding goals, generates a scenario of subjectivity, vagueness and uncertainty. This paper develops a prototype to support decision making in the assessment and monitoring the higher education in IFMG through the Process indicators, aimed at reducing the uncertainty through the use of fuzzy logic. The main objective is to contribute to the improvement of monitoring and evaluation of higher courses in IFMG and consequent decision making resulting from such processes by reducing uncertainty through fuzzy logic. This prototype also is an initiative to turn IFMG able to assess and monitor its performance using the concepts of governance from enterprise engineering. This governance should bring to IFMG the possibility to verify if its objectives and goals are being achieved.

Information Science, through the Information and Knowledge Management research line provides the theoretical foundation for work mainly with respect to Rational Decision Model proposed by Choo in 2006 and the concepts of enterprise governance using methods to control if the organization is achieving its goals. This study has a qualitative nature and is divided into two phases, in the first phase, a Fuzzy Model and Prototype (FMP) is developed with the aim to better handle the imprecision and reduce uncertainty in decision-making processes, and in the second phase, a study case of monitoring and evaluation of IFMG courses programs is conducted using Process indicators applied in the prototype. The second phase is also the prototype validation and generates the results of this work. The validation results of the prototype are achieved by the method of content analysis using the technique of categorical analysis proposed by Bardin, 1977.

2. LITERATURE REVIEW

The ability to use the right information at the right time is a significant differential and provides competitive advantage for the company. The Information and Knowledge Management is prerequisite for organizational efficiency. Davenport (1998, p. 173), declares that the management of information should be made by the organization as a dynamic evolving functional process, which must be assigned to a process manager. Knowledge, classified as tacit (residing in people's minds, hard to be structured and transmitted) and explicit (formalized, documents, files, processes) is present in people, processes and routines of a company, (Choo, 2006, p. 37). The experts tacit knowledge is critical in the decision making process, organizations that can convert this knowledge into models and tools for systemic application, could reach high level of competitiveness.

2.1 Corporate or Enterprise Governance

Globalization has brought significant progress in trade relations. These relationships become more interdependent creating a dynamic scenario in which the organization must be able to adjust rapidly to new concepts. In this environment, a state of control and governance is required to each company for safety purposes. The essence of Enterprise Governance is the company monitoring and supervision of its process. In this governance, there is uncertainty, due to the difficulty of making accurate predictions, therefore, to evaluate the performance means dealing with elements that managers may have little control (ELGHARBAWY and KADER, 2012, p.102, 110). In the private sector, corporate governance aims to create an environment of security and guarantee to stakeholders proving that the organization is meeting its goals and objectives. In the public sector, governance aims to bring more transparency to the actions taken and efficiency in the implementation of processes, mainly ensuring that public resources are being applied correctly. Enterprise governance has two dimensions - *conformance* and *performance*. The *conformance* dimension is what is most often referred to the structural governance, and covers issues such as board structures and roles, executive remuneration, financial reporting and assurance. The *performance* dimension focuses on strategy and value creation(RATNATUNGA and ALAM, 2011, p. 347). Internal controls can be implemented with the support of information systems capable of returning to managers accurate indicators for decision making. The decision shall be directed in accordance with results obtained from a state of continuous measurement provided by Enterprise Governance.

2.2 Decision Making

In organizations, usually individuals make decisions seeking satisfactory alternative and not the best alternative. Choo (2006, p.256) presents four models of decision making in the enterprise: the Rational Model which is goal-oriented, guided by rules, routines and performance programs; Politic Model in which conflicting objectives and interests, uncertain about approaches and results preferred; the Procedure that is goal-oriented, multiple options and alternatives and Anarchic Model in which the goals are ambiguous and the achievement of the objectives are unclear (Choo, 2006, p.276). There are fields of application in which vagueness is an inherent part of the problem analyzed. Decision making is modeled by rules and procedures, driven by preferences based on a common understanding of the objectives of the company, however, is inherent the influence of cultural, social, and political beliefs in the process aspects. It is necessary for the company to provide subsidies to individuals to reduce uncertainty in the process (CHOO, 2006, p. 41,42). Decision making is an action of the individual held in an environment of uncertainty created by potential ambiguity and vagueness. Our daily life is full of vague and ambiguous expressions. The ambiguity can be resolved through relativity, by the possible exchange one word for another or context analysis. Vagueness does not have this possibility. Fuzzy logic is an important tool to solve the problem of vagueness in the decision making process.

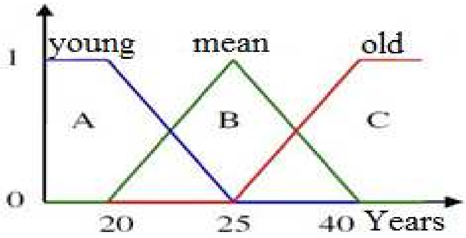
2.3 Decision Support Systems

The decision support systems develop a model of the constraints that govern the complex decisions making (Davenport and Prusak, 1998, p. 166).The decision support systems are conceptualized within the area of Computer Science in the field of Artificial Intelligence as Expert Systems. Studies in this area have limited results, not by the technical capacity of scientific development in the field of computer science, but rather the difficulty of analysis on the brain and its connections and ways to represent them. Decision Support Systems does not seek to replace human knowledge but complementary, providing a system of evaluation/monitoring within a model of rational decision making. Such systems support the individual to make choices invariant, impartially to its attention and emotional state, beliefs and cultural aspects. Some concepts of expert systems such as Neural Networks, Case-Based Reasoning, Knowledge Repositories, Bayesian Networks and Fuzzy Logic are used in the development of decision support systems.

2.3.1 Fuzzy Logic

The replacement of Boolean Logic based on crisp values (real) by fuzzy logic can make it possible to design systems with a higher Intelligent Quotient compared to those that can be designed through traditional methods(ZADEH, 1994, p.192).Using fuzzy logic it is possible to develop decision support systems for diverse applications. It is an extremely broad field, with applications in different areas of knowledge (TANSCHEIT, 2008, p. 2). Their technical application in the areas of control and decision making has brought great benefits in solving problems more accurately (MIRANDA, VILELA - JUNIOR, KRONBAUER, 2003, p. 18). Fuzzy logic expresses the concept of partial truth, so that you can determine values between completely true limit (1) and totally false (0), thus, each value can obtain membership in more than one fuzzy set (linguistic term). The figure below depicts the linguistic variable Age with linguistic terms (Young, Middle, Old). In this example, according to the fuzzy logic, a certain individual with 22 years, has relevance also in Young and Middle set:

Figure 1 Fuzzy Logic Sets for Age Variable



Source: TANSCHEIT (2008, p. 26).

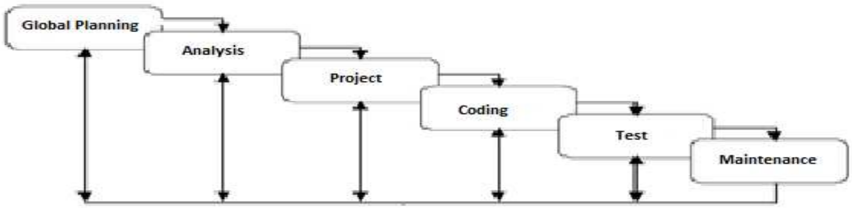
2.3.2 State of the Art

Fuzzy logic has been used in Education Assessment for several authors. Education shows a field with inherent vagueness and subjectivity aspects. Fourali, 1997, performs a work of assessment of competence in professional education using fuzzy logic as a tool to control the subjectivity and reduce the vagueness of evaluators in decision making. The process is to assess the competence of individuals for a given field and promote training actions aimed at possible areas of disability. Toledo and Consenza, 2004, develops a methodology for courses evaluation between educational institutions. For the authors, the qualitative assessment of courses needs a more "natural" language and fuzzy logic through approximate reasoning is important to the academic environment by enabling management of imprecise and subjective information. Semerci, 2004, conduct a study to define the importance of fuzzy logic in the evaluation of students. The author presents a comparison between the traditional assessment model and the model with fuzzy logic by extracting the knowledge of experts (teachers) with respect to models report results.

3. METHODS

This paper develops a prototype to manage decision making process with uncertainty reduction using fuzzy logic with application and validation problem in monitoring and evaluation of courses at the Federal Institute of Minas Gerais (IFMG) as a king of enterprise governance. Analyzing the concepts of Lakatos and Marconi (1991) and Gil (2009), this research can be classified as to its nature: as applied research because the result has practical application in organizations; how to address the problem: as qualitative research since the knowledge gained from the development of fuzzy prototype, and its application to the problem does not generate quantitative results; and as the technical procedures: as a study case because the proposal is based on showing an overview of the problem and identify possible factors that influence or are influenced by it. As described below, the work is conducted in two stages. In phase 1, the process of developing software using engineering classic, consisting of planning, collecting and analyzing requirements, designing (project), coding, testing (validation), maintenance (PRESSMAN, 1987, p.652). The figure below illustrates the classic process of development:

Figure 2 Classic Process Development



Source: Adapted from PRESSMAN, 1987.

Still in phase 1, we developed an API, which consists of a set of functions, commands and protocols that facilitate programming and systems integration, to integrate with external databases. Any user can insert their decision model in the prototype, and the data to evaluate decision alternatives could be automatically retrieved for external database.

Phase two consist of the application of FMP in the problem of monitoring and evaluation of IFMG courses. The application of FMP in IFMG conceives the presentation of the FMP to IFMG's Dean of Education (PROEN) for evaluation, extraction of expert's knowledge in this area and assembly of decision making in FMP model. After externalization of the knowledge, it is needed to evaluate courses and application in the FMP, we seek to extract the results with decision making by analyzing data from FMP using the method of content analysis with the categorical analysis technique consists of assessing qualitatively the result based on the theoretical framework (MENEGON, 2009, p.68). This phase is responsible for generating the final qualitative results of this work.

4. FUZZY MODEL AND PROTOTYPE (FMP)

The decision to develop an abstract prototype for solving the problem of evaluating courses had the main motivator, trying to contribution of the researcher about the fact that the prototype can be used by other institutions or individuals in their decision making processes in order to be a part of Enterprise Governance. The main software on the market used for fuzzy logic process is MATLAB, besides being a software purchase high value, this software has an interface geared for researchers, which hampers its use by other users with less experience in computational tools. FMP can support individuals in their Decision Making process using Fuzzy Logic to reduce vagueness aspects evolved. As a governance tool, it can be configured to create indicators and retrieve data automatically, so, managers can measure and analyze data from ERP system for decision making.

4.1 Design and Implementation

The FMP was developed using two-layer architecture (application and database server). The user makes the request via a browser, application server receives requests and communicates with the database returning to the user the answer. Requests made to the application server are performed asynchronously using Ajax technology that allows more interactivity between the user and the system (LIMEIRA 2006, p.12).The user must view among a universe of possible alternatives, which option obtains the best result (Fuzzy Score) using the input and output variables, terms and rules of inference informed by the user.

4.1.1 Database Management System

The management of data and information necessary for decision making is done through Database Management System (DMS) MySQL. Each user manages its decision models, input and output variables, linguistic terms, rules of inference. The relational database is designed to support the implementation of fuzzy logic in MISO format, Multiple-Input Single Output, because, as literature indicates, is the most widely used method of fuzzy logic. The FMP accept the registration of infinite input variables and their linguistic terms for fuzzy processing, however, are allowed only 8 combinations for the input variables to generate the result in the output variable.

4.1.2 API –External Database integration

An important feature developed in FMP is the API for integration with external databases. This API aims to make the FMP a dynamic tool for decision making, without the user having to re-enter the data for each variable every time he makes a decision. Through a structure that enables the retrieval of information from decision automatically, the FMP can integrate with ERP systems and becomes a single point for decision making, be it in any institutional sphere. The prototype has an area to setup external database, in these parameters, the user must select the type of database, the IP address, username and password to connect and the database name.

4.1.3 Fuzzy processing

The architecture of a fuzzy system has 3 stages (fuzzification, inference and defuzzification). The FMP was developed based on the most used principles of fuzzy logic in the literature. Fuzzification is the process of transformation of the real values (crisp) in fuzzy values. The FMP method uses the MISO (Multiple Input and Output only) for inference engine, you can insert multiple input variables, but only one output variable. Variables can have up to five linguistic terms, which are the boundaries between the possible linguistic classifications. In fuzzification process, variable face may have N linguistic terms which can be triangular or trapezoids. The Mamdani method is used to process the rules of inference. This method allows the final fuzzy value can be expressed in quantitative values (MAMDANI, 1974). The user can manipulate the input variables using operators disjunction (OR) or intersection operators (AND) and compose the knowledge base of fuzzy logic. The prototype uses the rules of type (IF THEN) to perform the aggregation of input variables and the corresponding fuzzy output. FMP was implemented in only Modus Ponens (MP) method which is based to generate the consequent on the history respecting the character of the MISO model (CAMPOS FILHO, 2004, p. 34). Defuzzification phase is responsible to convert fuzzy values into crisp values. The method used by the FMP for Defuzzification is the centroid method that calculates the center of the final fuzzy set area (NEGNEVITSKY 2011).Based on the fuzzy set generated by the method of Mamdani, the FMP estimates for each decision alternative its corresponding result. The final ranking with the result of each alternative is presented in descending order of Fuzzy Score, while the highest value is the best option for the decision model.

4.1.4 Coding

Fuzzy Model and Prototype was developed using the PHP programming language. The FMP uses the MySQL version 5.0.51 as DBMS to store the data of decision models. The system uses the Apache web server in version 2.2.9 to process requests and is available through http://develop.coipe.com.br/smartfuzzy/ address. The implementation of FMP intended for usage on the web, aims to make it easier to use by institutions and professionals who do not have much familiarity with desktop applications or even with fuzzy logic complex systems. The system has been developed to work in any browser using the concept of cross-browser, that allows an application to run in different browsers on the same way, however, was approved in only 3 browsers versions (Chrome 33.0.1750.154 m, 27.0.1 Firefox, Internet Explorer 10.0.9200.16844).

5. APPLICATION OF THE MODEL IN IFMG

The indicators are considered a comparable set of information that allows the diagnosis of the situation under study, be it global or partial. Allow through evaluation and monitoring check progress against objectives and targets outlined, and implement actions to direct the institution towards forming a desired dynamic, changeable system processes and routines improvement of courses (JACOB, 2003, p. 33). The act of monitoring and evaluate is a part of enterprise governance actions. To Gaetani and J. Schwartzman (1993, p.7), these indicators can be Outcome and Process indicators**.** Outcome indicators are based on assessment of graduates based on examinations of professional policy, wages, etc. However, such indicators are hard to obtain systematically and may be influenced by factors such as family income levels or prestige of the profession. Process indicators are intrinsic to the course and can be obtained from the student entrance capturing information during the execution of the course program by the student. Such indicators are easier to be obtained from the management educational systems, like Education ERP. According to Harvey and Green (1993), to these indicators be used effectively, they need to respect some essential features:

a) **Validity:** indicators represent the purposes of the review, changes to be achieved or the phenomenon being observed.
b) **Accuracy, reliability:** the indicators are consistent in relation to the purpose.
c) **Objectivity:** indicators reduce opinion uncertainty and personal judgment.
d) **Comparability:** perhaps the main feature, the indicators can be compared to another, standard, or reference information display.

In the decision making process of evaluating courses IFMG through the FMP, the indicators are considered as the input decision variables, the linguistic terms are possible classifications of indicators.

5.1 Definition of Process Indicators (input variables)

This step is aimed at defining the indicators that would be used in the IFMG's evaluation courses. These indicators provide part of the structural scaffold for assembly of the decision model based on fuzzy logic. As literature indicates, the great difficulty at this stage was really vague regarding which indicators best represent the performance of a course in IFMG. Since it was not possible to obtain Outcome indicators systematically initially chose to work only with the Process indicators. Indicators for assessment of courses in IFMG and their method for calculation were defined based on meeting with PROEN and based on Judgment 2.267/2005-TCU. The indicators used in the analysis are: Student Select Process Rate, Evasion, Quantity Student per Teacher, Teacher Degree, Retention, and Final Average Test Score. These indicators it will be used to measure the results of the courses as a kind of enterprise governance, cause IFMG managers will decide changes in the course's program such on those indicators.

5.2 Definition of the Output Variable

From the aggregation of input variables (indicators) on the Mamdani inference method, the output variable refers to the course evaluation before all entry criteria generating the course (alternative) Fuzzy Score. The score of each course is given in the range of 0 to 100 points. The fuzzy output generated will be presented in this interval. The terms were generated based on PROEN Experts Knowledge by dividing the maximum score 100 points in 4 equal parts (one for each classification), as shown in the table below:

Table 1 Course Evaluation Linguistic Terms based on PROEN Experts

Linguistic Term	Membership Function	Value 1	Value 2	Value 3	Value 4
Insufficient	Triangular	0	0	25	
Sufficient	Triangular	12.5	25	50	
Very Good	Triangular	37.50	62.50	75	
Excellent	Trapezoidal	62.50	75.00	100.00	100.00

Source: Create by the authors.

5.3 Inference - Definition Knowledgebase

A table with all possible rules of inference was created. The rules are designed for clustering evaluation of each indicator, for example: IF Evasion is Low AND Retention is Low OR Teacher Degree is High, THEN course Evaluation is Very Good. Evaluation indicators are considered in the antecedents of the rules, and the output variable is considered in the consequent of each rule. A team of 3 professionals from PROEN met to form the inference rules, the team should arrive at a consensus on the 144 inference rules. The six indicators are combined generating the result of the variable evaluation. In the FMP, the evaluation variable or course evaluation is represented by the column Fuzzy Score.

5.4 Implementation - Data collection of indicators

Trying to develop a dynamic Decision Making scenario for evaluation courses, in the IFMG, the FMP was integrated with IFMG ERP System, in that way, the indicators values were retrieved automatically using SQL queries. In this phase, the SQL queries for extracting data from the IFMG ERP System were developed. Between 2014/January and 2014/March the queries were created and validated using the concepts explained in section 5.1. For each input variable (indicator) was developed an SQL query, which was designed to retrieve the indicator’s value from IFMG ERP System. The data returned by the queries were validated with PROEN and this validation based courses to be monitored and evaluated were identified. The ERP database is hosted on SQL Server DMS.

5.4 Courses to be evaluated

The ERP System is in implantation in IFMG and due this fact was not possible to use all IFMG unities and to evaluate all courses, so there was a limitation in IFMG database. The course evaluation was conducted under the IFMG 17 higher courses. The 17 courses are formed by 9 from Bambuí(BI) unity, 3 from Congonhas(CNG) unity and 5 from Formiga(FGA) City. The indicators values were retrieved from the 2013 year. Ideally, the amount of courses could be larger, involving other units and thus reflect a more accurate picture of education in IFMG, but given research objective, scope and methodology proposal, that amount of courses is sufficient to perform the work and does not compromise the expected results.

5.4 Retrieving data from ERP IFMG by FMP

After defining the courses that should be evaluated, the ERP retrieving process was executed in FMP. The FMP retrieved all the values of each indicator for the courses. After validation of the data, the values were normalized (*Escore*). In FMP, the linguistic terms are generated from a specific function, the user must click "Generate Terms" and the prototype generates the terms of all the input variables are with the "Calculation" field set to Automatic based on the median of the set. Automatic generation based on the median allows courses to be evaluated based on the results of each other. The table below shows the linguistic terms of the indicators generated based on the median:

Table 2 Indicators Linguistic Terms Used

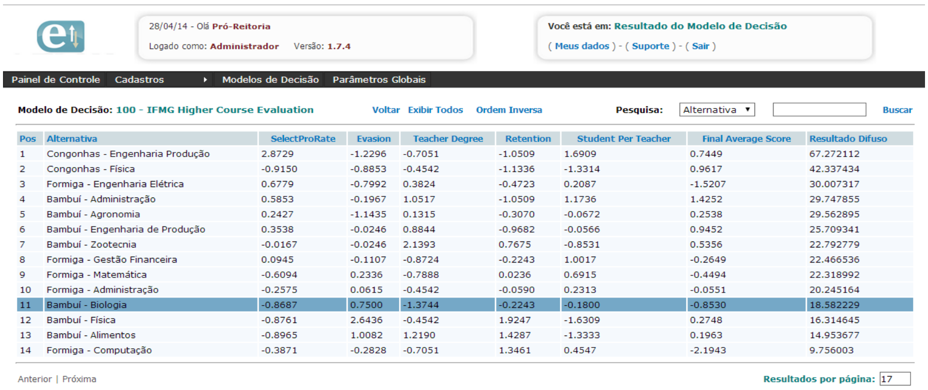
Indicator	Fuzzy Membership	*Escore*1	*Escore*2	*Escore 3*	*Escore*4
Student Select Process Rate	low (tria)	-0.95	-0.95	-0.35	
	average (tria)	-0.69	-0.14	0.69	
	high (trap)	-0.14	0.69	2.94	2.94
Evasion	low(tria)	-1.25	-1.25	-0.33	
	average(tria)	-0.66	-0.07	0.66	
	high(trap)	-0.07	0.66	2.68	2.68
Teacher Degree	low(tria)	-1.49	-1.49	-0.45	
	high(trap)	-0.97	0.96	2.36	2.36
Retention	low(tria)	-2.17	-2.17	-0.06	
	high(trap)	-1.12	0.81	1.68	1.68
Student per Teacher	low(tria)	-1.65	-1.65	0.08	
	high(trap)	-0.78	0.91	1.73	1.73
Final Average Score	low(tria)	-2.25	-2.25	0.23	
	high(trap)	-1.01	0.89	1.54	1.54

Source: Create by the authors.

5.4 Results and Prototype FMP Validation

After all the necessary settings, the fuzzy processing model registered in FMP for evaluating higher education was performed. As mention above, for each alternative, the prototype generates a Fuzzy Score based on aggregation of inference rules of the values of membership of each indicator. On the result screen, the FMP shows the Alternative, the input variables and their values and the Fuzzy Score column. The image and the table below shows the result of Fuzzy Processing of courses in FMP:

Figure 3 FMP Fuzzy Process Result



Pos	Alternativa	SelectProRate	Evasion	Teacher Degree	Retention	Student Per Teacher	Final Average Score	Resultado Difuso
1	Congonhas - Engenharia Produção	2.8729	-1.2296	-0.7051	-1.0509	1.6909	0.7449	67.272112
2	Congonhas - Física	-0.9150	-0.8853	-0.4542	-1.1336	-1.3314	0.9617	42.337434
3	Formiga - Engenharia Elétrica	0.6779	-0.7992	0.3824	-0.4723	0.2087	-1.5207	30.007317
4	Bambuí - Administração	0.5853	-0.1967	1.0517	-1.0509	1.1736	1.4252	29.747855
5	Bambuí - Agronomia	0.2427	-1.1435	0.1315	-0.3070	-0.0672	0.2538	29.562895
6	Bambuí - Engenharia de Produção	0.3538	-0.0246	0.8844	-0.9682	-0.0566	0.9452	25.709341
7	Bambuí - Zootecnia	-0.0167	-0.0246	2.1393	0.7675	-0.8531	0.5356	22.792779
8	Formiga - Gestão Financeira	0.0945	-0.1107	-0.8724	-0.2243	1.0017	-0.2649	22.466536
9	Formiga - Matemática	-0.6094	0.2336	-0.7888	0.0236	0.6915	-0.4494	22.318992
10	Formiga - Administração	-0.2575	0.0615	-0.4542	-0.0590	0.2313	-0.0551	20.245164
11	Bambuí - Biologia	-0.8687	0.7500	-1.3744	-0.2243	-0.1800	-0.8530	18.582229
12	Bambuí - Física	-0.8761	2.6436	-0.4542	1.9247	-1.6309	0.2748	16.314645
13	Bambuí - Alimentos	-0.8965	1.0082	1.2190	1.4287	-1.3333	0.1963	14.953677
14	Formiga - Computação	-0.3871	-0.2828	-0.7051	1.3461	0.4547	-2.1943	9.756003

Source: Create by the authors.

Table 3 Final Result extracted from FMP

Unity - Course	SSPR	EV	TD	RE	QST	FATS	Fuzzy Score
Cng – Production Engineering	2,87	-1,22	-0,70	-2,15	1,69	0,74	67.27
Cng – Physics	-0,91	-0,88	-0,45	-1,03	-1,33	0,96	42.33
Fga – Electrical Engineering	0,67	-0,79	0,38	-0,25	0,20	-1,52	30.00
Bi – Administration	0,58	-0,19	1,05	-0,71	1,17	1,42	29.74
Bi – Agronomy	0,24	-1,14	0,13	-0,12	-0,06	0,25	29.56
Bi - Production Engineering	0,35	-0,02	0,88	-0,64	-0,05	0,94	25.70
Bi – Animal Science	-0,01	-0,02	2,13	0,73	-0,85	0,53	22.79
Fga – Financial Management	0,09	-0,11	-0,87	-0,05	1,00	-0,26	22.46
Fga – Mathematics	-0,60	0,23	-0,78	0,14	0,69	-0,44	22.31
Fga – Administration	-0,25	0,06	-0,45	0,07	0,2	-0,05	20.24
Bi – Biology	-0,86	0,75	-1,37	-0,05	-0,18	-0,85	18.58
Bi – Physics	-0,87	2,64	-0,45	1,64	-1,63	0,27	16.31
Bi – Foods	-0,89	1,00	1,21	1,25	-1,33	0,19	14.95
Fga – Computation	-0,38	-0,28	-0,70	1,18	0,45	-2,19	9.75

Source: Create by the authors.

Legend: SSPR = Student Select Process Rate, EV = Evasion, QST = Quantity Student per Teacher, TD = Teacher Degree, RE = Retention, FATS = Final Average Test Score.

5.3.1 Prototype Validation

The results obtained for prototype validation will be performed through the content analysis method using the technique of categorical analysis. In categorical analysis, categories were created by observing the indicators essential features and research objectives. It were established 7 categories: 1-Validity Feature, 2- Accuracy and Reliability Feature, 3–Objectivity Feature, 4-Comparability Feature, 5-Reduction of Vagueness in Decision Making, 6-Knowledge Experts Externalization, 7- Flexibility of the FMP**.** The next step would be to identify whether these categories were present or not in accordance with the perception of PROEN Experts analyzing the results presented in the FMP. A questionnaire answered by two PROEN professionals responsible for the evaluation of higher education process was applied. Each professional answered 7 questions via an online form on Google Drive using the defined scale below: Fully Present, Partly Present and Absent. Category analysis results is presented in the table below:

Table 4 Category Analysis Result

Category	Professional1	Professional 2
Validity Feature	Fully Present	Fully Present
Accuracy and Reliability Feature	Partially Present	Fully Present
Objectivity Feature	Fully Present	Fully Present
Comparability Feature	Partially Present	Partially Present
Reduction of Vagueness	Fully Present	Fully Present
Knowledge Experts Externalization	Fully Present	Fully Present
Flexibility of the FMP	Fully Present	Fully Present

Source: Create by the authors.

The results indicate that the work's objective was achieved, therefore the process of decision making arising from the monitoring and evaluation of courses in IFMG was improved by reducing uncertainty. The professional 1 replied Partially Present for **Validity Feature category**, since in his opinion, it is important the use of **outcome indicators** to reflect a better evaluation of the course. The professional replied 1 Partially Present for **Accuracy and reliability Feature category**, since in his opinion it is necessary to perform more accurate analyzes over more years to assure that the results are accurate and reliable. The **Comparability Feature category** was answered by both professionals as partially present, mainly because the courses are evaluated by adding different areas of learning such as (Humanities, Biological Sciences, and Science) and in their opinion were best if the courses should be evaluation separately.

6. FINAL REMARKS

This research presents theoretical and practical contributions to Enterprise Engineering. The FMP prototype contributes to the implementation of fuzzy logic in decision-making processes. The work theoretically contributes to the outsourcing of knowledge showing that institutions need to build an environment conducive to conversion of tacit or explicit knowledge. The externalization of experts knowledge on business areas in tools that can serve to decision support, contributes significantly to the creation of an environment less dependent on the individual in enterprise governance. The work contributes practically by creating a tool to reduce uncertainty in the decision-making process that has been applied and validated in a case study on evaluation of IFMG courses, however, due its design was abstract, FMP can be applied in any decision making process. The FMP prototype can be used by any institution or individual that aims to implement a information system in order to contribute to its enterprise governance process.

6.1 Conclusion

This work contributes to the improvement of decision-making that occurs in the evaluation and monitoring of IFMG courses as the results showed by content analysis. Fuzzy logic is an important tool in reducing the vagueness of the criteria ratings that govern any decision, their potential is perceived in the literature and their use handle the possibility of constructing more accurate and more susceptible to the universe of systems problem, which naturally permeates presence of vague and uncertain aspects. Although not wholly reflect the quality of a given course, the evaluation of courses in FMP gives evaluators a management tool for monitoring course results and becomes indispensable by technical point of view if the propose is governance. The analysis courses through the FMP is a constant evaluation based on performance rules and monitoring programs, by reducing possible points of imprecision inherent in educational assessments arising from subjectivity and lack of consensus in this area. The limitations of existing data does not diminish the potential of the prototype, therefore, the fact that there is a larger database for analysis and review only enrich the basic characteristics of process indicators. In Brazil, institutions from Federal Network of Technological Education - Federal Network – ECPT in order to be more efficient, must have set goals, defined objectives and course programs undergo constant evaluation of performance using the concepts of Enterprise Governance.

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