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Audit of Financial Information Systems: a risk-based approach and fuzzy logic

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Abstract:

Nowadays, business is exposed to information system risks and threats. This justifies the growing inquiry, of investors and shareholders, on their business security. Information systems auditing has strong tools and techniques, which can assist organizations in minimizing these risks and threats. But the fast-changing and growth of information systems makes the audit missions more complex and surrounded by uncertainty, related to audit quality parameters like experience, knowledge, and others. In line with this, the auditors may be faced with discrepancies during auditing, with each anomaly typically triggering a binary evaluation of significance. In this paper, we develop a fuzzy expert system framework, which evaluates the level of significance in the audit by allowing a discrepancy to have a level between 0 and 1. Such a framework enables the auditor to have increased accuracy and more flexibility in evaluating the appropriate level of significance, and provides a better understanding of the scope of subsequent audits and examinations. As results, we show that a fuzzy expert system has the potential to assist the auditor in the process of including qualitative information in the frivolous level and identifying the anomalies that may be most worthy of investigation. The fuzzy expert system standardizes the process of auditing by providing a formal model structure. This may facilitate reporting within the audit organization and improve the coherence of the audit process between auditors, missions over time.

Keywords: Information systems auditing, risk-based-approach, fuzzy logic, complexity, uncertainty, expert system.
JEL Classification: C67, M15, M42
Paper type: Empirical research

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1. Introduction

The techniques of risk analysis are powerful tools that help professionals in managing uncertainty and can offer significant support in their decision-making process. These analysis helps the managers to take both certain and uncertain elements and incorporate them into a specific scenario of future events. Such techniques may be qualitative or quantitative depending on the availability and the level of information as well as the degree of complexity desired (Bennett and Bohoris,1996). While quantitative techniques are based largely on computational approaches, qualitative techniques tend to be judgmental rather than computational. In other word, any data that is the main focus of the above analysis can be categorized as hard and/or soft data. The hard data are mostly objective, quantitative, and precise and therefore measurable, whereas soft data are linguistic, intuitive, subjective and not measurable.

Classical risk models are often based on probability and classical theories, which are used extensively to evaluate market, credit, insurance, and business risks. But many risks still cannot be properly analyzed by following the conventional probability models due to the insufficient and limited expertise in addition to the inherent complex cause-effect interplay of some specific types of risks. Recently many researchers suggested that the optimal approach to addressing the challenges of any uncertainty is through fuzzy logic concept where was introduced by Lotfi A. Zadeh in 1965. It gives a mathematical advantage in attempting to capture the unknowns associated with human cognitive processes, such as thinking and arguing. Fuzzy logic is a subset of Boolean algebra that has actually been extended in order to cover the concept of partial truth, i.e., truth values situated between totally true and totally false values (Gupta & Celtek, 2001). In implementing fuzzy logic, the variables in a model are described in linguistic sense, rendering fuzzy logic programs more visually equivalent to human logic. However, for risks that do not have an accurate quantitative probability model, a fuzzy logic system can be helpful in modeling cause-and-effect relationships, gauging the degree of risk exposure, and identifying the type of risk in a coherent way, based on both existing data and the opinions (Shang & Hossen, 2013)

Fuzzy logic has been applied in several fields such as artificial intelligence, science, control engineering, decision theory, expert systems, operational research logic, robotics (Zimmermann, 2001). Related to risk assessment, many studies on fuzzy logic have appeared in the field such as information security, development, risk management of nitrates in groundwater, system failure, bank sector, etc. (Zirakja & Samizadeh, 2011.) There has been a significant development over the past decade in the field of internal auditing from systems-based auditing to process-based auditing. The internal auditors have been strongly involved in dealing with the concerns of management regarding business risks (Selim and McNamee, 2003). It was pointed out by Lindow and Race (2002) that internal auditors are expected to play a vital function in overseeing an organization's risk profile. Consequently, the scope of internal auditors is getting even more extended. Information systems auditing (ISA) is an important activity that can increase process performance and governance in business management. Although there is no standard definition of IS auditing, Ron Weber defined it as "the process of collecting and measuring information to determine if a system of information technology is able to provide the required level of service". Adopting best practices, procedures, and internal control framework, make this activity more efficient. ISA's goal is to determine weaknesses and vulnerabilities in an organization and/or technical information systems, in a perspective of ameliorating and enhancing control and security. Each ISA mission is motivated by a lot of factors that influence goals mission. However, these factors are grouped in 4 categories (GANTZ,2014) as below:

- ✓ Factors related to laws and regulations;
- ✓ Factors related to certifications and standards;

- ✓ Factors related to process improvement;
- ✓ Factors related to operational effectiveness and governance.

In response to the categories of factors mentioned above, the professional community produces a lot of good practices and measures that can reduce potential risks and ameliorate controls, grouped in a standards framework like Control Objectives for Information and Technology (COBIT), Committee of Sponsoring Organizations (COSO, 2004), Information technology infrastructure library (ITIL), and International Organization for Standardization (ISO). The ISA mission is designed based on one or more of those frameworks to conduct an audit mission. Moreover, ISA community address recommendations to adopt one of those control frameworks, like the Information System Audit and Control Association (ISACA, 2009). Similarities and differences of those standard frameworks are given in reference (Klir &Yuan, 1995). In Morocco, the DGSSI (the General Direction of Information Systems Security), which carry out security audit of the information systems of public administrations and organization, adopts ISO standards to build his own ISA guidelines.

This paper exposes information systems auditing with a risk-based-approach first, and the expert system in the next section. In section 3, we summarize some needed notions on fuzzy logic and uncertainty. In section 4, we present the approach adopted to make our model. Finding and results with conclusions are presented in the last section.

2. Literature Review

For several purposes, Fuzzy set theory may be very relevant to the practical work of auditors. First, fuzzy set theory in itself gives a computational approach where fuzzy notions of auditors are considered on a consistent basis, for instance, materiality adjustments. Consequently, auditors will be able to handle ambiguities as random events through the use of likelihood analysis (Zarif Fard,1999). Unlike standard set theory, fuzzy set logic eliminates the average exclusion rule and the logic of variance and means in which the classification of accounting purposes becomes superfluous because they are considered as typically artificial and unrealistic. This set approach, has been used to analyze different situations. Many studies show that may be used in different dimensions such as internal control, audit sampling, management accounting issues including capital budgets and strategic planning business, and many more.

In studies like, Friedlob and Schleifer (1999) claim that auditors generally describe risk as probabilities by considering the different forms of uncertainty in the audit. The authors have introduced the fuzzy logic method as a new treatment for examining audit uncertainty. In order to decrease the cost of fraud in insurance companies, Pathak et all (2005), have developed fuzzy expert systems to both estimate and delimit the risk and its related factors. As for financial statements, Comunal and Sexton (2005) applied a fuzzy set approach to fit the best financial statement by considering other criteria that ignored by traditional methods. Due to information asymmetry, a new algorithm has been developed by using fuzzy set logic to determine the shape the audit quality (Dereli et all, 2007). Systematic internal risk and new control procedures using fuzzy logic set are examined in (De Korvin et all, 2004) to enhance the security of a company. Finally, the concept of fuzzy logic set can be used in strategic decision-making (Oderanti, De Wild, 2010), strayrgic management accounting (Rangone, 1997) and finally in the development of corporate management (Cassia, 2005).

3. ISA risk based-approach:

Risk-based approaches have been gaining wide support from policymakers because they can be directly implemented on the basis of the similar requirements of economic efficiency (i.e., maximizing the wealth of goods and services delivered to the community at a given level of resource expenditure) that underlie other approaches in economic analysis. Risk management is also a tool that policymakers, decision makers, stakeholders and financial managers in the public and private sectors understand and regularly adopt. This such kind of approach is conducted in two processes: 1) risk assessment audit tasks orientation; 2) risk assessment that helps to reduce tasks during the audit mission performing. This approach allows the auditor to assess risk for a good decision-making in compliance tests and substantive tests. The risk-based approach auditing combines three components of the risk: Inherent risk (IR), risk related to control (RC) and non-detection risk (RND).

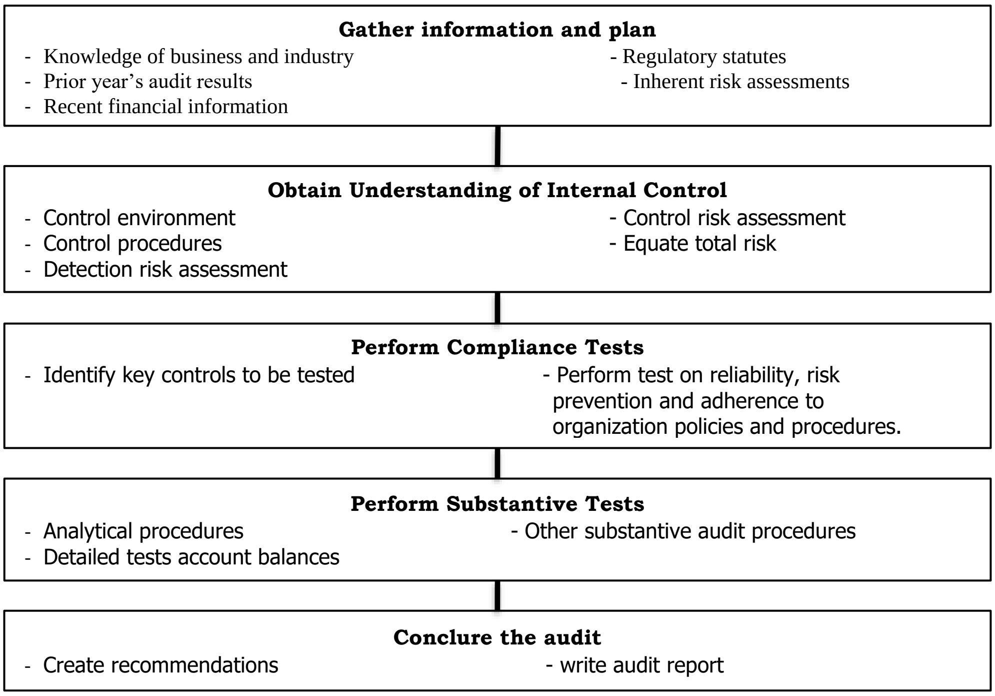
The risk audit is calculated by the following formula (Chang et al, 2008; Friedlob & Schleifer, 1999):

$$\text{Audit Risk} = IR \times RC \times RND$$

Where IR stand for the risk level or exposure without taking into account the actions that management has taken or might take, RC is related to the risk that a material error exists that would not be prevented or detected on a timely basis by the system of internal control and finally RND refer to the risk that the information system audits substantive procedures will not detect an error that could be material, individually or in combination with other errors (ISACA, 2013).

Those components of risk affect legal, financial, operational and technological areas. Moreover, risk measurement in information systems can be determinate by several methods and techniques. However, the institute of internal auditors (IIA). and ISACA-COBIT suggests a simplified method ranking that we have used in this work. The IIA identifies risk as the probability that an event will occur and may affect the achievement of objectives, which is measured as a function of both impact and likelihood (Rehage et al, 2008). The likelihood, probability or frequency commonly used term in COBIT RISK IT framework, mean the number of times an event occurs in a given time period (ISACA, 2008). In otherwise, impact means what would be the effects if some threats materialized (Kozhakhmet et al, 2012). This approach presumes that internal controls cannot be relied upon to ensure success. It focuses on the process of determining risk and then testing how well management reduces or handles that risk, instead of simply identifying and testing internal control procedures. The auditor that uses a risk-based approach focuses on risk rather than on internal controls. Using this approach, the auditor is therefore likely to cover a wide range of issues facing management. Usually ISA risk based-approach is conducted according to the following steps (figure 1). (ISACA, 2014):

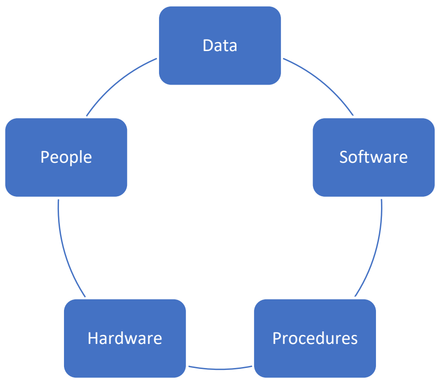
***Figure 1**: Steps for conducting an information system auditing.*



Source : Karya, Moertini, 2013.

Here, our research concerns a specific domain that representing a critical area for the most of organization, which is access control (SUDUC et al, 2010), this field of information system combine all information systems resources, including data, software, procedures, hardware and people as described in the following figure (figure 2):

***Figure 2**: Information systems resources*



Source: SUDUC et al, (2010)

4. Expert system

An expert system is a computational system that mimics the decision-making skills of a human expert (Kozhakhmet et al,2012). This expert system is based on the expertise and knowledge of human that express human in several ways, written, oral or other. This knowledge and expertise are transformed to an IF-THEN rules. Furthermore, this expertise and knowledge related to the field of information systems security, form the core of the expert system, and such expertise and knowledge can be founded in security standards like, ISO, COBIT, ITIL as guidelines or recommendations (Huang et al, 2010). This system is presented in a form of a questionnaire based on the interaction between users (auditors in our case) and the system itself in order to produce recommendations on the subject, after a process of analyzing answers. This system presents some advantages in the topic of the information system particularly (Giarratano & Riley, 2002):

1) Reduced cost: The development of such a system is relatively inexpensive.

2) Increased availability: Expert knowledge becomes available using any appropriate device at any time of the day.

3) Multiple expertise: The use of knowledge from multiple sources increases the total level of expertise of the system.

4) Time saving: The IS audit is a time-consuming process. Expert systems in certain phases of the audit (analysis of collected evidence, reporting) can save days (or weeks) by responding more quickly (compared to a human expert) and reducing the amount of paperwork.

5) A stable response, without emotion and complete always. By using the programs, the influence of human factors is moderates.

Expert system gives an interactive user interface for registering the collected audit evidence and clearly explains the reasons for the findings. It contributes to continuous quality improvement because it enhances the maintenance by quantifying its performance, it assists with and facilitates the implementation of the duties of auditors in charge of evaluating the performance, it also simplifies the time-consuming process of monitoring the audit results by keeping the quality of management processes, and finally it minimizes the influence of the variability arises by the use of different auditors.

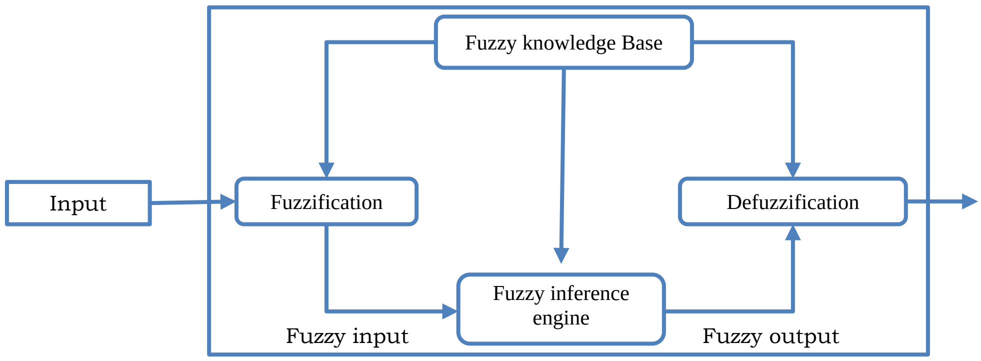
5. Fuzzy Logic and Complexity

The application of fuzzy logic, and the use of fuzzy set theory (or fuzzy subset), in the field of decision-making was first introduced by Professor Lotfi A. Zadeh in 1965 (Zadeh, 1975; Zimmermann, 2001) later on extended by (Yasamis et al., 2002; Cheung et al., 2004; Arditi and Lee, 2003, 2004; Lee and Arditi, 2006) provide comprehensive frameworks to assess a contractor's quality performance. The existing systems, however, do not provide a comprehensive description of each individual phase of the quality audit process. Instead of the binary logic and binary algebra that are used in all standard computers, fuzzy logic is scaled with different values. Instead of an element being a member of a set or not, fuzzy logic allows degrees of membership so that something can be partially true and partially false. Fuzzy logic values range between 1 and 0. i.e values ranging from totally true to totally false. Fuzzy sets, which are thus an essential part of fuzzy set theory, can be defined as uncertain quantities of objects or values.

All fuzzy logic systems use a rule-base (knowledge base) as their central structure. Rules, typically cast in an IF ...AND… THEN ... syntax, represent system operation and mapping inputs to outputs. Measured and calculated crisp input values are fuzzified, using membership functions, into fuzzy truth values (or degrees of membership). These rules are then used as conditions for the rules in the rule base, with the activated rules specifying the necessary actions, again in the form of fuzzy truth values. These responses are merged and defuzzified to deliver consistent and feasible results to the system outputs. Where inputs and outputs are continuous (as in control applications), this fuzzification inference-defuzzification process is performed on an ongoing basis, at regular sampling intervals. Conceptually this process is similar to the use of a Fourier Transform (FT), to transform time domain signals into the frequency domain, to process the resulting frequencies, and then to transform the results back into time domain. This basic fuzzy rule-based structure can be used in different types of applications, such as process control, decision-making, scheduling, prediction, and estimation. By enabling high degree of freedom in the definition of fuzzy logic algorithm, and especially in how the combination of all rules and the defuzzification is performed, the area of applications is even further increased.

The implementation of this logic is illustrated in the following scheme (figure 3) as described in (Zimmermann, 2001).

Figure 3**: **Fuzzy logic system



Source: Zimmermann, (2001)

It consists in the following steps:

Step 1: called Fuzzification, it consists in transforming the numerical variables, used as input, into linguistic variables. The definition of linguistic variables is given based on a basic language.

Step 2: Fuzzy inferences are based on fuzzy implication is the central part of the knowledge-based decision-making and is expressed by linguistical rules. Rules are statement s expressing a dependency relation among system inputs and system outputs. Individual rules represent parts of the solution to a problem. All rules considered together determine the final solution. Rule evaluation takes the fuzzy inputs (degrees of membership) from the fuzzification step and the rules from the knowledge base and calculates fuzzy outputs. In other word, they link the measured quantities and output variables by linguistic rules. Here, we have chosen MAMDANI method (based on Min-Max principle), for his simplicity and the mostly used.

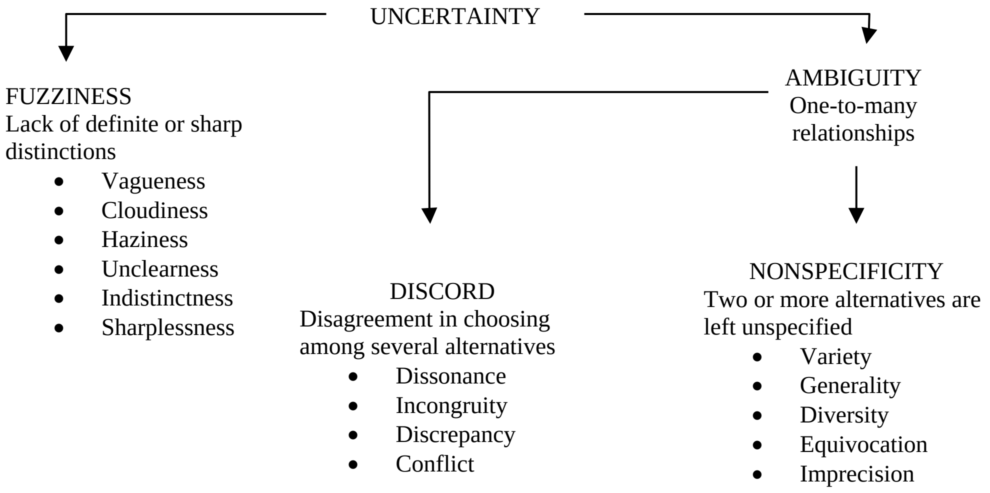
Final step is Defuzzification the fuzzy transformation, of the MAMDANI results into a precise piece of information is called a defuzzification (concretization). the defuzzification process converts the fuzzy outputs from the rule evaluation step into crisp system outputs. There are several possible methods of performing the defuzzification. A common defuzzification method, especially for control purposes, is the center of gravity or centroid defuzzification method. There are several defuzzification methods in the literature like the mean of maximum (MOM), maximum left (ML) or maximum right (MR) defuzzification.

Here we have used the default defuzzification method present in MATLAB (exist also with R programming language (Wagner et al, 2011), Mathematica and Python toolbox) using the centroid method. The main advantages of fuzzy systems are (Zimmermann, 2001):

- Direct incorporation of fuzzy and linguistic information from a human expert into the fuzzy system.
- There is no need to make a mathematical model of the system to be adjusted.
- The fuzzy system is a universal tool, that's mean, it is very enough to generate any action.
- Fuzzy logic is easily understood by those who are not specialists because it mimics the strategy of human reasoning.

Unlike the so-called Boolean logic, which limits the decision to true or false, the fuzzy logic allows to take into account the uncertainty (figure 4) with respect to the knowledge that are undifferentiated, vague or not clear.

Figure 4: The Three basic types of uncertainty.



Source: Klir and Yuan 1995.

6. Methodology

6.1.Approach and methodology

In a vision to develop our work that is relied to the practice of auditing, the case study methodology was adopted. This method is mostly used in information systems and management (Bryman, 2006), it is an empirical approach which studies a contemporary phenomenon (the 'case') in depth and in its real context. In fact, our work implies a study of information systems auditing field, in addition the purpose of how to apply the fuzzy logic tools to this field in real cases.

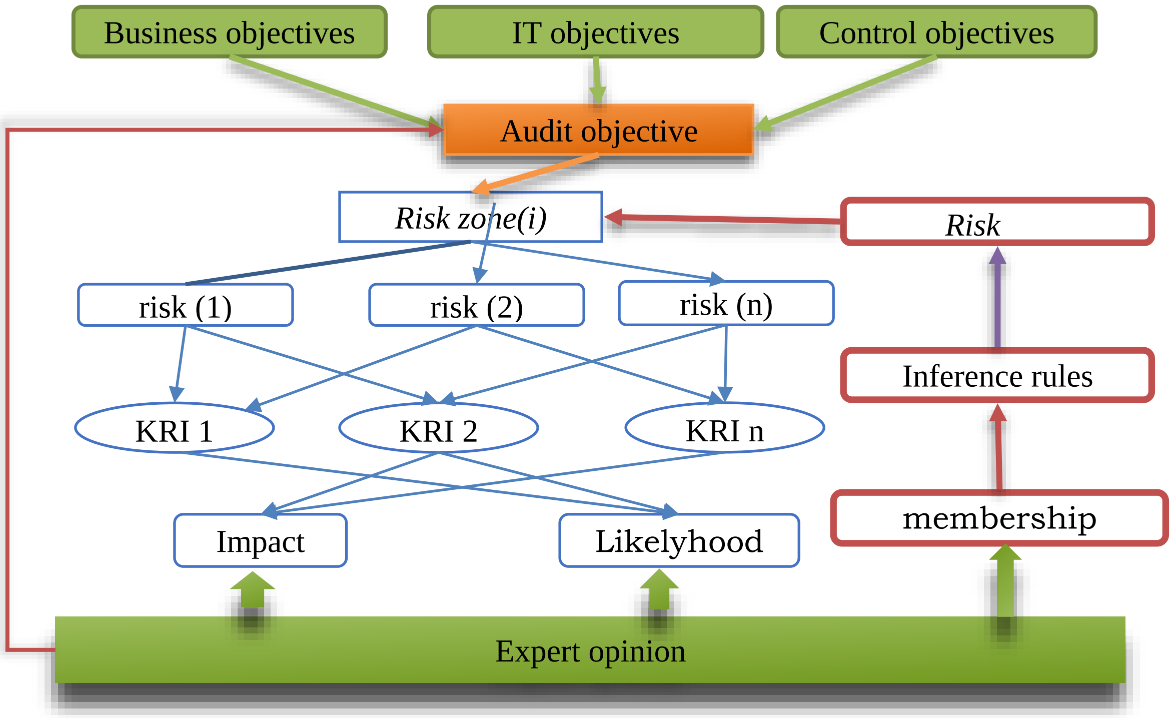
Case study is a method composed of six steps (yin, 2018):

- Plan: which consists of identifying the relevant situation for making a case study.
- Design: in this step we define the case to be studied, which is auditing control access to information systems in our case.
- Prepare to deal with a special case, the researcher needs to acquire the appropriate skills and competences.
- Collect: in this stage the researcher should build adequate tools to gather information and to collect data and evidence.
- Analyze: in this step, we should explore data collected in previous steps and try to extract from them a model and build the final design of the solution.
- Share: finally, the final design is shared with the targeted population, which is in our case the auditors of the ISACA chapter of Casablanca.

6.2.Model

The main idea here is to assist auditors in the field of information systems to make more benefit of expert system advantages and fuzzy logic to reduce complexity of their mission. To achieve this idea, we focus on COBIT information objectives, ISO 2700X control objectives and the audit objectives of the national directive on the security of information systems. Our model information objectives are inspired by COBIT that take CIA model (confidentiality, integrity and availability) as information criteria, furthermore, other criteria like effectiveness, efficiency, compliance and reliability. The most critical information criteria expressed by the experts (ISACA chapter Casablanca) basing on their answers to a questionnaire are CIA and compliance. The choice of objectives relating to internal control, the most important for the experts, is carried out by another questionnaire addressed to the same expert's community. And finally, we have retained the control objectives of the national directive on the security of information systems, because it also meets the objectives related to the information already validated in COBIT, as the objectives of auditing information systems of our model. Therefore, the model for our expert system is summarized as follows (figure 5):

***Figure 5**: Model of fuzzy expert systems.*



Source: Authors

Moreover, in a vision of designing our model the following steps are followed:

a. the creation of checklists (questionnaires):
   - the determination of the most critical information objectives
   - a limitation of the risk perimeter (risk zone)
   - the determination of general control objectives (also audit objectives) to be satisfied
   - the creation and validation of risk indicators related to each own risk
b. the determination of the impact and probability of each indicator
c. the definition of fuzzy subsets (subgroups): low, medium, high and very high
d. to establish rules of inference
e. to establish the validity of each rule.

7. Results and discussion

The audit objectives chosen were divided on several risk zones, and after that we were focused on one risk zone that guaranteed response to the most of audit objectives to reach (according to the questionnaires addressed to the auditors). Access control was the best zone of risk selected by the majority of our auditor target, then we have identifying risks (based on ISO 27002) related to this zone. Each risk allows us to create its key risk indicator (KRI) and based on these KRI we have made scenarios that enable us to assess the impact and likelihood (or probability). The probability that the risk can occur is noted on a scale from 1 to 4, translated to a fuzzy variable and a membership function due to expert opinions (screen of output, MATLAB below (figure 6)). The same procedure is used in assessing impacts.

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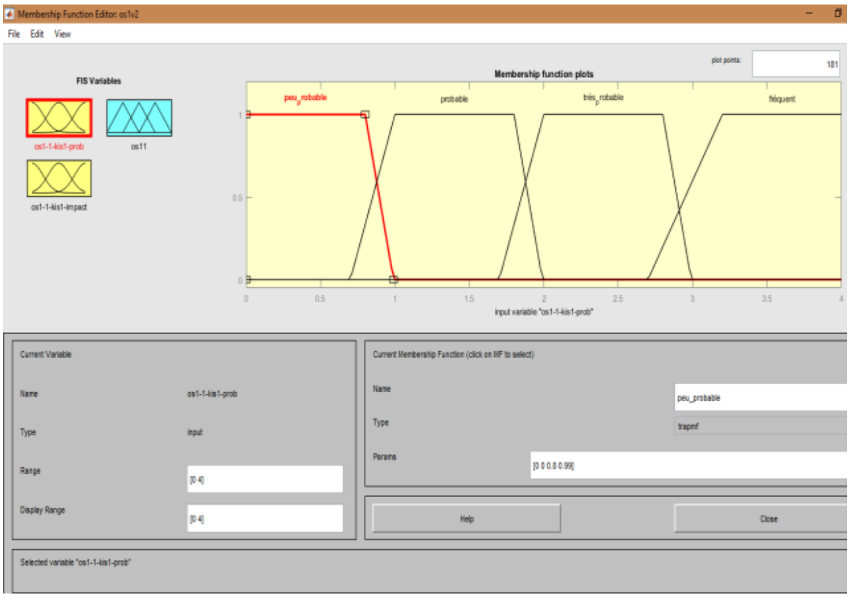
Figure 6: Membership function of occurrence.



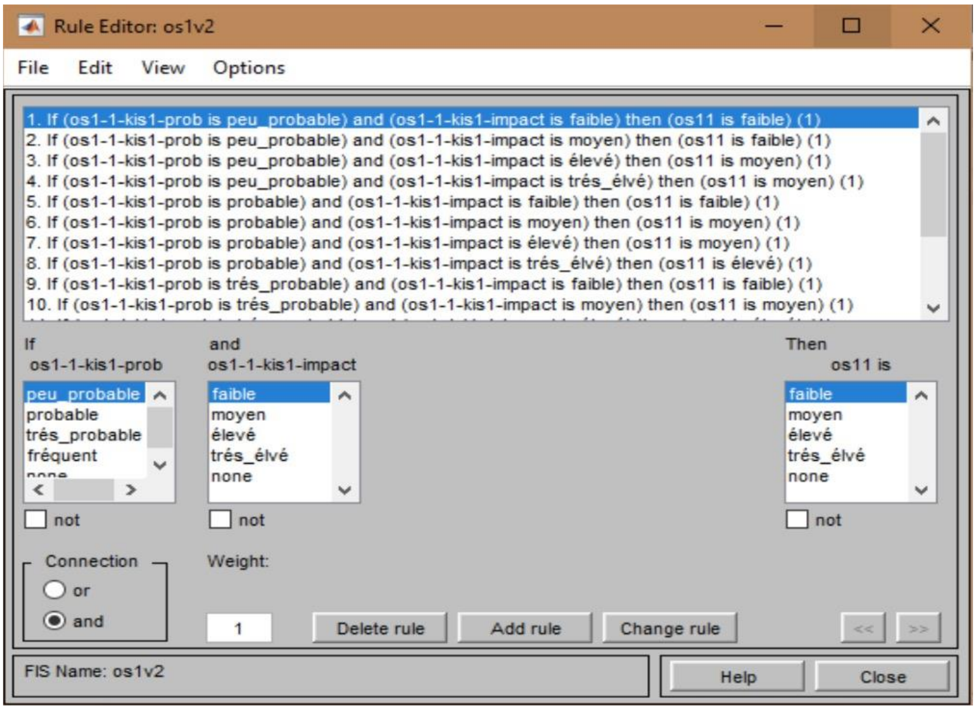
Source: Authors

Accordingly, an inference algorithm was developed depending on experts' judgments as shown in figure 7, and by adopting the MAMDANI method (by the impact and by likelihood). Finally, we have applied the centroid method to calculate the final risk assessment.

In light of this method, the relevant risks will be reported along with their scores and severity, that auditor should take in account in his mission. The score is calculated based on the two-risk components, namely the probability and the impact of the risk as shown in figure 8. Moreover, for each risk a list of indicators, that should be reviewed by the auditor, was given. These indicators will allow the auditor to start his mission with precision and without ambiguity and whatever his level of experience.

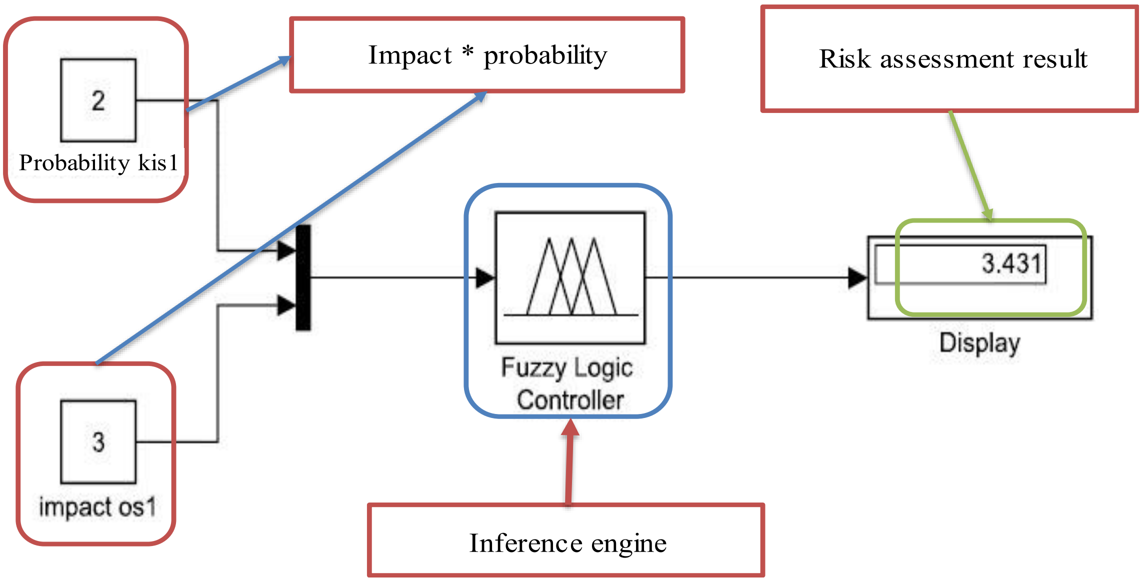
Finally, our work aims to introduce fuzzy logic, which has shown very good performance in the field of decision-making, to estimate risks related to access control of an information system, where the other work, as those described in literature review section, focus on a specific field like insurance fraud (Friedlob and Schleifer (1999)), financial statement (Comunal and Sexton (2005)), auditor quality (Dereli et all, 2007) and internal control (De Korvin et all, 2004). Besides the challenges presented by the computerization of information systems and the new trends of governments in the digitalization of public administration and especially the tax administration, auditors must acquire new skills that enable them to work in these new conditions (OUAADI and EL HADDAD (2021)), our work shows how can reduce this postulate by providing intelligent and quality work tools.

Figure 7: A sample of the inference algorithm.



Source: Authors

Figure 8: Risk score computing.



Source: Authors

8. Conclusion

The main aim of this contribution is to bring and review fuzzy set logic to the field of auditing and to investigate its relationship as a method for solving ambiguous accounting tasks by means of solving issues problems under the influence of ambiguities. Unlike traditional methods, fuzzy set logic provides a mathematical description for unpredictable behavior in human systems and decision-making that can be consistently implemented in a smart way and can be applied on a regular basis. Accordingly, fuzzy set logic can prove valuable to accounting professionals, specifically when there is uncertainty, ambiguity, and when it is not prudent to be conservative.

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This system allows auditors to better assess audit risk by, taking benefits from the expertise, and on the three components of auditing risks. For the constraint of control risk assessment is judged using the objectives of COBIT, ISO 27001 and DNSSI. Inherent risk assessment is judged by the universal model of controls recommended by international recognized communities. The risk of non-detection or the risk related to the auditor is minimized, because even the system relies on the opinions of experts in the field, the rating of key indicators remains the responsibility of the auditors in their missions, and the validity and credibility of the checks -lists used for the evaluation of the indicator. Therefore, the materiality is determined on a real and not estimated basis as the case of audits. Finally, we made the following recommendations:

First, encourage auditors to use the expert systems and especially the fuzzy expert systems in their areas instead of the classic risk-determination software. Next, the expert systems are very powerful tools in the audit field, according to the risk approach and allow to benefit from several advantages, for this reason we recommend to the companies working on the development of IT audit solutions to develop fuzzy expert systems instead of systems based on checklists. Moreover, the expert system is a very suitable tool for any size of the audit mission subject, and we are seeking more involvement from experts. Finally, the use of expert systems can save money and especially in terms of time and cost, both forming success parameters, for this reason we advise companies and both their auditors to exploit these tools in their missions.

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