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Research Article

Argumentative SOX Compliant and Quality Decision Support Intelligent Expert System over the Suppliers Selection Process

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The objective of this paper is to define a decision support system over SOX (Sarbanes-Oxley Act) compatibility and quality of the Suppliers Selection Process based on Artificial Intelligence and Argumentation Theory knowledge and techniques. The present SOX Law, in effect nowadays, was created to improve financial government control over US companies. This law is a factor standard out United States due to several factors like present globalization, expansion of US companies, or key influence of US stock exchange markets worldwide. This paper constitutes a novel approach to this kind of problems due to following elements: (1) it has an optimized structure to look for the solution, (2) it has a dynamic learning method to handle court and control gonvernment bodies decisions, (3) it uses fuzzy knowledge to improve its performance, and (4) it uses its past accumulated experience to let the system evolve far beyond its initial state.

1. Introduction

Enron, US multinational company, focuses on gas and electricity publishes in October 2001 its financial quarterly results with 600 US millions dollars of losses and its stocks decrease from 90 dollars to 30 cents. This is the beginning of its bankruptcy, firing thousands of employees, and significant loses on its shareholders; financial markets are collapsed by contagion and social alarm shoots up. Very few months before, on August 2001, Enron reached its historical maximum in the stock exchange market with 90 dollars per share, showing a very healthy financial situation.

The social alarm had jumped and the financial irregular practices begin to be visible. After Enron's collapse, other companies like Global Crossing, Worldcom, Tyco, or Adelphia show similar financial situation. Principal stock markets worldwide went down showing as well lack of confidence.

In July 2002, United States approved the SOX Law (Sarbanes-Oxley Act) in response to all of these financial scandals, with the last aim to increase the government control on the economic and financial operations of private sector, control the audits of its accounts, protect the investors, avoid massive dismissals, and try to return the calmness to the financial markets. This Law is mandatory inside USA, but, at the same time, turns into a worldwide facto standard due to the high degree of globalization.

Present paper shows a method to support decisions about the Suppliers Selection Process and its compliance with this law, using both technologies of Artificial Intelligence and Argumentation Theory.

The objective of the present method is on one side to design a decision support intelligent system based on argumentative negotiation technologies, to check if Suppliers Selection Process is compliant with SOX. This helps companies

to take corrective actions and helps as well auditors to support their findings and decisions. It provides as well an structured method based on recognized technologies of Artificial Intelligence, Negotiation Techniques and Argumentation Theory. On the other side, as secondary objective, this system will provide a quality measure of the analyzed business case according to a previously defined criteria.

With regard to the SOX Law, it is formed by eleven titles, and each title covers different aspects of the law. Articles 302, 404, and 906 of the 67 articles reflected in the SOX Law are the most important ones. Those articles state that top company management is responsible of published financial reports of their companies.

This paper is structured as follows: Section 2 describes the state of the art of both relevant areas in which this paper is based on and states the starting point of this work. Section 3 describes the proposed model specifying the key elements as well as the main protocols of the system. Section 4 presents a possible integration of the previously proposed system with a higher level multiagent system. Sections 5 and 6 will provide a clear real example of the use or our proposed model over a real business case. Finally, Section 7 will remark the conclusions here obtained.

2. State of the Art

2.1. Artificial Intelligence and Argumentation Theory Relationship. Nowadays Artificial Intelligence has been identified like one of the most important fields of application of the Argumentation Theory [1–9].

Artificial Intelligence and Argumentation Theory can be seen combined together in many other subjects like: (1) computational models of argumentation, (2) argument-based decisions making, (3) deliberation-based on argumentation, (4) persuasion-based on argumentation, (5) search of information for inquiring based on argumentation, (6) negotiation and resolution of conflicts based on argumentation, (7) analysis of risks based on argumentation (8) legal reasoning based on argumentation, (9) electronic democracy based on argumentation, (10) cooperation, coordination, and team building based on argumentation, (11) argumentation and game theory in multiagent systems, (12) argumentation human agent, (13) modeling of preferences in argumentation, (14) strategic behavior in argument-based dialogues, (15) deception, truthfulness, and reputation in the interaction based on argumentation, (16) computational complexity of the dialogues based on argumentation, (17) properties of dialogues based on argumentation (success, termination, etc.), (18) hybrid models of argumentation, and (19) implementation of multiagent systems based on argumentation.

There are two difference tendencies about automatic argumentation: (1) Abstract Argumentation and (2) Deductive Argumentation. The Abstract Argumentation is focused on the coexistence of arguments without getting into detail of its meaning. It only takes care about the attack relationships among arguments and their acceptability or not and in which grade. One of the most important studies so far and whose concepts are still valid nowadays is the Abstract Argumentation Systems of Dung [4]. Boella et al. [10] proposed an extension of Dung's model in which the arguments are dynamic elements not predefined in advance. Deductive Argumentation is another option to the Automatic Argumentation. Deductive models are based on formulas and based on Classical Logic. The arguments, opposite to the Abstract Argumentation, are complex elements that can be subdivided in elements or arguments of more simple structure. Deductive Argumentation is able to manage the complexity of the internal structure of the arguments. The key concept inside this type of argumentation is the logical deduction. The fundamental objective of whatever model of deductive argumentation is to reach a conclusion based on a support formed by arguments and reasoning of deductive logic. In the literature we find a recent study carried out by Besnard and Hunter [5] which is focused on Deductive Argumentation inside the area of artificial intelligence. Deductive Argumentation is about how to manage nonevident information (information that is not known if it is or not acceptable or truthful) and should generate arguments to support or against this information so that after a process of deductive reasoning, the conclusion about its truthfulness or admissibility is reached.

Argumentation Theory is a key area in Multiagent Systems due to the following two characteristics: (1) on one hand, Argumentation Theory finds in Multiagent Systems a wide field of practical application, allowing Multiagent Systems to get benefits from an entire formal solid theory and with a wide history and where formal existent models in Argumentation Theory offer a wide range of possibilities in the design of this kind of systems (2) On the other hand, Argumentation Theory offers a solid and formal base to Multiagent Systems which allows us to provide those systems with a syntactic and semantic structure which helps to the design of these kind of systems and to reach their own objectives.

Multiagent Systems area uses Argumentation Theory and their formal models, for internal reasoning, for their individual agents or in sharing reasoning among all the agents of the system. About shared reasoning, agents dialog among each other with the final objective to get the common shared previously defined objective. This communication among the agents, which conform the Multiagent System, is a key element to reach the objectives of this system.

And it is in this communication and in these dialogues where Multiagent Systems area is closed to Argumentation Theory, because those dialogues can be driven by previously well-defined dialog models. The success of a Multiagent System consists of achieving its objective for which it was designed. The grade of success in getting this objective will depend on the fruitful communication among its agents. And thanks to Argumentation Theory, we can provide a solid formal base to this communication and their corresponding dialogues.

Walton and Krabbe in 1995 made one of the most important initial works about communication in Multiagent Systems based on argumentation techniques [11]. They defined the most important basic types of dialogues: (1) dialogues based on information seeking, (2) dialogues based on questions, (3) dialogues based on persuasion, (4)

dialogues based on negotiation, (5) dialogues based on deliberation, (6) dialogues based on dialectical battles, (7) dialogues based on commands, (8) dialogues based on discovery of alternatives, (9) noncooperative dialogues, and (10) educational dialogues.

In 2005, Cogan et al. [12] made a work in which it is explained a new type of dialogue, the verification dialogues. Tang and Parsons [13] designed an specific deliberation dialogue model in which the global action plan of the full multiagent system is conformed by the union of the subplans of each agent after a deliberation process with the rest of the agents.

There are studies as well that propose modifications to the previously enumerated dialogues [14, 15], but always message interchanging between the participant agents is the key idea. This interchange of messages follows several guidelines according to the dialogue type, the initial knowledge of the agents, the reasoning protocol, or the mode of argumentation. In the literature we can find as well works suggesting different types of messages to be used depending on the type of dialogue: (1) Messages of Assertion, (2) Messages of Acceptance, (3) Question Messages, (4) Challenged Messages, (5) Testing Messages, and (6) Answer Messages. The semantic of those types of messages is specified by preconditions and postconditions.

Nowadays, Multiagent Systems and Argumentation Theory are both areas very much related as we can see in many present scientific researches like the following.

(1) In 2010 Belesiotis et al. [16] designed a dialogue model based on reasoning, deliberation, and tentative knowledge to use Argumentation Theory over calculus of situation plans.

(2) Devereux and Reed [17] proposed an specific model for strategic argumentation in rigorous persuasion dialogues which pushes the concept of attacking not only the initial knowledge of the agents, but as well this missing knowledge that does not belong to the agent.

(3) Matt et al. [18] designed a model based on dominant decisions on argumentative agents. The idea behind this work is that all possible decisions provided by each agent will be value based on previously indicated preferences looking for maximizing the final benefit. This mechanism is as well a procedure to auto explain the winner decision.

(4) Wardeh et al. [19] proposed a multiparty argument model based on the past experience of the agents to classify a specific case. This work promotes the idea that each agent uses data mining techniques and associative rules to solve the case based on its own experience.

(5) Morge and Mancarella [20] proposed an argumentation model based on assumptions to drive the argumentation process between agents with the objective to reach the optimal agreement between all the agents.

(6) Thimm [21] proposed an argumentation model for multiagent systems based on Defeasible Logic Programming in which each agent generates support and opposite arguments to answer the objective question. At the end the most feasible argument is selected to answer the initial question.

2.2. Artificial Intelligence Applied to SOX. We can find several studies showing the use of Artificial Intelligence in law financial topics. Some of those works are before SOX Law and show the existing concern about if the financial company reports show the real situation of the company or not.

Changchit et al. [22], before the SOX Law, remarked the concern about truthful financial reports of companies and remarked the positive impact of using intelligent systems to identify problems on the internal controls of those companies. It constitutes a good example of interaction between Artificial Intelligence and Financial Area. Meservy [23] designed an expert system to audit companies internal controls. This work is as well before the publication of the SOX Law.

O'Callaghan [24] suggested an artificial Intelligence model based on back propagated neural networks to simulate the revision of fixed activities of a company using an application of internal controls based on the COSO (Committee of Sponsoring Organizations of the Treadway Commission) model. Another work done by Liu et al. [25] presented an evaluation model of internal controls based on fuzzy knowledge, pattern classification, and data mining with the objective to check the effectiveness of company internal controls.

Kumar and Liu [26] is another example that uses techniques of patterns recognition to audit the internal controls and company processes. Changchit and Holsapple [27] proposed an expert model to evaluate the internal controls by company management with the objective to valuate the performance of the company internal controls.

Korvin et al. [28] made a work about which internal controls can be used inside an IT system and valuate using fuzzy knowledge techniques, the risk over specific threats.

Deshmukh and Talluru [29] is another example to value risks on specific threats in company internal controls. This work is based on fuzzy sets theory and lets the management of the company decide if their internal controls are or not effective and to take appropriate actions.

Fanning and Cogger [30] designed a fraud detection system based on Neural Networks using the data published by the company in its periodical results as input to the system. It is another example in which Artificial Intelligence provides its tools to the Financial Area. Fanning and Cogger based their work on other two previous studies which applied techniques of neural networks to economy and finances [31, 32] and combined them with traditional mathematics techniques to create their model of prediction of financial fraudulent reports.

Welch et al. [33] proposed a specific model to look for financial fraud and support audit decisions based on the use of genetic algorithms. This work is focused on fraud

research on government suppliers looking for fraud patterns to identify evidence of these frauds. Srivastava et al. [34] proposed a specific system to valuate and plan audits using belief functions based on intelligent expert systems.

Sarkar et al. [35] developed an expert model based on beliefs networks and use probabilistic models on the inference process.

Nowadays and in relation to the model here designed, after revising different international bibliographical sources and up to the best of our knowledge, any publication that uses Multiagent Systems and Argumentation Theory in the implementation of SOX internal controls with the objective to detect if a Supplier Selection Process of a specific business case is compliant with SOX Law supporting auditors and companies to take their appropriate decisions about this compliance is not found.

3. Proposed Model

The objective of the present work is to design an argumentative SOX compliant intelligent decision support expert system over the Suppliers Selection Process of the financial Purchasing Cycle using technologies of Artificial Intelligence and Argumentative Negotiation to support companies to identify non-SOX compliant situations before it will be too much late and to support financial auditor to decide if the economic and financial periodical results published by those companies are or not compliant with SOX Law. It is as well explained how this system can be incorporated into a higher level multiagent intelligent expert system to cover the full financial Purchasing Cycle. As well the second objective is to provide a quality measure of the selection process carried out in the analyzed business case.

There are seven different key financial typical cycles in whatever company: (1) Purchasing Cycle, (2) Inventory Cycle, (3) Sales Cycle, (4) Employees Payment Cycle, (5) Accounting Cycle, (6) Information Technologies Cycle (as support to other financial cycles), and (7) Cycle of Services Outsourcing. Financial results published by a company will be compatible with SOX Law, if all economic and financial operations that belong to these results are as well SOX compliant. All those economic and financial operations are SOX compliant if all projects or business cases which form those results are SOX compliant too. A specific business case will be SOX compliant if all its financial cycles are compatible with SOX Law.

The key processes of a typical Purchasing Cycle usually are (1) Suppliers' Selection, (2) Suppliers' Contracting, (3) Approval of Purchase Orders, (4) Creation of Purchase Orders, (5) Documentary Receipt of Orders, (6) Imports, (7) Check of Invoices, (8) Approval of Invoices without Purchase Order, and (9) Suppliers' Maintenance. The Purchasing Cycle of a certain business case will be compatible with SOX regulation if all of its processes, including the Suppliers Selection Process, are SOX compliant.

Financial cycles are sets of key processes with clear objectives. They share at the same time a common unique objective as well. This is the best scenario to implement a multiagent intelligent scientific approach providing well-founded tools and concepts to the solution of the problem.

The agent which is going to model this expert system has been designed with a specific optimized structure to reach the final objective. The elements of this agent are:

(1) Agent's Target;

(2) Original Starting Know-How;

(3) Facts Searching Discussion Protocol;

(4) Facts Scoring Protocol;

(5) Facts Scoring Matrix;

(6) Deductive Decision Making Protocol;

(7) Dynamic Fuzzy Learning Protocol.

3.1. Agent's Target. The agent's main objective is to verify if the selection of suppliers of the business case that is being analyzed is or not compatible with the SOX legislation. As secondary objective, it will provide a measure of the quality of the selection process carried out in the analyzed business case. For both objectives, it will be checked if every belief on the initial beliefs base matches or not with a fact of the facts base of the business case, and in case of matching, how much is this matching (quantitative value of this matching).

3.2. Original Starting Know-How. Here it is stored the initial knowledge of the agent as a set of beliefs. It represents the knowledge the agent has on the specific analyzed process without taking in mind any other possible knowledge derived from the experience and from the learning. Those beliefs will be enumerated and their characteristics will be indicated.

(1) *Participant Suppliers.* This is a key belief of the knowledge base of the Suppliers' Selection Agent. The existence or not of a fact of the analyzed business case that matches to this belief will be a key point for SOX compatibility as well as for the final valuation of the quality of the Suppliers Selection Process.

This is a critical factor from SOX legislation point of view. SOX legislation always looks for the transparency in all business cases managed by the companies and decisions of these companies should always look for the interest of investors fulfilling always the effective legislation. It is critical that Suppliers Selection Process for a certain contract or business case should be transparent and aligned to previously defined selection criteria. Due to that, the number of invited suppliers to the process is really important for the Suppliers Selection Process. A contract should never be assigned to an specific supplier without keeping in mind a selection process among several suppliers.

It is as well an important fact from quality point of view because it shows that the best possible candidate supplier for the company is always searched.

(2) *Agreement of Confidentiality.* This is another fundamental belief of the base knowledge of this agent. The existence or not of a fact of the analyzed business case that matches with this belief will be fundamental for SOX compatibility as well as for the final valuation of the quality of the Suppliers

Selection Process. It is a critical factor from SOX legislation point of view because the full transparency and clarity of any economic operation of the company is always pursued as objective.

Basically this belief analyzes if, in the business case, it has been signed a confidentiality agreement with invited suppliers that clearly states that whatever shared information during the selection process will be strictly confidential and it will not be disclosed, published, neither shared with third parties.

(3) *RFI (Request for Information).* This is another belief of the agent's selection process. It is not a mandatory belief to fulfill SOX, but its presence denotes high quality in the Suppliers Selection Process.

This RFI will allow to request from each of the suppliers important information that will let us understand suppliers' profile. RFI will request different kind of details from those suppliers like management board members identification, number of employees, sectors of activity, product portfolio, financial information, main customers' identification, main competitors' identification, strategy of the company, technologies, products and services, environmental strategy, certifications of quality, logistical capacity, and so forth.

This information will allow us to make a detailed analysis of each of the invited suppliers to the selection process and will allow us to evaluate each supplier in different aspects: structure and organization, technical capabilities, level of prices, quality, flexibility, and so forth. Those valuations will help to compare the candidate suppliers between each other and to take a decision on the right candidate to be selected based on transparent criteria.

(4) *Financial Analysis.* This belief is not critical for SOX compatibility, but it helps in the improvement of the quality of the Suppliers Selection Process. If there is a fact in the facts base of the business case that matches this belief, it will denote a good quality in the Suppliers Selection Process carried out in this business case.

The objective of financial analysis is to study financial health of each of the candidate suppliers by analyzing their balance sheets and economical results of the last two or three years. Those results should be compared with representative figures of the specific industrial sector to understand if this company is inline, below, or above tendency of that industrial sector and as well let us compare those results with results of rest of candidate suppliers.

(5) *Followed Selection Process.* This belief is not critical for SOX compatibility, but it helps in quality improvement of the Suppliers Selection Process. If a fact of facts base of the analyzed business case matches this belief, it will mean that the selection process will have been carried out in a structured and organized way, following a clear and transparent criteria from the beginning of the process and applying same approach to all candidate suppliers.

Possible criteria to be used during the Suppliers Selection Process are

(1) suppliers structure and organization;

(2) technical capability;

(3) level of prices;

(4) quality, security, and processes;

(5) flexibility and risk management.

(6) *Structure and Organization of the Supplier.* This belief is not critical for SOX compatibility, but it will help in quality improvement of Suppliers Selection Process. The objective of this belief is to research if in the analyzed business case, it has been taken into consideration details of company structure and company organization like:

(1) dedicated department of project management;

(2) appropriate resources for project execution tasks like employees and subcontractor companies;

(3) appropriate management systems;

(4) appropriate geographical coverage;

(5) appropriate strategy and business plan;

(6) appropriate level of sales and revenues that will allow the supplier an appropriate self-financing;

(7) appropriate subcontractor system and appropriate control processes to control it;

(8) appropriate accounting system, payment of social loads, taxes, and so forth;

(9) appropriate products and services portfolio;

(10) appropriate logistics management system.

(7) *Technical Capability.* This belief is not critical for SOX compatibility, but it will help to improve the quality of the Suppliers Selection Process. The objective of this belief is to check if during the Suppliers Selection Process, technical capability criteria have been taken into consideration to value each of candidate suppliers.

Key aspects to analyze the technical capability of candidate suppliers can be

(1) competences of the suppliers in terms of tasks to carry out in the business case;

(2) appropriate level of languages managed by the employees;

(3) appropriate development programs to improve competencies of the employees;

(4) previous experience of that supplier in other similar projects;

(5) appropriate certification levels that support the employees qualification;

(6) external and internal references about this supplier;

(7) appropriate employee resources like tools, materials, and equipment in general;

(8) appropriate competencies of the management in terms of managing external subcontractors.

(8) *Level of Prices.* This belief is not critical for SOX compatibility but will help in quality improvement of the Suppliers Selection Process. The objective of this belief is to check if during Suppliers Selection Process, pricing criteria have been taken into consideration to value each candidate supplier. With pricing criteria, we are referring to the pricing rates of the present proposal as well as pricing rates of this supplier in previous similar business cases.

Not only prices but terms and conditions as well should be taken into consideration to value the total cost of that specific analyzed supplier. Here it is a list of details that can be taken into consideration to analyze this belief:

(1) price;

(2) payment terms: to 30, 60, or 90 days, usually;

(3) procedure of billing;

(4) stability of prices;

(5) bank bonds;

(6) own financial resources.

(9) *Quality, Security, and Processes.* This belief is not critical for SOX compatibility, but it will help in the improvement of the quality of the Suppliers Selection Process. The objective of this belief is to check if during the suppliers' selection process, quality and security criteria have been taken into consideration to value each of the candidate suppliers. Criteria are like

(1) suppliers quality certifications;

(2) report and information systems;

(3) development and control of quality and security processes;

(4) control systems and audit of processes;

(5) claim management systems;

(6) documentation systems;

(7) management and supervision of response times of the suppliers.

(10) *Flexibility and Risks Management.* This belief is not critical for SOX compatibility, but it will help in the improvement of the quality of the selection process. The objective of this belief is to check if during the suppliers' selection process, flexibility and risks management criteria have been taken into consideration to value each of the candidate suppliers. Criteria are like

(1) availability of the supplier to accept contractual terms indicated by end customer for that specific project;

(2) flexibility and availability of the supplier to decrease the needed time of a task in that specific project;

(3) flexibility and availability to accept changes in the scope of the project;

(4) flexibility and availability to accept changes in the geographical location of the project;

(5) flexibility and availability to increase the number of resources in the project;

(6) flexibility and availability to manage derived risks of the project execution;

(7) flexibility and availability to accept penalizations just in case of no fulfillment of the previously agreed conditions;

(8) predefined mitigation plan for risk management;

(9) flexibility and availability to support external audits of realized tasks.

3.3. Facts Searching Discussion Protocol. This protocol is designed to let the agent interrogate the analyzed business case looking for relevant information about the Suppliers Selection Process to be analyzed later on to determine on the basis of the initial knowledge of the agent, the quality degree of the followed process in that business case, as well as to value if the previously mentioned process has complied with SOX. The agent inquires the business case according to the beliefs it has in its initial knowledge, and for every question, the agent will gather from the business case an answer with the needed detailed information accordingly to every belief.

This protocol is designed taking in mind two ideas: (1) one of the most important elements of an agent is its initial knowledge formed by its beliefs, and (2) a business case (the followed Supplier Selection Process) can be considered as a set of facts which constitute all the information about how things were done along the life of the previously mentioned business case. The aim of this protocol is to capture for every belief of the agent the correspondent fact of the facts base of the business case which corresponds with the previously mentioned belief. Once captured, it will be necessary to see how much it is in line with the specific belief of the agent both from a quality point of view and from SOX compliant point of view.

Basically this protocol consists of the idea that the agent asks to the business case (about the Suppliers Selection Process), "how did you do this?", and the business case will answer to the agent with the "arguments" or "evidence" of how it did it. Evidence later on will be analyzed by the agent. It is necessary to keep in mind that the agent has a clear idea of how it is necessary to do things in every stage of the business case based on its initial knowledge and that what the agent is looking for is to analyze if, inside the business case, things were done as should be.

This Facts Searching Discussion Protocol constitutes a phase in which the agent individually explores the whole documentation of the analyzed Suppliers Selection Process with the objective to compile as much evidence as possible on how things were done. Those beliefs as already commented constitute the initial knowledge or original starting know-how of the agent and represent the fundamental characteristics of the process that the agent is analyzing.

The Suppliers Selection Agent analyzes the Suppliers' Selection Process, and in the previously mentioned process there is a series of key characteristics as the number of companies invited to the contest, requested information from those companies, or followed process to value and select the final companies. This kind of details is "beliefs" of the agent and more important, inside these beliefs, inside its agent's

initial knowledge, the agent has a clear idea of how things should be done.

When the agent analyzes the business case with this protocol, it compiles all the facts of the Suppliers Selection Process which match with its beliefs. It can happen that for a certain belief a fact does not exist in the facts base of the business case, denoting steps inside the business case that they should have done and have not been like that, for example, not inviting different companies to the contest and assigning without any criteria the contest to a certain company. With this protocol, the agent will take this under consideration for future stages at the time to value the quality of the process and take the appropriate decision about SOX compatibility according to this situation.

The inspection of the agent over the business case will be realized across a mediating agent which will facilitate the communication between both. This mediating agent represents the person responsible for the business case in the company and, for each question of the agent who analyzes the case, can seek inside the business case documentation (documentation of the followed Suppliers Selection Process) to analyze the previously mentioned documentation and to provide a response to the formulated question.

Here (Figure 1) the protocol in which the agent inquires the analyzed business case with the objective to gather needed information about its beliefs is presented. This collected information will allow to value the initial beliefs of the Suppliers Selection Process from SOX compatibility point of view and from quality point of view.

Let us see later the next section how to value these collected facts.

3.4. Facts Scoring Protocol. This protocol allows the agent to be able to value the facts previously gathered as evidence from the business case (Suppliers Selection Process) with the Facts Searching Discussion Protocol. The valuation of these evidences will be carried out based on two approaches: (1) quality of the process and (2) compatibility with SOX legislation. Two weight factors have been assigned to each belief, respectively, for quality and for SOX compatibility. The weight of quality will denote the relevance of that belief in the global valuation of quality of the whole analyzed process. The weight of SOX compatibility will only denote if this specific belief is relevant or not from SOX compliant point of view. Qualities' weight will be used in a numeric way to calculate the final quality of the specific analyzed process. SOX compatibilities' weight will not be used in a numeric way, it will indicate if that belief are or not relevant for the compatibility with SOX legislation.

Regarding valuation of quality, there will be numeric values inside the range $[-10, 10]$, where -10 will denote a penalization in the valuation of quality and 10 will denote the maximum value of quality. Regarding valuation of SOX compatibility, the possible values will be logical boolean values: true (t) or false (f). True denotes that this belief matches a fact of the facts base of the analyzed business case (about the Suppliers Selection Process), and therefore the analyzed process by this agent, regarding that belief, is compatible with the SOX legislation. False value will mean the opposite.

This is an example (see Table 1).

This agent has ten key beliefs composing the original starting know-how of the agent: (1) participant suppliers, (2) agreement of confidentiality, (3) RFI (Request for Information), (4) financial analysis, (5) followed selection process, (6) structure and organization of the supplier, (7) technical capability, (8) level of prices, (9) quality, security, and processes, and (10) flexibility and risks management. This is the Scoring Protocol for each of those beliefs:

(1) participant suppliers (see Table 2);

(2) agreement of confidentiality (see Table 3);

(3) RFI (Request for Information) (see Table 4);

(4) financial analysis (see Table 5);

(5) followed selection process (see Table 6);

(6) structure and organization of the supplier (see Table 7);

(7) technical capability (see Table 8);

(8) level of prices (see Table 9);

(9) quality, security and processes (see Table 10);

(10) flexibility and risks management (see Table 11).

3.5. Facts Scoring Matrix. In this section, all valuations gathered by the previous Facts Scoring Protocol over each one of the facts of the analyzed business case are showed in table format (Table 12).

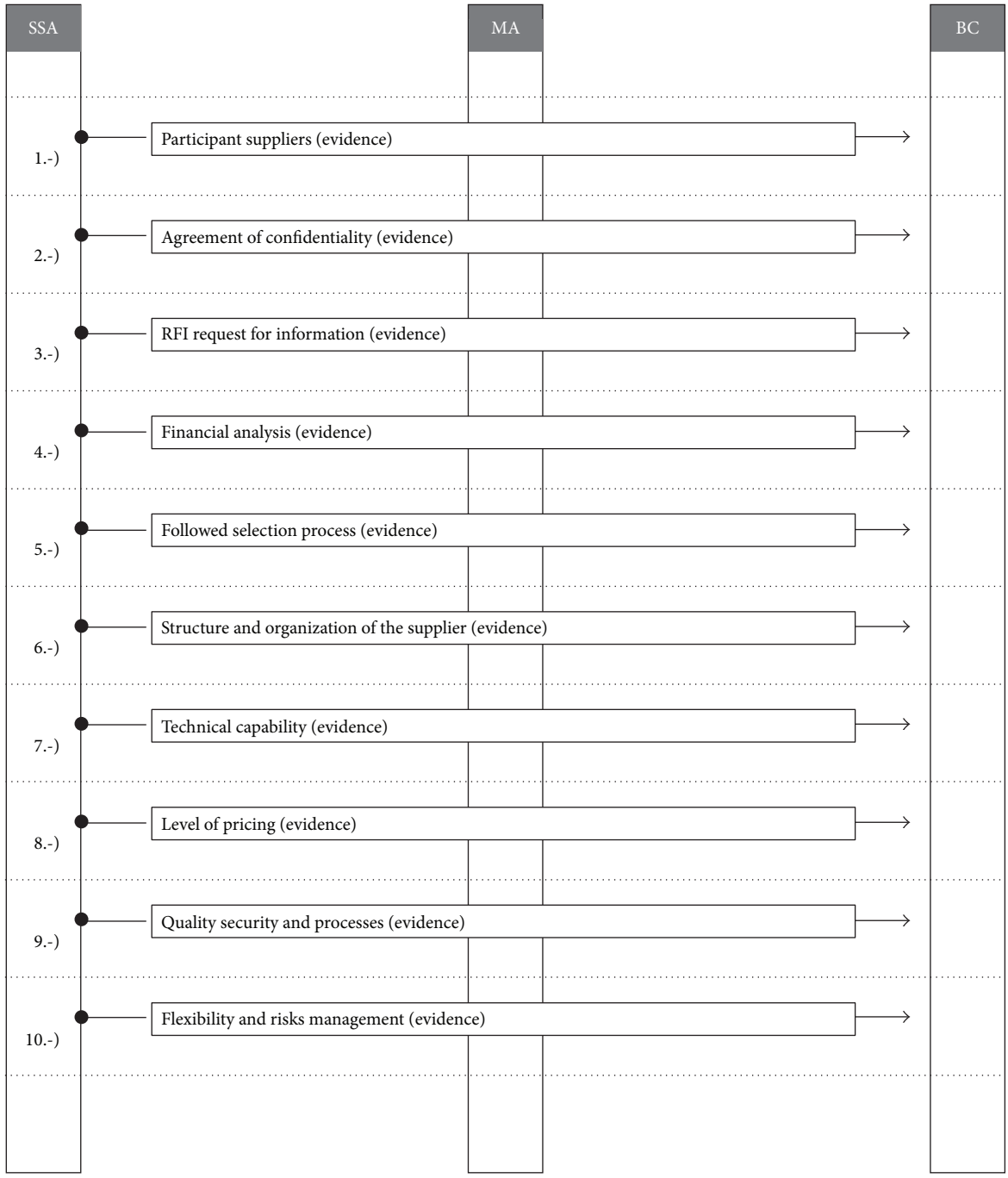
It is needed to highlight, as indicated before, that SOX compatibility weights are indicators of if that belief is or not relevant from SOX compatibility point of view. In the case of being a relevant belief for SOX compatibility, it will be indicated with an unitary weight (1), and its value according to the previous protocol will be true (t) meaning that it is SOX_COMPLIANT or false (f) meaning Non-SOX compliant. In the case of being an irrelevant belief for SOX compatibility, its weight will be null (0), and their value will not be relevant (it doesnot apply, NA).

The final valuation of SOX compatibility of the whole agent over the Suppliers Selection Process will be calculated by an inference rule described more in detailed in the next protocol (Deductive Decision Making Protocol). The final valuation of quality of the analyzed process by this agent will be given by the weighted sum of all the quality values obtained in each one of the analyzed facts of the business case.

Table 13 describes more in detail the Facts Scoring Matrix for the Suppliers Selection Process.

3.5.1. Detailed Explanation of SOX Weights. As indicated in Table 1, the key beliefs of the agent can be relevant or irrelevant from SOX point of view. Relevant ones will have weight 1 and irrelevant ones will have weight 0.

3.5.2. Detailed Explanation of Quality Weights. As indicated in Table 1, agent's beliefs donot have the same relevance from



SSA: suppliers selection agent
MA: mediator agent
BC: business case

Figure 1: Facts Searching Discussion Protocol.

quality point of view. When we are analyzing the full process among the 10 beliefs of the agent, we have two groups: the SOX important ones (2 beliefs) and the non-SOX important ones (8 beliefs). The number of beliefs in both groups is different but from quality point of view, both groups have same relevance (50%). This is a subjective decision coming from our experience in this field.

As we have 2 SOX relevant beliefs, each respective weight will be 50% divided by 2. (0.5/2). Rest of the non-SOX relevance beliefs will have the rest of the relevance: this means

Table 1: Facts Scoring Protocol.

Belief type	Critical or irrelevant for SOX compatibility Important or not for the quality of the process
SOX compatibility weight	1 if it is needed and mandatory for SOX compatibility 0 in rest of cases
Quality weight	X (The agent's beliefs do not have the same relevance in the quality of the process. Critical SOX beliefs will have a total relevance of 50% over the rest of agent's beliefs although these would be less in number)
SOX compatibility valuation	Logical boolean valuation: true (t) or false (f) (t) if this belief exists in the facts base of the analyzed business case (f) in rest of cases (NA) in case this belief is irrelevant for SOX compatibility
Quality valuation	Valuation of the fact of the analyzed business case corresponding to this belief inside the range [−10 (penalization), 10]

Table 2: Participant Suppliers Scoring Protocol.

Belief type	Critical for SOX compatibility. Important for the quality of the process
SOX compatibility weight	1 (needed and mandatory belief for SOX compatibility)
Quality weight	0.5/2 (The 10 beliefs that compose the base knowledge do not have the same relevance in terms of quality over the Suppliers Selection Process. The SOX critical beliefs have a total relevance of 50% over the rest of beliefs. In this case there are 2 SOX critical beliefs and 8 non-SOX critical ones)
SOX compatibility valuation	Logical boolean valuation with values true (t) or false (f) (t) if this belief occurs in the facts base of the analyzed business case. That is to say, if several suppliers have been invited to participate in the Suppliers Selection Process and the selected supplier was not selected without keeping in mind other suppliers (f) in rest of cases
Quality valuation	Valuation of the fact of the business case that corresponds to this belief inside the range [−10 (penalization), 10] −10 (penalization) if a supplier has been selected without keeping in mind other suppliers 10 if several suppliers were invited to the Suppliers Selection Process

the other 50% are divided by 8 non-SOX relevance beliefs. (0.5/8).

3.6. Deductive Decision Making Protocol. In this section it is shown the reasoning side of the Suppliers Selection Agent which uses a deductive argumentation protocol. It makes its own decision about if the Suppliers Selection Process of the analyzed business case is or not SOX compliant. This protocol is based on Classical Logic Theory or Logic of Predicates, and the central base of this protocol is an inference rule which uses as arguments the result of the valuation of beliefs from the previous phase (Facts Scoring Matrix). Specifically those relevant beliefs for SOX compatibility.

The objective of this protocol is to try to demonstrate the truthfulness of a hypothesis that establishes that the process that is being analyzed by this agent is compatible with the SOX legislation (Table 14).

To demonstrate the truthfulness of this hypothesis, the agent relies on the following elements:

(1) Agent's Target;

(2) Original Starting Know-How;

(3) Facts Searching Discussion Protocol;

(4) Facts Scoring Protocol;

(5) Facts Scoring Matrix;

(6) Deductive Decision Making Protocol;

(7) Dynamic Fuzzy Learning Protocol.

The Supplier Selection Agent will determine the trufulness or not of the corresponding hypothesis based on an inference rule using the Deductive Decision Making Protocol. This inference rule will come specified in advance by a combination of the agent's beliefs or the agent's initial knowledge with a learning factor that will gather the previous accumulated experience in past business cases, together with the option of new dynamic knowledge collected by a human expert just if needed (Figures 2 and 3).

This protocol uses notation of Classical Logic or Predicates Logic with its logical operators: ¬ (negation), ▲ (conjunction), ▼ (disjunction), → (implication), ↔ (biconditional).

The arguments to be used in this protocol are (1) Participant Suppliers in the Selection Process, (2) Agreement of

Table 3: Agreement of Confidentiality Scoring Protocol.

Belief type	Critical for SOX compatibility Important for the quality of the process
SOX compatibility weight	1 (needed and mandatory belief for SOX compatibility)
Quality weight	0.5/2 (The 10 beliefs that compose the base knowledge do not have the same relevance in terms of quality over the Suppliers Selection Process. The SOX critical beliefs have a total relevance of 50% over the rest of beliefs. In this case there are 2 SOX critical beliefs and 8 non-SOX critical ones)
SOX compatibility valuation	Logical boolean valuation with values true (t) or false (f) (t) if this belief occurs in the facts base of the analyzed business case. That is to say, if a confidentiality agreement has been signed with each of the invited suppliers to the selection process (f) in rest of cases
Quality valuation	Valuation of the fact of the business case that corresponds to this belief inside the range [−10 (penalization), 10] −10 (penalization) if there is no signed confidentiality agreement with invited suppliers to the selection process 10 in rest of cases

Table 4: RFI Scoring Protocol.

Belief type	Irrelevant for SOX compatibility Important for the quality of the process
SOX compatibility weight	0 (not needed belief for SOX compatibility)
Quality weight	0.5/8 (The 10 beliefs that compose the base knowledge do not have the same relevance in terms of quality over the Suppliers Selection Process. The SOX critical beliefs have a total relevance of 50% over the rest of beliefs. In this case there are 2 SOX critical beliefs and 8 non-SOX critical ones)
SOX compatibility valuation	(NA) does not apply
Quality valuation	Valuation of the fact of the business case that corresponds to this belief inside the range [−10 (penalization), 10] −10 (penalization) if RFI (Request For Information) has not been carried out over each invited supplier to the selection process 10 in rest of cases

Confidentiality, and (3) Learning Factor. First two arguments represent the agent's static knowledge based on their beliefs or base knowledge. The third argument represents its experience or dynamic knowledge; it means the knowledge that this agent has acquired as the time went on in the analysis of other business cases.

The arguments that represent the static knowledge are part of the antecedent of the inference rule and are the result of the valuation of their boolean respective functions in the process followed with the Facts Scoring Protocol for SOX compatibility, and therefore they are variables with true (t) or false (f) value.

The argument that represents the dynamic knowledge, will also have true (t) or false (f) value depending on the result of the learning protocol. This learning protocol will take into consideration evidence presented by the business case in this selection process.

SOX compliant is defined like a boolean function or logical predicate that can take boolean true (t) or false (f) values and its semantic represents the compatibility with the SOX regulation. SOX compliant (Process of selection) composes the consequent of the main inference rule and therefore based on its arguments; this rule allows us to obtain its truthfulness or falsehood. The conclusion is represented by the consequent of the previous inference rule, and its truthfulness will depend on the truthfulness of the predicates that form the antecedent of the rule.

These previous inference rules establish that SOX compliant (Process of selection) will be true if their two antecedents belonging to the static knowledge (arguments 1 and 2) are true at the same time, or, if the learning factor (3) that represents the dynamic knowledge indicates this truthfulness. SOX compliant (Process of selection) will be true (t) if all critical beliefs for SOX compatibility (static knowledge) are true, or, although they werenot, it will be also true (t) if its dynamic knowledge (learning factor) indicates it, based on its past experiences. This means Dynamic Fuzzy Learning Protocol will be taken in use only if the initial static knowledge by itself cannot determine a positive SOX compatibility.

The truthfulness or not of SOX compliant (Process of selection) will allow us to demonstrate or to reject the hypothesis previously outlined. Non SOX compliant (Process

Table 5: Financial Analysis Scoring Protocol.

Belief type	Irrelevant for SOX compatibility Important for the quality of the process
SOX compatibility weight	0 (not needed belief for SOX compatibility)
Quality weight	0.5/8 (The 10 beliefs that compose the base knowledge do not have the same relevance in terms of quality over the Suppliers Selection Process. The SOX critical beliefs have a total relevance of 50% over the rest of beliefs. In this case there are 2 SOX critical beliefs and 8 non-SOX critical ones)
SOX compatibility valuation	(NA) does not apply
Quality valuation	Valuation of the fact of the business case that corresponds to this belief inside the range [−10 (penalization), 10] −10 (penalization) if a financial analysis was not carried out over each invited supplier to the selection process 10 in rest of cases

Table 6: Followed Selection Process Scoring Protocol.

Belief type	Irrelevant for SOX compatibility Important for the quality of the process
SOX compatibility weight	0 (not needed belief for SOX compatibility)
Quality weight	0.5/8 (The 10 beliefs that compose the base knowledge do not have the same relevance in terms of quality over the Suppliers Selection Process. The SOX critical beliefs have a total relevance of 50% over the rest of beliefs. In this case there are 2 SOX critical beliefs and 8 non-SOX critical ones)
SOX compatibility valuation	(NA) does not apply
Quality valuation	Valuation of the fact of the business case that corresponds to this belief inside the range [−10 (penalization), 10] −10 (penalization) if a structured and predefined selection process with predefined criteria for all suppliers was not properly done 10 in rest of cases

of selection) is defined as well as a boolean function or logical predicate which can take true (t) or false (f) values and is the logical complementary predicate of SOX compliant.

3.7. Dynamic Fuzzy Learning Protocol. The agent uses its static knowledge or fundamental beliefs to determine the SOX compatibility of the analyzed Suppliers Selection Process. If the static knowledge cannot determine a positive SOX compatibility; this Dynamic Fuzzy Learning Protocol will be taken in use. There is the possibility based on the agent's previous experience that it can be verified if, in similar cases with similar evidence and after consulting to the human expert, it was decided to value this process as compatible with SOX, in other words, to see if this case is an exception to the static knowledge of the agent.

There are specific situations that can go beyond the static initially predefined beliefs and that they will be based on specific court judgments over real cases in which a very specific context after the analysis of the court gives a result of SOX compatibility even though static initial knowledge states a non-SOX compatibility. It means we would be under exceptions of real cases that the human expert knows and that belong to court resolutions or decisions of the control organisms on specific business cases where a series of specific evidences, opposite to what it is indicate by the initial knowledge, would have determined a positive SOX compatibility. These exceptions, through the learning protocol, will allow our agent to learn and to evolve beyond the initial knowledge formed by its beliefs.

As indicated by Capobianco et al. [36], the agents should be able to adapt to dynamic and changing environments. Pinzon et al. (2011) establish the need of self-adaptation ability as an important characteristic in multiagent systems. In this line, Fukumoto and Sawamura [37] proposed a model in which the results or conclusions are back propagated to the initial knowledge to enrich future possible argumentations. With this protocol, the agent is able to change its beliefs, improving its knowledge beyond its initial state.

As the time goes on, the system should learn from its previous experiences (PE) with previous analyzed business cases as well as from the consultations to an external human expert (HE) representing the knowledge over recent court decisions on exceptional situations so it can define the following learning factor relationship (lf) that represents how the

Table 7: Structure and Organization Scoring Protocol.

Belief type	Irrelevant for SOX compatibility Important for the quality of the process
SOX compatibility weight	0 (not needed belief for SOX compatibility)
Quality weight	0.5/8 (The 10 beliefs that compose the base knowledge do not have the same relevance in terms of quality over the Suppliers Selection Process. The SOX critical beliefs have a total relevance of 50% over the rest of beliefs. In this case there are 2 SOX critical beliefs and 8 non-SOX critical ones)
SOX compatibility valuation	(NA) does not apply
Quality valuation	It does not penalize, but it is a convenient belief. Valuation inside the range [0, 10] (+10/10) for each one of the 10 different selection aspects of this belief is taken into consideration

Table 8: Technical Capability Scoring Protocol.

Belief type	Irrelevant for SOX compatibility Important for the quality of the process
SOX compatibility weight	0 (not needed belief for SOX compatibility)
Quality weight	0.5/8 (The 10 beliefs that compose the base knowledge do not have the same relevance in terms of quality over the Suppliers Selection Process. The SOX critical beliefs have a total relevance of 50% over the rest of beliefs. In this case there are 2 SOX critical beliefs and 8 non-SOX critical ones)
SOX compatibility valuation	(NA) does not apply
Quality valuation	It does not penalize, but it is a convenient belief. Valuation inside the range [0, 10] (+10/8) for each one of the 8 different selection aspects of this belief is taken into consideration

knowledge of the system is evolving with each new business case. Here, it can be seen how the previous experience combines with the opinion of the external human expert and feeds the "future" previous experience term, allowing the system to accumulate the knowledge and learn.

In real life, sometimes we can find previous similar experiences but not exactly the same ones. This is model under the SE (similar experiences) term that models some kind of uncertainty or fuzzy knowledge. In this case a certain par of evidence ($e1'$, $e2'$) can be considered ($e1$, $e2$) if only their respective degree of belonging to those evidence is for example 90%. This percentage is called degree of certainty and will be represented by ϕ. If we donot want to take uncertainty of fuzzy knowledge into consideration, we will take this parameter as 100%:

$$\mathrm{lf}: \underset{(\mathrm{pe}_t,\ \mathrm{he}_t,\mathrm{se}_t)}{\mathrm{PE}\times\mathrm{HE}\times\mathrm{SE}} \longrightarrow \underset{\mathrm{lf}(\mathrm{pe}_t,\mathrm{he}_t)}{\mathrm{PE}}. \tag{1}$$

Given a state "t" in which the model is analyzing a specific business case, for each specific pair of evidence $e1$ and $e2$, the learning factor (lf) can be defined as a function of the previous experience (pe) in that moment, similar (but not equal) to previous experiences (assuming a certain risk or degree of uncertainty) and the opinion of the human expert (he) taking into consideration the combination of both evidences:

$$\mathrm{lf}_t^{e1e2} = \alpha_t^{e1e2}\cdot \mathrm{pe}_t^{e1e2} + \beta_t^{e1e2}\cdot \mathrm{se}_t^{e1e2} + \gamma_t^{e1e2}\cdot \mathrm{he}_t^{e1e2}. \tag{2}$$

α_t^{e1e2} is the activation factor of the previous experience (pe) on a specific instant t and for specific pieces of evidence $e1$ and $e2$. Its value on instant t will be 1 just in case there is previous (equal) experience for those pieces of evidence and 0 if there is no previous experience:

$$\alpha_t^{e1e2} = \begin{cases} 1 & \text{if } \exists\ \mathrm{lf}_i^{e1e2} \in \{0,1\},\ i \in \{1,\ldots,t-1\}, \\ 0 & \text{otherwise.} \end{cases} \tag{3}$$

β_t^{e1e2} is the activation factor of the similar experiences (se) term on a specific instant t and for specific pieces of evidence $e1$ and $e2$. Its value on instant t will be 1 just in case we accept a certain risk or degree of uncertainty in our approximation to the pieces of evidence $e1$ and $e2$:

$$\beta_t^{e1e2} = \begin{cases} 1 & \text{if } \phi < 100\%, \phi \in [0\%,\ldots,100\%], \\ 0 & \text{if } \phi = 100\%. \end{cases} \tag{4}$$

ϕ is the degree of certainty we assume. A value of 100% means no uncertainty. This means 100% of certainty so we

Table 9: Level of Prices Scoring Protocol.

Belief type	Irrelevant for SOX compatibility Important for the quality of the process
SOX compatibility weight	0 (not needed belief for SOX compatibility)
Quality weight	0.5/8 (The 10 beliefs that compose the base knowledge do not have the same relevance in terms of quality over the Suppliers Selection Process. The SOX critical beliefs have a total relevance of 50% over the rest of beliefs. In this case there are 2 SOX critical beliefs and 8 non-SOX critical ones)
SOX compatibility valuation	(NA) does not apply
Quality valuation	It does not penalize, but it is a convenient belief. Valuation inside the range [0, 10] (+10/6) for each one of the 6 different selection aspects of this belief is taken into consideration.

Table 10: Quality, Security and Processes Scoring Protocol.

Belief type	Irrelevant for SOX compatibility Important for the quality of the process
SOX compatibility weight	0 (not needed belief for SOX compatibility)
Quality weight	0.5/8 (The 10 beliefs that compose the base knowledge do not have the same relevance in terms of quality over the Suppliers Selection Process. The SOX critical beliefs have a total relevance of 50% over the rest of beliefs. In this case there are 2 SOX critical beliefs and 8 non-SOX critical ones)
SOX compatibility valuation	(NA) does not apply
Quality valuation	It does not penalize, but it is a convenient belief. Valuation inside the range [0, 10] (+10/7) for each one of the 7 different selection aspects of this belief is taken into consideration

are not assuming any kind of risk at the time to find similar experiences in the past. If ϕ is minor than 100%, then we are assuming a certain degree of uncertainty when we are approximating two past pieces of evidence $e1'$ and $e2'$ like $e1$ and $e2$, respectively, under specific previously defined criteria. ϕ is the degree of certainty, so it means that (100%-ϕ) represents the degree of uncertainty or risk we are assuming in our approximations of two past pieces of evidence $(e1', e2')$ by $(e1, e2)$.

We defined $\mu_{e1'}^{e1}$ as well, like degree of belonging of $e1'$ to $e1$, being $e1'$ a past evidence and $e1$ the evidence we are analyzing on instant t.

We defined $\mu_{e2'}^{e2}$ as well, like degree of belonging of $e2'$ to $e2$, being $e2'$a past evidence and $e2$ the evidence we are analyzing on instant t.

The condition to consider or approximate a past evidence $e1'$to $e1$ should be that $\mu_{e1'}^{e1} >= \phi$.

The condition to consider or approximate a past evidence $e2'$to $e2$ should be that $\mu_{e2'}^{e2} >= \phi$.

Taking in mind that evidence $e1$ represents the participant suppliers, we correlate $\mu_{e1'}^{e1}$ with the number of participating suppliers (no. of suppliers) of both pieces of evidence. This criteria are subjective and come from our experience:

$$\mu_{e1'}^{e1} = \frac{\#\text{suppliers of } e1'}{\#\text{suppliers of } e1} * 100. \quad (5)$$

Taking in mind that evidence $e2$ represents the confidentiality agreements we have, we correlate $\mu_{e2'}^{e2}$ with the number of confidentiality agreements (no. of confidentiality agreements) of both pieces of evidence. This criteria are subjective and come from our experience:

$$\mu_{e2'}^{e2} = \frac{\#\text{confidentiality\_agreements of } e2'}{\#\text{confidentiality\_agreements of } e2} * 100. \quad (6)$$

γ_t^{e1e2} is the activation factor of the human expert (he) on a specific instant t and for specific pieces of evidence $e1$ and $e2$. Its value on instant t will be 1 just in case there is no previous experience for those pieces of evidence (equal or similar) and 0 if previous experience (similar or equal) for those pieces of evidence exists:

$$\gamma_t^{e1e2} = \begin{cases} 1 & \text{if } \alpha = 0 \text{ and } \beta = 0, \\ 1 & \text{if } \alpha = 0 \text{ and } \beta = 1 \text{ and no } \exists\, se_t^{e1e2}, \\ 0 & \text{otherwise.} \end{cases} \quad (7)$$

Table 11: Flexibility and Risks Management Scoring Protocol.

Belief type	Irrelevant for SOX compatibility Important for the quality of the process
SOX compatibility weight	0 (not needed belief for SOX compatibility)
Quality weight	0.5/8 (The 10 beliefs that compose the base knowledge do not have the same relevance in terms of quality over the Suppliers Selection Process. The SOX critical beliefs have a total relevance of 50% over the rest of beliefs. In this case there are 2 SOX critical beliefs and 8 non-SOX critical ones)
SOX compatibility valuation	(NA) does not apply
Quality valuation	It does not penalize, but it is a convenient belief. Valuation inside the range [0, 10] (+10/9) for each one of the 9 different selection aspects of this belief is taken into consideration

Table 12: Facts Scoring Matrix.

Agent's facts scoring matrix over the suppliers selection process	SOX compatibility valuation weight (value)	Quality valuation of the suppliers selection process weight (value)
(1) Fact corresponding to the belief 1	[1 or 0] [T or F or NA]	w12 V12
(2) Fact corresponding to the belief 2	[1 or 0] [T or F or NA]	w22 V22
(3) Fact corresponding to the belief 3	[1 or 0] [T or F or NA]	w32 V32
⋮	⋮	⋮
(N) Fact corresponding to belief N	[1 or 0] [T or F or NA]	wn2 Vn2
	V.SOX_COMP = [T OR F] (Intra-agent SOX inference rule)	V.quality = P12 V12 + P22 V22 + P32 V32 + ⋯ + Pn2 Vn2

pe_t^{e1e2} represents the previous experience and will exist just in case there is a previous learning factor for those specific pieces of evidence $e1$ and $e2$, in a previous instant before t. If that is the case, the specific activation factor α_t^{e1e2} will be 1:

$$\mathrm{pe}_t^{e1e2} = \begin{cases} 1 & \text{if } \alpha_t^{e1e2} = 1 \text{ and } \exists\, \mathrm{lf}_i^{e1e2} = 1,\ i \in \{1, \ldots, t-1\}, \\ 0 & \text{if } \alpha_t^{e1e2} = 1 \text{ and } \exists\, \mathrm{lf}_i^{e1e2} = 0,\ i \in \{1, \ldots, t-1\}. \end{cases} \tag{8}$$

This factor represents as well the accumulated experience in the past:

$$\mathrm{pe}_t^{e1e2} = \mathrm{lf}_{t-1}^{e1e2}. \tag{9}$$

As we have indicated before, this protocol handles fuzzy knowledge letting us to approximate the pieces of evidence ($e1$, $e2$) by similar but not equal pieces of evidence ($e1'$, $e2'$) from the past. This is managed under the term similar experience (se_t^{e1e2}), and this lets us to approximate $e1$ and $e2$ by $e1'$ and $e2'$ only after a specific previously defined threshold ϕ (degree of certainty)

$$\mathrm{se}_t^{e1e2} = \mathrm{lf}_t^{e1'e2'}, \quad \text{if } \mu_{e1'}^{e1} > \phi,\ \mu_{e2'}^{e2} > \phi. \tag{10}$$

Last but not least is the human expert indicator he_t^{e1e2} that will be activated by its activation factor just in case there is no previous experience (equal or similar) available for indicated pieces of evidence in previous instants of time. This human expert factor will be 1 just in case the human expert indicates a positive SOX compatibility and 0 if negative SOX compatibility is determined:

$$\mathrm{he}_t^{e1e2} = \begin{cases} 1 & \text{If } \gamma_t^{e1e2} = 1 \text{ and positive SOX compatibility is determined by the human expert for both } e1 \text{ and } e1 \text{ pieces of evidence,} \\ 0 & \text{If } \gamma_t^{e1e2} = 1 \text{ and negative SOX compatibility is determined by the human expert for both pieces of } e1 \text{ and } e2 \text{ evidences.} \end{cases} \tag{11}$$

Our original learning factor expression can be shown as well like

(1)

$$\text{If } \alpha = 1 \Longrightarrow \beta = 0 \text{ and } \gamma = 0 \text{ then } \mathrm{lf}_t^{e1e2} = \alpha_t^{e1e2} \cdot \mathrm{pe}_t^{e1e2}. \tag{12}$$

(2)

$$\text{If } \alpha = 0 \text{ and } \phi = 100\% \ (\beta = 0) \Longrightarrow \gamma = 1 \quad \text{then } \mathrm{lf}_t^{e1e2} = \gamma_t^{e1e2} \cdot \mathrm{he}_t^{e1e2}. \tag{13}$$

Table 13: Facts Scoring Matrix of the Suppliers Selection Process.

Suppliers selection	SOX compatibility valuation weight (value)	Quality valuation of the suppliers selection process weight (value)
(1) Participant suppliers	1 (v)	0.5/2 (v)
(2) Agreement of confidentiality	1 (v)	0.5/2 (v)
(3) RFI request for information	0 (NA)	0.5/8 (v)
(4) Financial analysis	0 (NA)	0.5/8 (v)
(5) Followed selection process	0 (NA)	0.5/8 (v)
(6) Structure and organization of the supplier	0 (NA)	0.5/8 (v)
(7) Technical capability	0 (NA)	0.5/8 (v)
(8) Level of prices	0 (NA)	0.5/8 (v)
(9) Quality security and processes	0 (NA)	0.5/8 (v)
(10) Flexibility and risks management	0 (NA)	0.5/8 (v)

Table 14: Agent's hypothesis.

	Individual hypothesis
(1) Agent of suppliers selection	H1: the Suppliers Selection Process followed in the analyzed business case complies with the SOX regulation

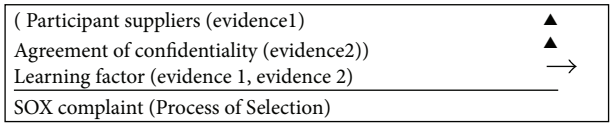


Figure 2: Main rule.

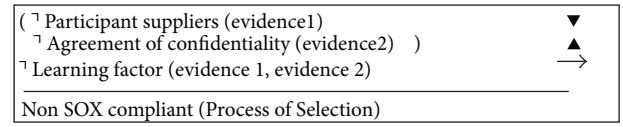


Figure 3: Complementary rule.

This protocol lets us as well work with no risk, with no fuzzy knowledge leaving the full responsibility of noncrystal clear decisions to the human expert. To do this, we only need to establish our working degree of certainty as 100%. If we do this, we have the following:

$$\phi = 100\% \Longrightarrow \beta_t^{e1e2} = 0. \tag{14}$$

And developing the learning factor initial expression we get the following:

$$\begin{aligned}
\mathrm{lf}_t^{e1e2} &= \alpha_t^{e1e2} \cdot \mathrm{pe}_t^{e1e2} + \beta_t^{e1e2} \cdot \mathrm{se}_t^{e1e2} + \gamma_t^{e1e2} \cdot \mathrm{he}_t^{e1e2},\\
\mathrm{lf}_t^{e1e2} &= \alpha_t^{e1e2} \cdot \mathrm{pe}_t^{e1e2} + \gamma_t^{e1e2} \cdot \mathrm{he}_t^{e1e2},\\
\mathrm{lf}_t^{e1e2} &= \alpha_t^{e1e2} \cdot \mathrm{lf}_{t-1}^{e1e2} + \gamma_t^{e1e2} \cdot \mathrm{he}_t^{e1e2},\\
\mathrm{lf}_t^{e1e2} &= \alpha_t^{e1e2} \cdot \left(\alpha_{t-1}^{e1e2} \cdot \mathrm{pe}_{t-1}^{e1e2} + \gamma_{t-1}^{e1e2} \cdot \mathrm{he}_{t-1}^{e1e2}\right)\\
&\quad + \gamma_t^{e1e2} \cdot \mathrm{he}_t^{e1e2},\\
\mathrm{lf}_t^{e1e2} &= \alpha_t^{e1e2} \cdot \left(\alpha_{t-1}^{e1e2} \cdot \mathrm{lf}_{t-2}^{e1e2} + \gamma_{t-1}^{e1e2} \cdot \mathrm{he}_{t-1}^{e1e2}\right)\\
&\quad + \gamma_t^{e1e2} \cdot \mathrm{he}_t^{e1e2},\\
\mathrm{lf}_t^{e1e2} &= \alpha_t^{e1e2} \cdot \left(\alpha_{t-1}^{e1e2} \cdot \left(\alpha_{t-2}^{e1e2} \cdot \mathrm{pe}_{t-2}^{e1e2} + \gamma_{t-2}^{e1e2} \cdot \mathrm{he}_{t-2}^{e1e2}\right)\right.\\
&\quad \left. + \gamma_{t-1}^{e1e2} \cdot \mathrm{he}_{t-1}^{e1e2}\right) + \gamma_t^{e1e2} \cdot \mathrm{he}_t^{e1e2}\\
&\quad \vdots
\end{aligned} \tag{15}$$

And generalizing this development, we get the following expression that represents the accumulated learning experience via propagated past experiences or via consultation to the human expert. The consultation to the human expert in a specific instant of time for a pair of specific evidence $e1$ and $e2$ is propagated to the future via (pe) previous experience factor and will let us reuse this specific consultation in similar future cases:

$$\mathrm{lf}_t^{e1e2} = \sum_{i=2}^{t} \prod_{j=i}^{t} \alpha_j^{e1e2} \cdot \gamma_{i-1}^{e1e2} \cdot \mathrm{he}_{t-1}^{e1e2}. \tag{16}$$

This expression represents the learning factor model (without fuzzy knowledge, with 100% of certainty) here proposed and will take value 1 in case of positive SOX compatibility and 0 in case of negative SOX compatibility. This value will come via accumulated past experiences or via consultation to the human expert.

The following diagram represents this learning process and it will only be used when the static knowledge or the base beliefs establish a negative SOX compatibility. The learning process consists of checking the previously managed business cases by this agent and is based on the pieces of evidence provided by the present business case; see if there were cases in which the human expert indicated under a similar

situation, a positive SOX compatibility. Otherwise, it will mean that there is not previous experience and the protocol will step to consult the human expert with the evidence provided by this business case.

Human expert based on knowledge of this matter and based on knowledge of court specific resolutions will determine if there is or not a positive SOX compatibility. Just in case of a positive SOX compatibility, this compatibility will solve the present process of our business case, and at the same time it will increase our agent's knowledge for similar future cases, storing this decision in the dynamic knowledge base. Figure 4 describes more in detail this protocol.

The agent by itself and based on its experience over several analyzed business cases will grow up in knowledge and will fine tune its final conclusions. This part of agent learning begins to be useful during a massive use of the system with a big number of business cases and where specific cases show complex situations that come out the static SOX regulation and where specific control organisms and courts need to take SOX compliant decisions that will be taken into consideration as precedents for future similar cases or situations.

These kind of resolutions over exceptional situations not covered by the static SOX regulation will generate a jurisprudence base which experts can consult and apply using the learning protocol here described. At the same time the agent using this protocol is able to assimilate and add those resolutions to its initial knowledge growing in terms of knowledge.

There are several recent researches [38–43], where it has being shown the need to design multiagent systems able to adapt to the changes happened in their closed environment. With this Learning Protocol our model follows this tendency being able to adapt to legislation changes and to exceptional situations too.

4. Integration with a Higher Level Multiagent Intelligent System

Kakas et al. [44] stated that the communication protocols between the agents of the systems should be defined in advance and customized taken in mind the objectives of the agents both infidel and global ones.

The idea is to model each key process of the Purchasing Cycle with a dedicated agent which individual objective will be to determine its SOX compatibility, and all together in cooperation will discuss about the common objective to determine if the full Purchasing Cycle is or not SOX compliant.

To make this possible, it is needed that all agents establish a Mutual Shared Communication Protocol in which they will cooperate together looking for a final decision about the SOX compatibility of the full Purchasing Cycle. After this Mutual Shared Communication Protocol, the agents together as a hole multiagent system will take the final decision with the Conclusive Inter-Agent Cooperative Decision Making Protocol.

Rodríguez et al. [45] reflects the fact that a good coordination is needed to let individual agents cooperate together to reach the global objective on top of the individual ones. Here, in our model, this coordination is implemented via indicated Mutual Shared Communication Protocol.

4.1. Mutual Shared Communication Protocol. Deliberative communication among agents is a key element in multiagent technology to let the full system evolve towards a common agreed decision or step in its way to reach the final objective [46, 47].

This section is dedicated to the Mutual Shared Communication Protocol, in which the Supplier Selection Agent will carry out a proposal towards the rest of the agents that compose the multiagent system. This proposal will consist of proposing that the Suppliers Selection Process, based on the data obtained after having interrogated and analyzed the business case, is or not compatible with the SOX regulation (Figure 5).

As being answered, each of the other agents will send to this agent during the deliberation process an attack message, contradicting its proposal, or a support message, supporting it. Veenen and Prakken in 2005 (Veenen J., Prakken H., 2005) proposed a model in which agents are able to reject the original proposal at the same time they give a justified reason about it.

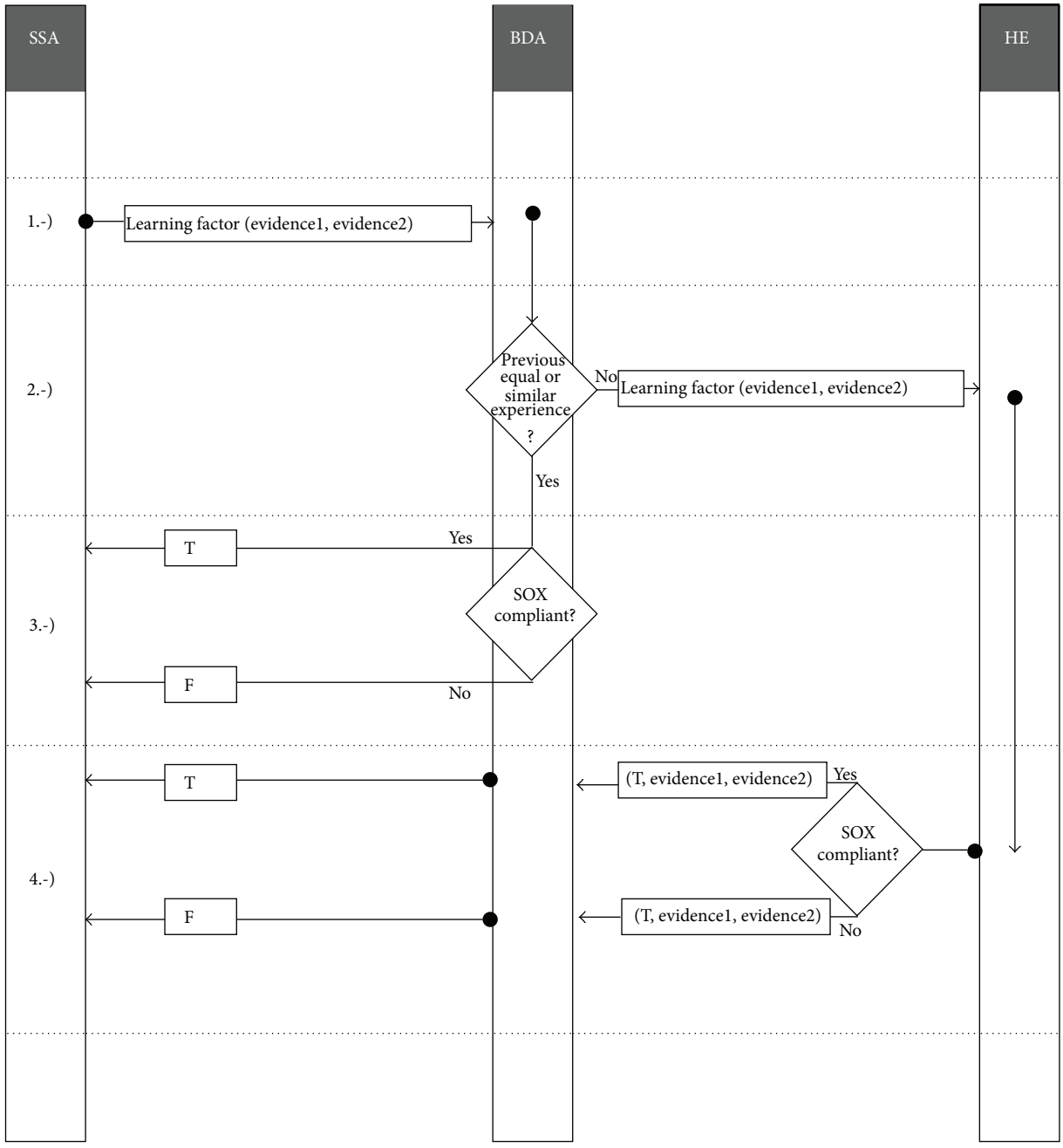
The attack message that an agent will answer to another with the objective of contradicting its initial proposal will consist of sending an opposite message to the one proposed. That is to say, if a SOX compliant (compatible with the SOX regulation) was proposed, a non SOX compliant (not compatible with the SOX regulation) would be answered. If a non SOX compliant is proposed, a SOX compliant would be answered.

The support message that an agent will answer to another with the objective of supporting its initial proposal will consist of sending a message that reaffirms and supports the agent's proposal. That is to say, if a SOX compliant was proposed, a Sox compliant would be answered and if a NON_SOX_COMPLIANT was proposed, a non SOX compliant would be answered (Figure 6).

At the end of this protocol, and after all the agents in an individual way have decided about the compatibility or not with the SOX regulation of their process, the system will be in a stage in which all the agents know the results or individual decisions are made by the rest of agents.

There are in the literature several studies [48–50] showing the fact that multiagent systems need a higher level of organization to coordinate all the agents of the system. The Mutual Shared Communication Protocol proposes a parallel alternative in which all the agents share its individual findings among the rest of the agents of the system with final idea that in a further phase all those agents together will use this shared knowledge to find a common agreed decision about the final compatibility over the full Purchasing Cycle.

4.2. Inter-Agent Cooperative Decision Making Protocol. Here the basic idea of this protocol is described. The objective is to demonstrate if the analyzed business case is SOX compliant or not.

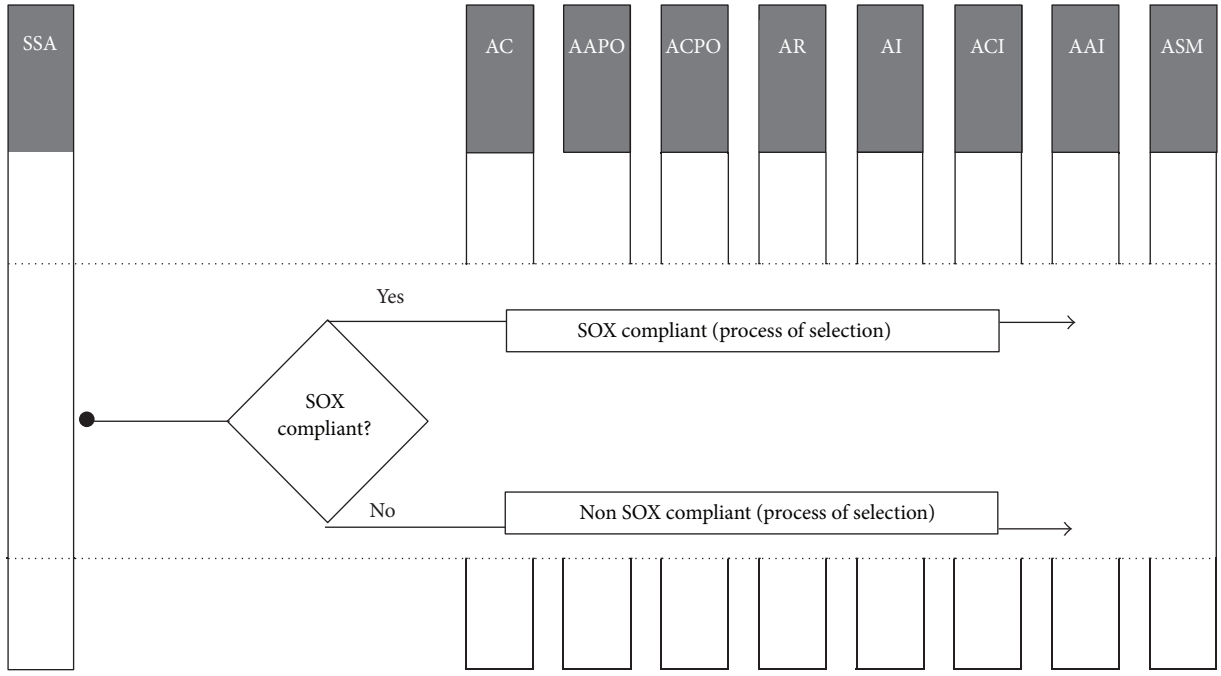


SSA: suppliers selection agent
BDA: base of dynamic knowledge of the agent
HE: human expert

Figure 4: Dynamic Fuzzy Learning Protocol.

This can be done using classical logic and we determine that just in case all the involved processes of the Purchasing Cycle are SOX compliant, then the full Purchasing Cycle should be as well SOX compliant. With this approach each of the agents involved in the Purchasing Cycle combines its specific initial objective with the common shared objective of the full multiagent system.

Morge and Mancarella [51] proposed an argumentation model in which conflicts are solved based on the arguments that justify each possible action. With this Inter-Agent Cooperative Decision Making Protocol, even although each agent could have a different opinion about the SOX compatibility, a final common share decision is taken among all the agents that conform the full system.



A0 = agent of suppliers selection agent = SSA
A1 = agent of suppliers contracting = AC
A2 = agent of approval of purchase orders = AAPO
A3 = agent of creation of purchase orders = ACPO
A4 = agent of documentary receipt of orders = AR
A5 = agent of imports = AI
A6 = agent of checking of invoices = ACI
A7 = agent of approval of invoices without purchase order = AAI
A8 = agent of suppliers' maintenance = ASM

Figure 5: Mutual Shared Communication Protocol.

5. Case Study

Here it is presented a real business case study in which proposed model was applied during Suppliers Selection Process. This business case was a real project happened in a European country in 2010 and covered all needed tasks to replace the radio network elements of one specific mobile telecommunications operator in one country for similar equipment of another manufacturer.

There were twenty different companies invited to Suppliers Selection Process. All those companies were invited to participate on Suppliers Selection Process to select a group able to implement the project with quality and in reasonable time. Competition was done over four phases of requests for quotations, where it was given detailed information of the project to the invited companies, and at the same time some discounts were requested till an acceptable level of pricing. With the information gathered during these four phases, the selection process was carried out, in which, all those aspects and details needed to take the final selection were kept in mind besides the economic approaches. At the end of the competition between all the initial 20 invited companies, only 5 were selected.

6. Results

Here it is shown the results obtained after applying the proposed model to the previously explained real business case. The following table summarizes the results of the first two protocols: (1) Facts Searching Discussion Protocol and (2) Facts Scoring Protocol (Table 15).

According to the Facts Scoring Protocol based on the agent's beliefs, between all beliefs of the agent's static knowledge, there are only two that are decisive for the SOX

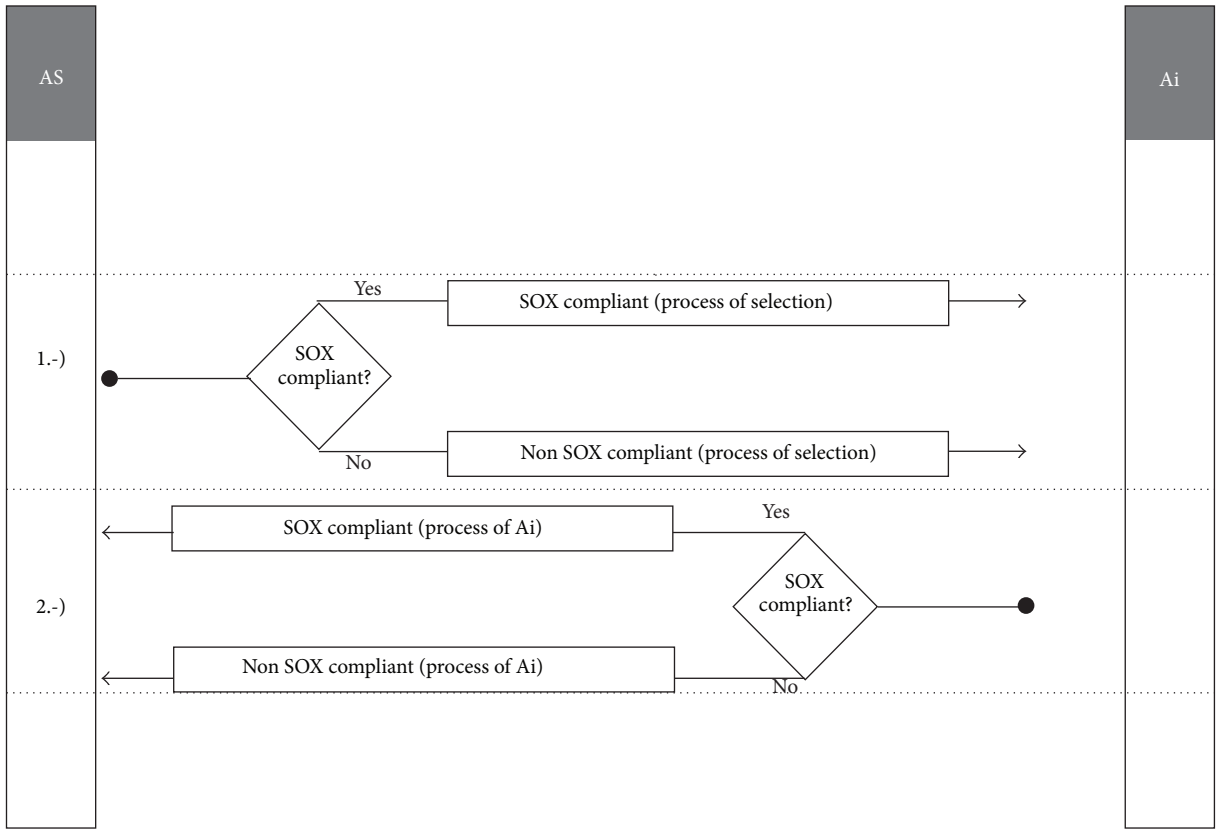


Figure 6: Mutual Shared Communication Protocol (question and answer).

compatibility. These are (1) participant suppliers and (2) agreement of confidentiality. These two together with the other ones determine the quality of the followed process in the suppliers selection of the analyzed business case.

From quality point of view all the key facts of the business case have obtained the maximum value as indicated in Table 16, and according to the weight factors, the final punctuation has the maximum value too.

From SOX compliance point of view, both relevant SOX facts have obtained a true value according to the Facts Scoring Protocol.

About the SOX key fact "participant suppliers" there were twenty invited suppliers to the Supplier Selection Process in this business case. From SOX compatibility point of view, it is verified that the number of invited suppliers to the competition was enough to generate competitiveness and had enough alternatives to select the suppliers.

About the SOX key fact "agreement of confidentiality", there was an agreement of confidentiality signed with all the invited companies; it means that this fact is compatible with the SOX regulation.

The valuation of both key SOX facts is the input for the Deductive Decision Making Protocol during the conclusive individual phase of the agent (Figures 7 and 8).

According to the Deductive Decision Making Protocol, the first two antecedents of the main rule are true, and therefore it is not necessary to appeal to the third antecedent

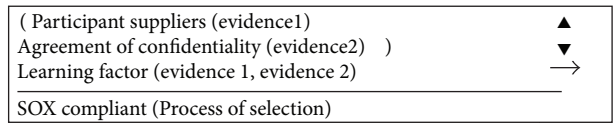


Figure 7: Suppliers Selection Process. Deductive Decision Making Protocol.

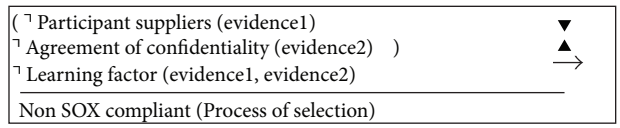


Figure 8: Suppliers Selection Process. Deductive Decision Making Protocol, Complementary Rule.

(learning factor) to be able to conclude that SOX compliant (Process of selection) is true. The previous reasoning process, based on the agent's static knowledge, has been able to state that the followed Suppliers Selection Process is compatible with the SOX regulation, and past experiences and human expert knowledge are not needed to make the decision.

In this case the agent and their static knowledge have been enough to reach the conclusion. This fact is positive in the sense that the process has followed the SOX legislation rigorously (Table 16), but on the other hand, it has not allowed

Table 15: Agent's facts scoring matrix over the business case facts based on its beliefs.

Agent's facts scoring matrix over the suppliers selection process facts	SOX compatibility valuation weight (value)	Quality valuation of the supplier selection process weight (value)
(1) Participant suppliers	1 (T: true)	0.5/2 (10)
(2) Agreement of confidentiality	1 (T: true)	0.5/2 (10)
(3) RFI request for information	0 (NA)	0.5/8 (10)
(4) Financial analysis	0 (NA)	0.5/8 (10)
(5) Followed selection process	0 (NA)	0.5/8 (10)
(6) Structure and organization of the supplier	0 (NA)	0.5/8 ((10/10) 10)
(7) Technical capability	0 (NA)	0.5/8 ((10/8) 8)
(8) Level of prices	0 (NA)	0.5/8 ((10/6) 6)
(9) Quality security and processes	0 (NA)	0.5/8 ((10/7) 7)
(10) Flexibility and risks management	0 (NA)	0.5/8 ((10/9) 9)
	SOX compatibility valuation	Quality valuation of the supplier selection process
		= 2.5 + 2.5 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 = 10

Table 16: Agent's hypothesis.

	Individual hypothesis
(1) Agent of suppliers selection	H1: the Suppliers Selection Process followed in the analyzed business case complies with the SOX regulation

the agent to be able to learn, to be able to increase its dynamic knowledge. Finally, the present agent concludes that the followed Process of Suppliers Selection of the analyzed business case is SOX compliant.

Nowadays and in relation to the model here designed, after revising different international bibliographical sources and up to the best of our knowledge, it isnot found any publication that uses Multiagent Systems and Argumentation Theory in the implementation of SOX internal controls with the objective to identify if the Supplier Selection Process of a specific business case is or not compatible with the SOX Law supporting auditors and companies to take their appropriate decisions about this SOX compliance. Due to it, trying to compare our model with other existing models, although it was not possible to identify similar existing models, we have tried to select models that at least use similar technologies to the one here presented.

ARGUGRID is an existing model designed under the sixth R&D framework program of the European Union with its main focus on e-business area and using Multiagent Systems and Argumentation Theory as its main technology. Table 17 shows the comparison of both models taking into consideration several relevant features.

7. Conclusions

The problem described before is a decision making problem with the following main characteristics.

(1) Decision making problem: at the end, it is needed to take a decision about the compatibility or not of the specific business case with this law.

(2) Decision based on evidence: those pieces of evidence will be the support of the decision and will be the probe towards auditors and control organisms.

(3) Needed initial expert nonstandardized knowledge: this law states what should be done but not how should be done. This means that the source of the initial knowledge should be a human expert with enough experience in driving business cases inside a SOX compliant state.

(4) Being able to learn from present court resolutions to be able to use this extra knowledge in the future: some kind of learning method is needed to let the initial knowledge evolve and grow far beyond its initial state.

This law affects whatever economical or financial major process in a company, like for example purchasing cycle, financial cycle, or sales cycle. Those major cycles are divided in different processes. For example, purchasing cycle can be divided in suppliers' selection process, suppliers contracting process, approval of purchase orders, and so on. This kind of structure can be very well modeled with a Multiagent System (MAS) structure. Taking in mind as well that the final decision should be based on evidence, the Argumentation in combination with MAS is an optimal approach to model this kind of problems.

Present existing models using this kind of techniques like MAS and Argumentation show limitations like the following.

(1) They are being designed mainly to solve other type of problems like medical, legal, negotiations, trading, education, or e-business (COSSAC, CARNEADES, AAC, TAC, INTERLOC, ARGUGRID).

Table 17: Comparison of proposed model versus argugrid.

Compared features	ARGUGRID[1]	Suppliers selection intelligent expert system
Argumentation oriented	*	*
Structure dialog between agents	*	*
Interagent reasoning	*	*
Decision making between agents	*	*[2]
Multiagent architecture	*	*[3]
Client (questions) and server (answers) agents structure	*	*[4]
Agents sharing knowledge to make automatic reasoning	*	*
Deductive decision engine based on previously defined criteria	*	*
Predefined syntactic and semantic elements	*	*
Support for auditors		*
Support for top company management		*
Communication via Facts Searching Discussion Protocols		*[4]
Deductive oriented		*
Dynamic knowledge fuzzy learning		*[6]
Expert system		*
Facts Scoring Protocol based on human expert knowledge base		*[7]
Financial oriented		*
Logic oriented		*
Initial existing human expert knowledge		*[8]
Inference oriented		*
Internal Agent Decision Making Engine		*[9]
Mutual shared communication among agents		*[10]
Quality approach		*
SOX oriented		*

*Feature supported.
[1]ARGUGRID: www.argugrid.eu.
[2]Feature provided by Deductive Decision Making Protocol.
[3]Feature provided by the integration with a higher level Multiagent Intelligent System.
[4]Feature provided by Facts Searching Discussion Protocol.
[6]Feature provided by Dynamic Fuzzy Learning Protocol.
[7]Feature provided by Facts Scoring Protocol.
[8]Feature provided by Original Starting Know-How of the Agent.
[9]Feature provided by the Inter-Agent Cooperative Decision Making Protocol.
[10]Feature provided by the Mutual Shared Communication Protocol.

(2) They do not have an initial expert based on SOX compliant knowledge.

(3) They do not have a learning method able to incorporate court resolutions to the initial knowledge base.

The model here presented is a *novel approach* to solve this kind of problems due to the fact that it has *an optimized structure* to solve this specific problem, incorporates an *initial expert knowledge* base coming from the experience of a human expert, and incorporates a specific *dynamic fuzzy learning protocol* to add present court resolutions to the initial knowledge base, letting the system *evolve* far beyond its initial knowledge state and letting the system increase its efficiency as the times goes on based on its *accumulated experience*.

Disclosure

The content of this paper reflects only the opinion of the authors with independence of their affiliations. The authors do not have a direct financial relation with the commercial entities mentioned in this paper.

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