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Implementing a fuzzy expert system for ensuring information technology supply chain

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Abstract

In the business environment, information technology (IT) plays an important role for firms' performance. It provides information flow that makes the supply chain more robust and resilient without undermining its efficiency. Smart systems use artificial intelligence methods for solving problems and facilitating decision-making through rule-based deduction. Accordingly, these systems can present specialists' skills and simulate their thinking process. The primary goal of expert systems is to implement knowledge acquisition process by converting knowledge to wisdom. This process is vital for critical decision-making regarding important issues such as determining necessities of a particular contract. Companies use professional liability insurance of the products and services to ensure the purchasers and prevent potential losses. Although this practice is highly prevalent, there is not any particular procedure for measuring necessities of contracts. The main purpose of this paper is to design a fuzzy expert system for measuring the necessities of professional contracts regarding insurance coverage and improve the supply chain management using IT. This system can measure and report these obligations, considering specifications of each project. Taking into perspective variety of professional services/products, we consider software as a type of professional contracts, extract its important indices and give it to the system as the input. After the necessary stages, the system produces a proper response and presents the generated response to the user. The software of this expert system is web based, and there are four operating layers in its architecture. We implemented this program in MS Visual Studio Framework with C#.NET programming language. Moreover, we implemented MS SQL-Server Database Management.

KEYWORDS

fuzzy expert system, inference engine, knowledge rule base, professional liability insurance, suppliers

1 | INTRODUCTION

One of the most important processes of designing expert systems is knowledge engineering. Knowledge engineering is a part of knowledge management process. Knowledge management is known as an evolving field that has currently attracted a plethora of attention (Mezher, Abdul-Malak, Khaled, & El-Khatib, 2009). This process includes many stages such as problem selection, knowledge collection, knowledge presentation, knowledge engineering, knowledge testing, and knowledge evaluation. Expert systems operations covers “identification” to “problem-solving” stages. (Shokouhyar, Ataafarin, & Tavassoli, 2017) The main steps in knowledge engineering are knowledge domain structuring, setting rules for proper access to knowledge, and transferring skills of specialized person to the expert system. It should be mentioned that one of the most important and challenging stages of creating such systems is the initial design stage.

Many studies have been conducted to present conceptual models of knowledge engineering, but none of these models have been used practically for the implementation of knowledge-based systems. Even Common KADs methodology, which was created for design and development of knowledge management system with object-oriented approach, is not particularly used of the implementation of knowledge-based systems. Today, with the emergence of concepts such as No SQL and Big Data, the proposed conceptual models no longer have sufficient efficiency due to the increasing volume of information. Consequently, researchers should help develop knowledge engineering and management practices by presenting new and efficient strategies. In order to exploit the benefits of knowledge-based expert systems, these developments should be in pace with the growth of the related knowledge and technologies in other fields. In this paper, we focused on insurance contracts in professional liability insurance section. Insurance means compensation for potential damages and protection from financial loss of the insured assets. The expert systems are abundantly applied in this study, detection and management of insurance risks. The most important applications are contract risk management, estimation of the incurring damages for compensation, compensation of premium based on specifications, crimes prevention, and work.

But none of the present papers is focused on expert systems for guiding decisions regarding professional insurance contracts, and most of them relate to other issues such as ensuring benefits of the insurance companies and preventing potential losses resulting from inaccurate calculations. Although professional liability insurance is executed in production and presentation of products and services in the advanced countries in the world, no system has been implemented and designed for deciding about the necessities of insurance contracts. Today, insurance of contracts is a common type of insurance. Employers and contractors insure the work contracts for different reasons such as compensation for damages resulting from performance or accidents; however, the present necessities of these contracts for insurance and their effect on risk management of the project is not estimated. In this field, even no research has been conducted to refer to. Decision-making about insurance coverage of contracts requires attendance and exchange of opinions of the experts in different fields because each of these contracts has different dimensions and indices. In this regard, experts of the related industries—insurance and finance sector—should achieve a final agreement over the extent to which each contract needs insurance coverage by studying all aspects. It is evident that it is not only impossible to gather these people to compromise on each contract but also extremely costly.

On the other hand, in literatures, the collaborative investment in information technology (IT) among supply chain management (SCM) has become a strategic thrust to achieve more transparent and supply chains (Zhou, 2009). With the increasing use of intelligent information systems such as expert systems and fuzzy systems and other enabling technologies, it has become possible now to create seamless supply chains linking suppliers to customers in order to eliminate poor performance of the suppliers, unpredictable customer demands, and uncertain business environment. Nevertheless, the investment required among supply chain stakeholders to adopt new IT often does not occur as a desired, even though such collaborative efforts can create unique value that a single firm cannot attain independently (Tseng, Wu, & Nguyen, 2011).

The main questions that we want to answer are as follows:

- How does an expert system decide about contracts' liability insurance?
- How does the system help suppliers and improve SCM?
- What specifications do main sections of the desired expert system such as knowledge rule base and inference engine have?
- How does the system measures the necessities of each contract?
- What are the affecting criteria on the software contracts, which need to be insured, and what are the related knowledge rules regarding this subject?
- What is the performance of inference engine, user interface, and other sections of this system?

Therefore, this research aims to design and implement a smart information system for making accurate comments on each contract. The system should put different aspects—the experts' points of view, the past successful/unsuccessful experiences, and the specifications of powerful insurance companies and qualified contractors in this field—into consideration. At first place, the system collects the information. Afterwards, the system will continuously update the information. Subsequently, the system compares the resulted output with the current knowledge base and will only add new rules to the knowledge rule base. With each project information entrance to the system, the knowledge rules will be enhanced permanently. We designed this system in a way that it is accessible from anywhere, and there is no need for each user to purchase, install, and support it. In addition to the introduction of primary concepts of the research including "application of the expert systems in insurance contracts," we studied "the necessities of using expert systems for insuring professional contracts." Subsequently, we elaborated the stages of designing and implementing a fuzzy expert system with the desired capability by reviewing the literature in this field and studying some examples of the similar expert systems. Finally, the authenticity of performance of the system is assessed by conducting a case study.

2 | RESEARCH BACKGROUND

2.1 | Expert systems in the SCM and insurance contracts

A supply chain is a system of organizations, people, activities, information, and resources involved in moving a product or service from supplier to customer. Supply chain activities involve the transformation of natural resources, raw materials, and of course information. There are plenty of researches about the role of SCM in companies and investment of IT in SCM. Researches presented the direct relationship between technology use in SCM. It was reported that organizations use IT more than the norm in their industry, achieving more operational benefits, such as reduced cost and cycle time. However, the effective between IT use and supplier network performance is moderated by industry clock speed (Tseng et al., 2011, Shokouhyar & Mansour, 2013).

Supplier selection is the process of selecting a supplier to acquire the necessary materials to support the outputs of organizations. Selection of the best and/or the most suitable suppliers is on the basis of assessing supplier capabilities. To survive in the intensely competitive global economy, it is often critically important not only to develop existing suppliers but also to discover new suppliers. This section outlines the process of finding viable new suppliers. Beil and Ross (2010) and Shokouhyar, Safari, and Mohsenian (2018) reported that organizations use IT more than the norm in their industry, achieving more operational benefits, such as reduced cost and cycle time. However, the effective between IT use and supplier network performance is moderated by industry clock speed.

By applying fuzzy processors in an expert system, a system was generated in order to assess individuals' health. This system helps insurance specialists in making decision about each life insurance case. This system makes comments on the acceptance of different life insurances and their prices by taking into account the physical conditions of individuals such as height and weight. Furthermore, the system also considers each person's habits such as exercising, eating, smoking, and drinking alcoholic beverages. The expert system receives the medical recommendations given to each patient and his conditions as input and makes comments on the validity of the recommendations. Subsequently, the system decides whether the insurance company should pay to each patient (Lipińska, Szydło, & Lipiński, 2009). A knowledge rule-based system helps improve decisions about life insurance with fuzzy processing by assessing risks (Montequin, Cousillas, Alvarez, & Villanueva, 2016). Another expert system is suggested for recognizing group violations in automotive insurance and its consequent researches (Šubelj, Furlan, & Bajec, 2011). We utilized a fuzzy logic controller model to determine the doubtfulness of the requested cases of automotive insurance (Stefano & Gisella, 2001). It gives justification of application of the expert systems in increase of productivity and effectiveness of risk management in life insurance. The expert systems are highly important in investigation and detection of the life insurance risks.

2.2 | The reasons for using expert systems in insurance industry

Nowadays, insurance companies operate in a highly competitive environment. (Yeo & Smith, 2003). Although professional liability insurances are common in the advanced countries in the world, there is no standard method to analyse these contracts with respect to the cost effectiveness of each case.

Making decision about insurance coverage of professional contracts requires attendance and exchange of opinions of the experts in various areas. The utilization of similar experiences and cases in this field can be useful. In this sector, dimensions of projects and ability of the producers and suppliers of products and services depend on many variables; therefore, one cannot make similar standard comments on all contracts. Therefore, the proposed strategy in this research is to use a fuzzy expert system for making accurate and standard comments and recommendations in this field. In this regard, this system can be suitable for different types of professional contracts for making comment on different cases in variety of contexts by changing the content of knowledge rule base of the system.

2.3 | The reasons for insuring IT contracts

The growing use of IT and its undeniable impact on the performance of other activities in economic, social, cultural, and political fields has led the success or failure of the industry's products and services to be directly effective on the related industries and services, and this dependency will increase the risk taking of IT products and services.

Studies show that 75% of IT projects fail in the world. The majority of projects costs reach to the projected level of 200%. Thirty-one percent of projects fail during operation, and 53% of finished projects meet only 61% of their basic needs (Montequin et al., 2016). According to the recent studies of IBM, only 40% of projects are finished on their estimated deadlines and within the specified budget (Dorsey, 2000).

Standish Journal reported that 65% to 80% of IT projects fail to achieve their goals (Dorsey, 2000). Researchers report on IT projects in America: Over 50% of projects have 189% budget increase and they have 222% time delay. Only 16% of projects were conducted under the specified time and budget (Sutton, 2010). Clearly, the respective risk of larger projects is higher. In this article, we consider large-scale projects of a large company.

National Iranian Copper Industries Company (NICICO) held a tender in order in 2002, in order to find a complete Enterprise resource planning (ERP)/ERPII solution to implement throughout the company, replacing the legacy information systems. ERP is the integrated management of core business processes, often in real time and mediated by software and IT. Despite all the efforts, no integrated system has been deployed in NICICO yet. As a result, NICICO incurred losses were high. It was possible preventing the damage if there were a predefined procedure or strategy to predict the risk of such investment at the beginning. One of the ways to manage such risks is the use of information liability insurance in the field of IT that is very common in America and Australia.

3 | LITERATURE SURVEY

In many consultation environments, any expert system can be used as a knowledge-based consultation system by replacing the knowledge base of an expert system with that of a medical, judicial, or sport system. A web-based fuzzy expert system has been designed as an educational consultant to help students solve their decision-making problems during their studies. Most of the students should take the credit to enrol in each semester, considering the educational records and educational laws. Because these laws are changing regularly, it is difficult to make decisions for students without the help of the educational specialists who are adept at laws and regulations. In addition, the educational records of each student is different, and decision parameters about different students are not the same. (Huang, Chen, Kuo, & Jeng, 2008).

Many companies have created a rule-based expert system to assess profit and life, disability, and death insurance risks. Imriyas (2009) concluded that the performance of expert system is a function of organization's strategy and is created with respect to the primary goals of the organization, customers, products, or services.

Researchers have emphasized on the use of fuzzy inference systems for risk assessment in banking, medical, and health industry (Sreekantha & Kulkarni, 2013). Table 1 shows a summary of the literature in the field of application of the expert systems and decision support systems in insurance industry.

To the best of our knowledge, no one has presented a framework for using expert systems in making primary decisions regarding professional insurance coverage contracts. Past researchers have mostly delt with issues such as correct estimation of premium, prevention of potential crimes, protection of benefits of the insurance companies, and prevention of potential problems resulting from inaccurate calculations.

The professional liability insurance is applied to reduce the loss of the insured in the professional contracts and to help supplies at the beginning of the section "review of literature." Policyholders insure many products and services, but in some cases, the insured items are of particular importance.

4 | SYSTEM OVERVIEW

4.1 | System mechanism

The primary knowledge, which is available to the knowledge engineer through admin section, is entered to the system manually. A knowledge engineer can design and create some pages for displaying the knowledge in the system to observe knowledge rules in the system through it. The user inserts final/numerical responses in the login form. The input information is transferred to the working memory, and the linguistic and fuzzy values of inputs and outputs are displayed on the output page. Here, the user can observe system recommendations regarding the necessity of contract insurance on the same page by pressing final output display button.

Figure 1 shows the architecture of system.

Four operating layers of the system are as follows:

- User Interface Layer as the web forms for the entry of information and observation of system responses.
- System rules layer, which includes control classes, operating methods, and system processes.
- Data Access Layer, which includes special classes.
- Database

In some researches, there are two general stages of system design and decision-making (Cebeci, 2009). The stage of system design includes several activities such as the determination of decision-making criteria, the design of fuzzy sets, and the explanation of rules for the fuzzy expert system. In the decision-making stage, the inputs should pass the ordinary cycle of each expert system to be converted into the required certain output (Cordona, Gomideb, Herreraa, Homannc, & Magdalenad, 2004; Pajak, 2015). Many papers have focused on the methods of selecting criterion/indices and subcriterion/indices, weighting them, and statistical methods of computations (Guedes Soares & Kolev, 2008; Piegat, 2006). A decision support system includes four main sections, which are different from main sections of an expert system. For example, an important section, called model base, is found in addition to the knowledge base, which can be regarded as a part of the inference engine in the expert system (Chang, Hung, Yen, & Tseng, 2009).

To conduct a more accurate study, we limited the study domain to the software projects. Accordingly, we can extract indices. Two main sections are available in this research. In the first part, all types of potential damages in the software production/presentation projects and their compensation methods are raised by insurance. Then how to design and implement the fuzzy expert system is described. In order to collect knowledge, it is necessary to study documents relating to the subject of the research. In addition, it is essential to interview with IT and particularly software experts. In order to develop this system, some main steps are performed as follows:

- Identification of indices;
- Fuzzification of indices;
- Production of rules.

4.2 | Determining indices

We obtained the most important indices concerning software projects with respect to the conducted studies on factors affecting software contracts and also interviews with some of the experts in the academic fields and IT industry (Table 2). In this research, to reduce the number of states, we have produced 16 important subindices among 20 subindices. Thereafter, we designed and built the system according to these

TABLE 1 Results of the review of literature in the field of application of the expert systems and decision support systems in insurance industry

Row	Reference	Type of insurance	Subject matters	Research results	Development tools and medium
1	Carretero, 2003	Nonlife insurance industry	Return value to the policyholders	Improve the classical bonus-malus rating system	—
2	Lipińska et al., 2009	Medical insurance industry	Analysing data assisted by medical specialists	The system reduces costs and improves reliability of the insurance decision-making process	Clips, Lisp, Prolog, Aitech sphinx package (pc-shell)
3	Arora & Vij, 2012	Health insurance	Solving the classification problem in The sector of health insurance	Help the insurance seeker to identify the degree of risk he is having if he is not taking health insurance	Anfis (neuro-fuzzy inference system)
4	Šubelj et al., 2011	Automotive insurance	Detecting violators in automotive insurance	Identifying specifications of the people in violators group	The emphasis is over display of information on network and iterative assessment algorithm (IAA)
5	Stefano & Gisella, 2001	Insurance of all types of business –automotive insurance	Insurance violations in Italian labour market	Determining doubtfulness of the requested cases for performing inspection	Only the use of fuzzy logic controller (FLC) mentioned
6	Imriyas, 2009	Building construction projects' insurance	Advocates real-time assessments of project hazards, safety, market conditions and insurers' internal factors	Minimizing insurers' financial risks	—
7	Sreekantha & Kulkarni, 2013	Banking, medical and health insurance	Implementation of insurance risk assessment techniques	The use of fuzzy inference system in insurance applications	Use of fuzzy inference system mentioned
8	Aderina & Petruta, 2011	Agricultural insurance	Need for agricultural insurance expert systems	Development of agriculture, to the creation of insurance products tailored to farmers' needs	Corvid system

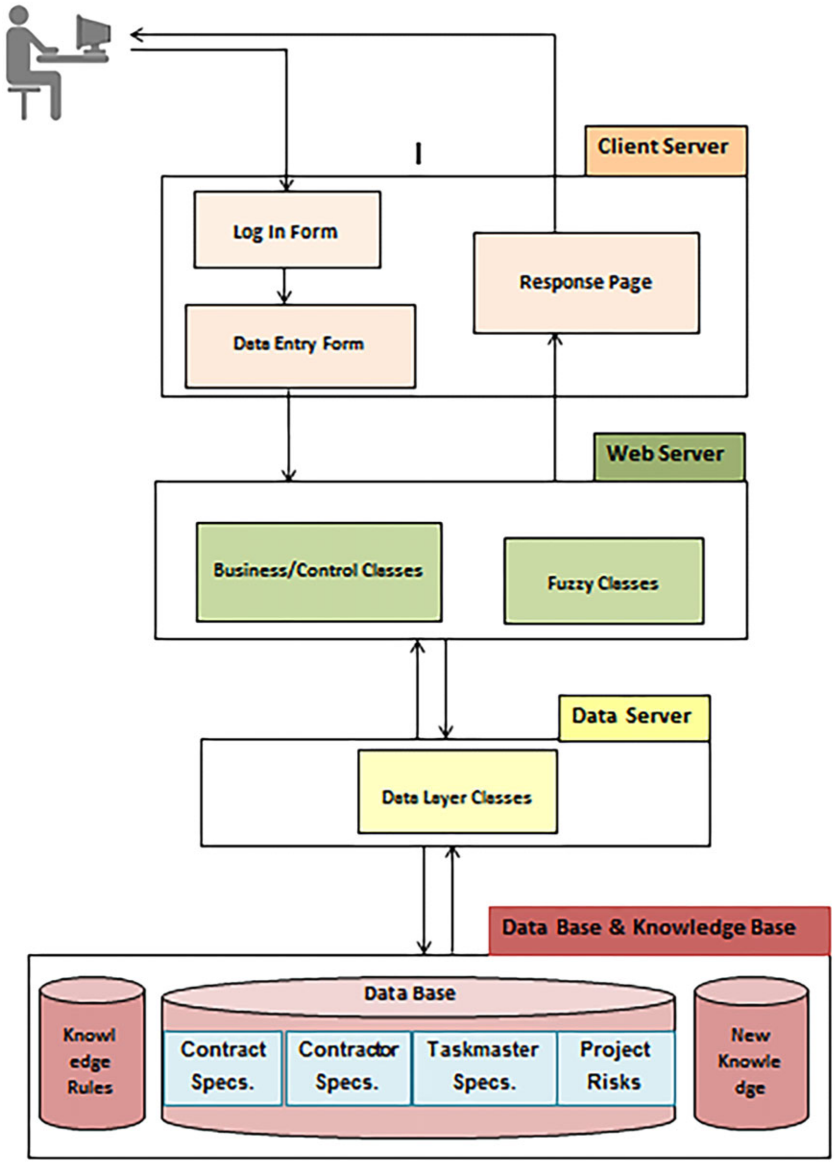

FIGURE 1 System architecture

subindices. These subindices are depicted in Table 3. After studying these factors, we divided these factors into four main groups—software projects risks, contractor's specifications, employer's specifications/workplace, and specifications of software contracts. These indices are the main input parameters of the system, and each of the four subindices has been formed.

4.3 | Explaining indices and subindices

- Contract specifications index includes the following subindices:

1. Contract Price (Lopez & Salmeron, 2014; Montequin et al., 2016; Ngai & Wat, 2003): The higher the contract price, the higher the sensitivity and risk-taking. Therefore, its insurance will be regarded as risk management to the employer and the contractor.
2. The number of system users: Higher number of users indicates the larger size of system. Extensive systems with more users are always exposed to human errors; therefore, more time should be spent on all types of tests during the production. As a result, production costs and the need for insurance coverage will increase.
3. Duration of the contract (Alami, 2016; Cebeci, 2009; Lopez & Salmeron, 2014): Long-term contracts are usually concluded for larger systems, with more details and more complicated production process. Duration of the contract increases the uncertainty. Insurance coverage can compensate this uncertainty to some extent.
4. Work quality/rank of the consultant and supervisor of the contract (Alami, 2016; Lopez & Salmeron, 2014; TechInsurance, 2010): Any professional contract needs a consultant or primary designer and the project needs at least one supervisor. The consultant of technical contracts supervises the execution of that contract. Therefore, it is evident that projects with more professional supervisors are executed with higher confidence factor. Supervision and consultation can lead to failure of the project. Therefore, it increases necessity of the contract insurance.

TABLE 2 Factors affecting each project/software contract

Row	Reference	Indices
1	Lopez & Salmeron, 2014; Ngai & Wat, 2003; Montequin et al., 2016	Price of contract (the contract cost)
2	Lopez & Salmeron, 2014; Montequin et al., 2016	The number of the system users
3	Alami, 2016; Lopez & Salmeron, 2014	Duration of the contract
4	Alami, 2016; Lopez & Salmeron, 2014	Work quality/rank of the consultant or supervisor of the project
5	Lopez & Salmeron, 2014; TechInsurance, 2010	Standard nature of the technical specifications of the contract
6	Lopez & Salmeron, 2014; Montequin et al., 2016; TechInsurance, 2010	Permissibility of change/increase of the needs of users during the project
7	Alami, 2016; Lopez & Salmeron, 2014; Montequin et al., 2016	Existence of relation between the final system and other systems in site of the employer
8	Alami, 2016; Lopez & Salmeron, 2014; Montequin et al., 2016	The presence of information conversion and transfer in the contract
9	Lopez & Salmeron, 2014	Type of contract: 1. Purchase, installation, and commissioning 2. Production of a new software
10	Alami, 2016; Lopez & Salmeron, 2014; TechInsurance, 2010	Predicting and analysing project risks in contract
11	Lopez & Salmeron, 2014; Cebeci, 2009	The number of contractor's personnel
12	Alami, 2016; Lopez & Salmeron, 2014; Montequin et al., 2016	The number of similar products sold by the contractor within the past 3 years
13	Alami, 2016; Montequin et al., 2016	Positive commercial record of the contractor (by giving good performance certificate)
14	Lopez & Salmeron, 2014	Work quality/rank of the contractor
15	Lopez & Salmeron, 2014; Cebeci, 2009	Financial condition of the contractor
16	Lopez & Salmeron, 2014	The relationship of users education with system
17	Lopez & Salmeron, 2014	The users experience in working with information systems
18	Lopez & Salmeron, 2014	The suitable software and hardware equipment for training users in site of the employer
19	Alami, 2016; Lopez & Salmeron, 2014; TechInsurance, 2010	Observance of quality management standards by employer
20	Alami, 2016; Lopez & Salmeron, 2014; TechInsurance, 2010	Awareness of senior manager to information systems
21	Alami, 2016; Lopez & Salmeron, 2014; TechInsurance, 2010	Permissibility of changing/increasing the users' needs during the project
22	Lopez & Salmeron, 2014)	Percent of the work performed by subcontractors
23	Alami, 2016; Lopez & Salmeron, 2014; TechInsurance, 2010	Business processes reengineering/modifying accomplished in the organization
24	Alami, 2016; TechInsurance, 2010	The extent to which the senior management supports the system establishment
25	Lopez & Salmeron, 2014	Readiness of the users for acceptance of new system
26	Lopez & Salmeron, 2014; TechInsurance, 2010; Yunusoglu & Selim, 2013	Allocation of resources to the project
27	Lopez & Salmeron, 2014	Documentation of requirements
28	Alami, 2016; Lopez & Salmeron, 2014; TechInsurance, 2010	Readiness of the system infrastructures

- Contractor specifications indices are as follows:

1. The number of contractor's personnel (Cebeci, 2009; Ngai & Wat, 2003): This factor indicates the commercial level of contractor. Bigger contractors are able to capture more markets by employing more professional staff. Therefore, the need for contract insurance has a reverse relationship with the number of contactor's personnel.
2. Work quality/rank of the contractor (Ngai & Wat, 2003): This index indicates the specialty and professional experience of the contractor. More experienced contractors have higher chance to gain better positions in the market. Like rank of the consultant/supervisor of the contract, high rank of contactor (in lower number ranking system) causes more assurance about correct and timely performance of the system, which lowers the need for contract insurance coverage.
3. The number of similar products sold by the contractor within the past 3 years (Alami, 2016; Montequin et al., 2016; Ngai & Wat, 2003): A greater number of sold products signals less risk. Therefore, it is evident that there is less need for insurance coverage of the contract.
4. Positive commercial records of the contractor (by giving good performance certificate; Lipińska et al., 2009; Montequin et al., 2016): Historical records and variety of the contractor's contracts do not necessarily indicate high quality of his performance. At the end of each contract, the employers issue good performance certificate for him. In the documents that the contactors present for introducing them to the next employers, these good performance documents have been issued.

TABLE 3 Knowledge base rules/relations between inputs and outputs of the system

Row	Main index	Subindices/outputs	Conditions of inputs (subindices) and outputs				
1	Contract specification	Contract price (thousand dollars)—crisp Price range—linguistic	Below 1 Very cheap	From 2 to 3 Cheap	From 4 to 5 Medium	From 6 to 7 Expensive	Above 8 Very expensive
Output of subindex 1		Insurance necessity—crisp Insurance necessity—linguistic	Below 10% Arbitrary	From 20% to 30% Useful	From 40% to 50% Necessary	From 60% to 70% Mandatory	From 80% to 100% Vital
2	Contract specification	Number of system users—crisp Extent of the system—linguistic	Below 10 Very low	From 20 to 30 Low	From 40 to 50 Medium	From 60 to 70 High	Above 80 Very high
Output of subindex 2		Insurance necessity—crisp Insurance necessity—linguistic	Below 10% Arbitrary	From 20% to 30% Useful	From 40% to 50% Necessary	From 60% to 70% Mandatory	Above 80 Vital
3	Contract specification	Duration of contract (month)—crisp Length of contract—linguistic	Below 6 Very short	From 12 to 18 Short	From 24 to 30 Medium	From 36 to 42 Long	Above 48 Very long
Output of subindex 3		Insurance necessity—crisp Insurance necessity—linguistic	Below 10% Arbitrary	From 20% to 30% Useful	From 40% to 50% Necessary	From 60% to 70% Mandatory	From 80% to 100% Vital
4	Contract specification	The presence/absence/rank of contract consultation—crisp Certainty about success of project—linguistic	Internationally valid (rank 1) Very high	Below 3 (2 or 3) High	Below 5 (4 or 5) Medium	Below 7 (6 or 7) Low	No rank Very low
Output of subindex 4		Insurance necessity—crisp Insurance necessity—linguistic	Below 10% Arbitrary	From 20% to 30% Useful	From 40% to 50% Necessary	From 60% to 70% Mandatory	From 80% to 100% Vital
5	Contractor specification	The number of contractor's personnel—crisp Ability to perform work—linguistic	Above 80 Very high	From 60 to 70 High	From 40 to 50 Medium	From 20 to 30 Low	Below 10 Very low
Output of subindex 5		Insurance necessity—crisp Insurance necessity—linguistic	Below 10% Arbitrary	From 20% to 30% Useful	From 40% to 50% Necessary	From 60% to 70% Mandatory	From 80% to 100% Vital
6	Contractor's specification	Work quality/rank of contractor—crisp Certainty about success of project—linguistic	Internationally valid (rank 1) Very high	Below 3 (2 or 3) High	Below 5 (4 or 5) Medium	Below 7 (6 or 7) Low	No rank Very low
Output of subindex 6		Insurance necessity—crisp Insurance necessity—linguistic	Below 10% Arbitrary	From 20% to 30% Useful	From 40% to 50% Necessary	From 60% to 70% Mandatory	From 80% to 100% Vital
7	Contractor's specification	The number of similar products sold by the contractor within the past 3 years—crisp Certainty about success of project—linguistic	Above 20 Very high	From 10 to 19 High	From 4 to 9 Medium	2 or 3 Low	0 or 1 Very low
Output of subindex 7		Insurance necessity—crisp Insurance necessity—linguistic	Below 10% Arbitrary	From 20% to 30% Useful	From 40% to 50% Necessary	From 60% to 70% Mandatory	From 80% to 100% Vital
8	Contractor's specification	Positive commercial records of contractor (by giving good performance certificate) Certainty about performance of the contractor—linguistic	Above 80% Very high	Between 60% and 70% High	From 40% to 50% Medium	From 20% to 30% Low	Below 10% Very low
Output of subindex 8		Insurance necessity—crisp Insurance necessity—linguistic	Below 10% Arbitrary	From 20% to 30% Useful	From 40% to 50% Necessary	From 60% to 70% Mandatory	From 80% to 100% Vital
9	Project risk	Percent of the work performance by subcontractors—crisp Impossibility of supervision on project—linguistic	Below 10% Very low or weak	From 20% to 30% Low	From 40% to 50% Medium	From 60% to 70% High	Above 80% or unspecified Very high

(Continues)

TABLE 3 (Continued)

Row	Main index	Subindices/outputs	Conditions of inputs (subindices) and outputs				
Output of subindex 9		Insurance necessity—crisp	Below 10%	From 20% to 30%	From 40% to 50%	From 60% to 70%	From 80% to 100%
		Insurance necessity—linguistic	Arbitrary	Useful	Necessary	Mandatory	Vital
10	Project risk	Business Processes Reengineering/ Modifying accomplished in the organization—crisp	Above 80%	Between 60% and 70%	Between 40% and 50%	Between 30% and 20%	Below 10%
		Certainty about execution of system success—linguistic	Very high	High	Medium	Low	Very low
Output of subindex 10		Insurance necessity—crisp	Below 10%	From 20% to 30%	From 40% to 50%	From 60% to 70%	From 80% to 100%
		Insurance necessity—linguistic	Arbitrary	Useful	Necessary	Mandatory	Vital
11	Project risk	The extent to which the senior management supports the system establishment—crisp	Above 80%	Between 60% and 70%	Between 40% and 50%	Between 30% and 20%	Below 10%
		Certainty about execution of system success—linguistic	Very high	High	Medium	Low	Very low
Output of subindex 11		Insurance necessity—crisp	Below 10%	From 20% to 30%	From 40% to 50%	From 60% to 70%	From 80% to 100%
		Insurance necessity—linguistic	Arbitrary	Useful	Necessary	Mandatory	Vital
12	Project risk	Readiness of the users for acceptance of new system—crisp	Above 80%	Between 60% and 70%	Between 40% and 50%	Between 30% and 20%	Below 10%
		Certainty about success of the system in trial execution (as a part of software contracts)—linguistic	Very high	High	Medium	Low	Very low
Output of subindex 12		Insurance necessity—crisp	Below 10%	From 20% to 30%	From 40% to 50%	From 60% to 70%	From 80% to 100%
		Insurance necessity—linguistic	Arbitrary	Useful	Necessary	Mandatory	Vital
13	Employer's specification	Allocation of resources to the project—crisp	Above 80%	Between 60% and 70%	Between 40% and 50%	Between 30% and 20%	Below 10%
		Certainty about success of project—linguistic	Very high	High	Medium	Low	Very low
Output of subindex 13		Insurance necessity—crisp	Below 10%	From 20% to 30%	From 40% to 50%	From 60% to 70%	From 80% to 100%
		Insurance necessity—linguistic	Arbitrary	Useful	Necessary	Mandatory	Vital
14	Employer's specification	Documentation of requirements—crisp	Above 80%	Between 60% and 70%	Between 40% and 50%	Between 30% and 20%	Below 10%
		Certainty about success of system—linguistic	Very high	High	Medium	Low	Very low
Output of subindex 14		Insurance necessity—crisp	Below 10%	From 20% to 30%	From 40% to 50%	From 60% to 70%	From 80% to 100%
		Insurance necessity—linguistic	Arbitrary	Useful	Necessary	Mandatory	Vital
15	Employer's specification	Readiness of the system infrastructures—crisp	Above 80%	Between 60% and 70%	Between 40% and 50%	Between 30% and 20%	Below 10%
		Certainty about timely establishment of system—linguistic	Very high	High	Medium	Low	Very low
Output of subindex 15		Insurance necessity—crisp	Below 10%	From 20% to 30%	From 40% to 50%	From 60% to 70%	From 80% to 100%
		Insurance necessity—linguistic	Arbitrary	Useful	Necessary	Mandatory	Vital
16	Employer's specification	The users experience in working with information systems—crisp	Above 25 years	From 15 to 20 years	From 5 to 10 years	From 3 to 4 years	Below 2 years
		Certainty about success in use of system—linguistic	Very high	High	Medium	Low	Very low
Output of subindex 16		Insurance necessity—crisp	Below 10%	From 20% to 30%	From 40% to 50%	From 60% to 70%	From 80% to 100%
		Insurance necessity—linguistic	Arbitrary	Useful	Necessary	Mandatory	Vital

- Taskmaster/workplace specifications index includes the following subindices:

1. Allocation of resources to the project (Ngai & Wat, 2003; TechInsurance, 2010; Yunusoglu & Selim, 2013): One of the principles of project management is allocation of the necessary and sufficient resources. This index relates to the employer specifications that indicate success chance of the project. A project with more allocations has a greater chance of success.
2. Documentation of the requirements (Ngai & Wat, 2003): It is necessary to specify functional specifications of the system. This process is called documentation of the requirements. Verbal expression of the requirements is not a professional practice, which results in ambiguity in the project specifications and its failure. The documented needs are regarded as a part of the contract. It is evident that the produced system will function according to these requirements. If these needs are documented well, the customer will be satisfied and there will be no reworking.

On the contrary, failure to document the needs completely and justify the contractor about customer's demands lead to the project failure and dispute among the parties. Therefore, projects with more documentations regarding the desired outcome specifications are less likely to fail.

3. System infrastructures readiness (Alami, 2016; Ngai & Wat, 2003; TechInsurance, 2010): Each software needs soft and hard platforms for execution. These platforms are called infrastructure. The system that is produced and tested well and is ready for operation, in case there are no necessary grounds for, it will not function and one cannot ensure authenticity of its performance. This issue postpones the completion of the contract. These delays cause dispute. The timely readiness of the infrastructures reduces the need for insurance.
4. The user experiences in information systems (Ngai & Wat, 2003): In the organizations that users have the experience of working with the information systems, the new system is accepted and replaced with this system more easily. In addition, the users will be trained faster and better. In this regard, high numerical value of this index lowers the need for insurance coverage.

- Project risks index includes the following indices:

1. The extent to which the project is assigned to a subcontractor (Ngai & Wat, 2003): As it is evident in the contractor indices section, high work quality, work experience, and contractor power have reverse relationship with the need for insurance coverage. However, in case the contractor assigns some parts of the project to other contractors, the presumable failure rate increases. Therefore, the lower percent of assigned work to the subcontractor, the less necessity of contract insurance and vice versa.
2. Business processes reengineering/modifying accomplished in the organization (Alami, 2016; Ngai & Wat, 2003; TechInsurance, 2010): The information systems are produced and established in order to mechanize work processes, increase speed, and reduce human errors. However, the processes cannot be mechanized in the same way, and they need review or change. If the organization does not review its processes before production of the software, the system will not be impeccable. In fact, they are not justified about the work procedures, and the system will never obtain the necessary efficiency. In such cases, despite the spent time and cost, the software will be useless. This issue can lead to dispute between the employer and the contractor. Therefore, the more the extent of improvement/reengineering of working processes in the organization before the establishment of the system, the more the success percent and the lower the need for insurance of the contract.
3. The extent to which senior management supports system establishment (Alami, 2016; TechInsurance, 2010): Top management support is an obligation not only for the software contracts but also for any contract that leads to the purchase of new services or products for the organization. In the software contracts, this support can include financial support, reform or change of the working methods, and supervision on the cooperation of members of the organization with the contractor. Lack of these supports can cause irreparable damages to the project and increase its failure chance. In this regard, percent of need of the contract for insurance coverage has reverse relationship with extent of this support.
4. The readiness of the users for acceptance of the new system (Ngai & Wat, 2003): The readiness of the users can include training the users to adapt to the new systems and also accept mechanization of tasks. In case the users of the system are not ready for these changes, the project will fail. In other words, low readiness for the project is regarded as a risk. The insurance strategy can be effective for managing this risk. In this regard, the need for insurance coverage has a reverse relationship with the readiness of users to accept the new system.

The crisp and linguistic values of relevant indices and their outputs are presented in Table 3. For example, the index "contract price" is divided to numerical form and five numerical and verbal intervals in thousand dollars. In this regard, simple and primary laws are extracted from this table. The following example shows one of these laws in its crisp and linguistic form:

- Crisp form: IF a contract costs from 2 to 2.5 Million Dollars, Then the insurance necessity is 60–70%.
- Linguistic form: IF the Project is midrange, then the contract insurance is necessary.

4.4 | Fuzzification of inputs and outputs

The information is in crisp form when it is entered into the system and should be specified before entering the fuzzy inference engine with fuzzy degree. For example:

IF The Project costs 1.2 milliard, THEN it is Cheap - degree 0.2 and Very Cheap - degree 0.8.

For fuzzification of the indices, symmetrical trapezoid functions ((1)) are used due to their overlapping nature in some intervals. Figure 2 shows trapezoid function.

$$\mu(x) = \begin{cases} 0 & x < \min \\ (x - \min)(mid1 - \min) & \min < x < mid1 \\ 1 & mid1 < x < mid2 \\ (\max - x)/(\max - mid2) & mid2 < x < \max \\ 0 & x < \max \end{cases} \tag{1}$$

xx is the crisp amount of each indices

μ (x) is the Membership function of the indices

n

Equation (1) relates to trapezoid functions of this diagram in different intervals.

4.5 | Extraction of laws for storage in the knowledge base

By specifying the subindices that affect the output, the obtained information will turn into the previous state as observed in the previous section. Subsequently, the outputs have been specified and fuzzified. For each input state, we will have an output state. Then five different outputs are obtained for each input subindex with five states. Table 3 shows these subindices with outputs resulting from them. The sum of the possible states obtained from 16 subindices—each with five different states—is equal to $5 \times 5 \times 5 \times \ldots \times 5 = 5^{16}$, which will be produced with fuzzy inference engine. The simple rules are stored with a subindex in the knowledge base. Therefore, the number of rules stored at the beginning of the system production is 16 × 5.

It is recommended to use a program for the production of all outputs to develop this system, the software that can produce 528 outputs into one of the inference methods like a multiplexer microchip with 5 × 28 = 140 input states. These outputs have been obtained from the combination of different states of inputs. The following figure shows the production of 528 outputs from 5 × 28 inputs (Figure 3).

4.6 | How to complete knowledge base

The information extracted from Table 3 is stored in the knowledge base as the primary knowledge rules. However, because the number of different compositions of subindices is too big (5^{16}), storing manually in knowledge base is a time-consuming task. As a result, it is recommend that initially these rules be stored automatically in the knowledge base by executing the system. Subsequently, a new output will be produced and

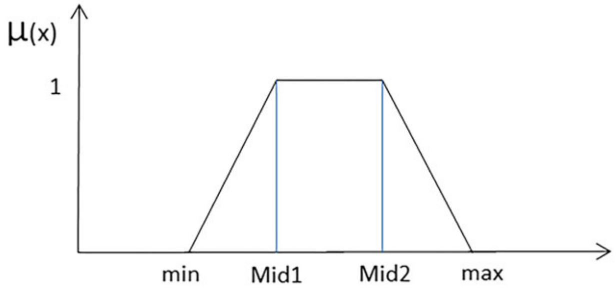

FIGURE 2 Fuzzy trapezoid function

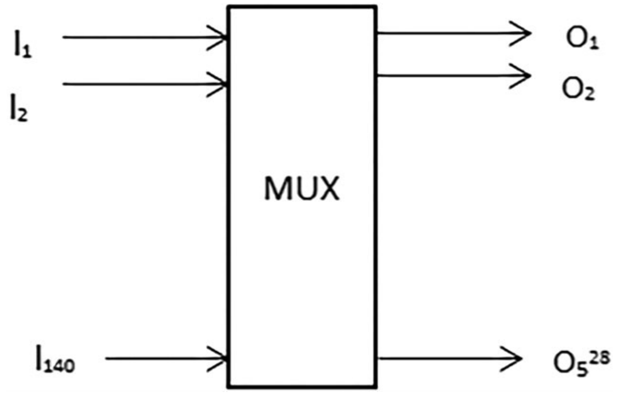

FIGURE 3 The production of 5^{28} outputs from 5 × 28 inputs

stored in the knowledge base with each execution of the system in response to each input arrangement. Some of the knowledge rules of the system are as follows:

IF the contract cost is expensive **AND**

The contract is long **AND**

BPR has not accomplished in the company yet **AND**

The Top Management does not support the project enough **AND**

The level of resource assignment to the project is not enough **AND**

The users of the system have been training well **AND**

The level of resource assignment to the project is not enough **AND**

The system requirements are documented as well **AND**

The contract has an International consultant **AND**

The contractor assigns a major part of work to sub-contractors **AND**

The same system has developed or installed seldom for other companies,

THEN

The contract probably needs to be insured with 60% certainty, consult the CIO and CFO for final decision.

ELSE

The required information is not in the knowledge base.

4.7 | Performance of the inference engine

In this research, the fuzzy inference engine is used on the basis of Mamdani method, which includes two sections—the fuzzy inference system and the defuzzification section. For this purpose, we applied the inference to the subindices of each main index in our scope. Afterwards, we applied the same method to calculate the outcomes of every four main indices. The results of the inference stage are defuzzified by the defuzzification section. In this research, the centre of gravity method is used for defuzzifying (defuzzification). This method finds the balance point of the fuzzy area with a weighted mean of the desired area. Equations (2) and (3) show the method of calculation of the centre of gravity in two continuous and discrete states:

$$\begin{gathered} = \int \mu A(X).X\,dx / \int \mu A(X) \\ \text{X is the main variable} \\ \mu A(X) \textit{ is the Membership function of X} \\ \alpha \text{ is the difuzzified amount of } \mu A(X) \end{gathered} \tag{2}$$

$$\begin{gathered} \alpha = \sum \mu A(X).X / \sum \mu A(X) \\ \text{X is the main variable} \\ \mu A(X) \textit{ is the Membership function of X} \\ \alpha \text{is the difuzzified amount of } \mu A(X) \end{gathered} \tag{3}$$

4.8 | System user interface

This part of the system has two pages of input information receiver and system responses display. When information about 16 subindices is entered in the login page, the system prepares a response and shows the fuzzified values of fuzzy inputs and outputs obtained from them in addition to the final response of the system to be seen by the user concurrently.

4.9 | System architecture

Because we intend to design and implement a web-based expert system, the location of database and program source, web server, and location of working stations should be clear, and only the users of this program are authorized to gain access to the system. These users can connect to the system through internet or intranet.

5 | EVALUATION

5.1 | Testing the system for an executive sample

It is necessary to compare the expected results of execution (by including the experts' views) with the real results obtained from the system in order to ensure the authenticity of the system performance. The inputs of a contract of an integrated system are presented in Table 4 with regard to the determined parameters in Table 2.

The specifications of the price of the software contracts, which have been fuzzified on the basis of values of Table 3, are shown in Figure 4. The fuzzy values for the price of this contract and the need for insurance based on this price are found in the same figure.

According to Figure 4 for the final value of 3.6 milliard, the fuzzy value of the contract price is 0.4 Cheap and 0.6 Midrange and the output value is 0.4 Useful and 0.6 Necessary.

TABLE 4 Fuzzification of input numerical parameters of the contract

			Input		Output	
Question no.	Question description	Numerical response	Linguistic variable	Fuzzy value (μA)	Linguistic variable	Fuzzy value (μA)
1	Contract cost	1.2 million dollars	Cheap–Midrange	0.4–0.6	Useful–Necessary	0.4–0.6
2	Number of system's users	2,000	Very much	1	Vital	1
3	Duration of contract	4 years	Very Long	1	Vital	1
4	Rank of contract's consultant	1	Very high	1	Arbitrary	1
5	Number of contractor's personnel	2,500	Very high	1	Arbitrary	1
6	Rank of contractor	1	Very high	1	Arbitrary	1
7	Number of similar products sold/worked by the contractor	>20	Very high	1	Arbitrary	1
8	Positive commercial records of the contractor	>95%	Very high	1	Arbitrary	1
9	The use of subcontractors	0	Very low	1	Arbitrary	1
10	Accomplished BPR in organization	70%	High	1	Useful	1
11	Senior management's support	65%	High	1	Useful	1
12	Readiness of users to acceptance the new system	50%	Medium	1	Necessary	1
13	Allocation of resources to project	65%	High	1	Useful	1
14	Requirements Documentation	80%	Very high	1	Arbitrary	1
15	Readiness of the system infrastructures	25%	Low	1	Mandatory	1
16	Previous experience of users in working with information systems	15–20 years	High	1	Useful	1

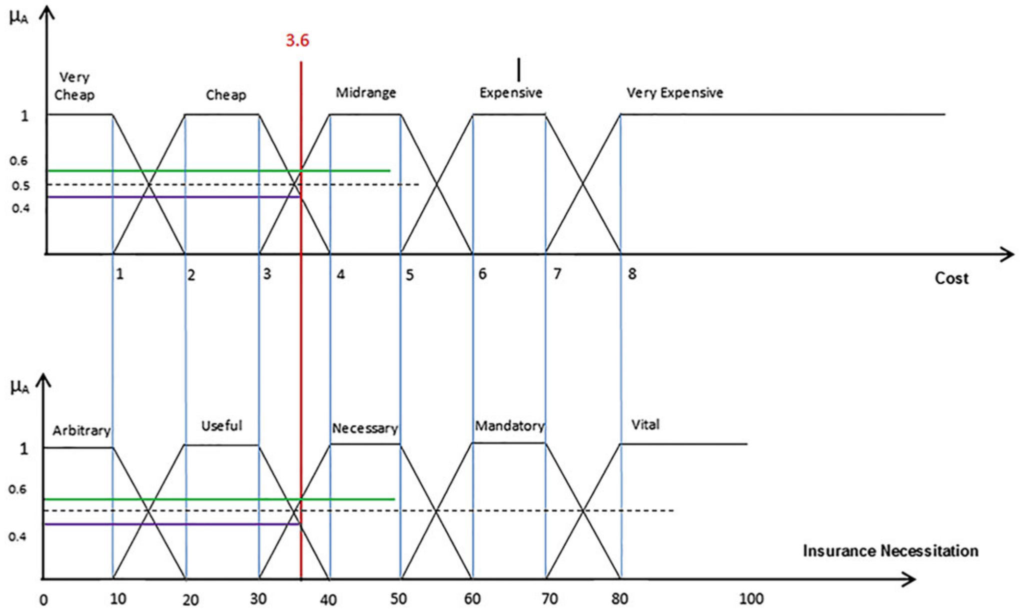

FIGURE 4 Fuzzification of contract price

After the fuzzification of all input indices and their submission to fuzzy inference section, the final output of the system is obtained. This output should become finalized with defuzzification section and be announced to the user.

- The result of system execution for this project is as follows:
- The necessity of contract insurance is about 43.8%.
- The opinion of the specialists is as follows:
- This contract is imperative and long-term and involves many users, and its failure loses human capitals of the company. Moreover, the company will sustain more financial losses, which should be compensated by all means. Therefore, the necessity of its insurance is above 70%.

5.2 | Analysis of the system performance

This contract is very important and long-term and involves many users, and its failure leads to losses in human and financial capitals of the company. However, reviewing all of the subindices shows that the number of strengths of this contract is greater than that of its weaknesses. Rows 4 to 10 of Table 4 are the weaknesses of this contract, which reject the necessity of contract insurance with certainty. Rows 14 and 16 are also regarded as strengths but with lower confidence. Weaknesses can be observed only in rows 2, 3, and 15 of the table. Other rows are in medium range. In other words, they are regarded as neither weakness nor strength. Therefore, such contract does not need insurance coverage, and the same system response, that is, 43.8%, seems to be suitable. This need has been created for some reasons such as unready infrastructures, great number of users, and relatively long duration of the project.

Rules are first extracted, summarized, and finalized in meetings with the presence of experts. Thereafter, these rules are added to the rule base at the beginning of the model implementation. Subsequently, system feedback is returned to the experts during the implementation of the model and after receiving the results. Finally, if necessary, the rules will be corrected by the experts according to the results obtained from the implementation of the model. The model is currently implemented for 20 projects, and current rules are the result of feedback from these 20 implemented projects.

The following table (Table 5) contains five other examples that can support more systemic results as more experimental data:

It is worth noting that the researchers presented the results of the implementation of the model to the experts and compared the output of the experts with the model output and found that the results are consistent with each other.

Therefore, it is clear that the execution of a diagnostic system is much more accurate than receipt of the specialists' views without performing careful studies. Furthermore, as explained at the beginning of the paper in the section “advantages of the expert systems,” it is difficult, time-consuming, and expensive to collect views of the theorists. Therefore, it is recommended to insure not only software contracts but also all IT contracts on the basis of the results of the system outcomes.

TABLE 5 Five other examples of experimental data

Question no.	Question description	E procurement for NIGC	Customers portal for Mellat Bank	Customer club for Tejarat Bank	Education system for Khatam University	Electricity subscribers system
1	Contract cost (milliard tomans)	12.5	10.3	0.74	2.5	2
2	Number of system's users	400,000	1,500,000	500,000	50,000	1,000,000
3	Duration of contract (months)	12	24	12	18	24
4	Rank of contract's consultant	2	—	—	—	1
5	Number of contractor's personnel	19	12	8	17	22
6	Rank of contractor	1	1	1	1	1
7	Number of similar products sold/worked by the contractor	2	0	1	15	1
8	Positive commercial records of the contractor	80%	60%	60%	90%	95%
9	The use of subcontractors	0	15%	0	0	0
10	Accomplished BPR in organization	50%	0	10%	70%	45%
11	Senior management's support	90%	80%	70%	75%	60%
12	Readiness of users to acceptance the new system	55%	60%	40%	75%	70%
13	Allocation of resources to project	70%	50%	65%	40%	30%
14	Requirements Documentation	25%	45%	30%	20%	50%
15	Readiness of the system infrastructures	50%	50%	90%	30%	80%
16	Previous experience of users in working with information systems (years)	7	15	10	8	12
Need insurance		49.5%	46.2%	50%	50%	50%

6 | CONCLUSION AND RECOMMENDATIONS FOR FURTHER STUDY

The use of expert systems as decision support systems will always be useful for organizations, provided that the knowledge rules stored in them are correct, sufficient, and helpful. IT and information systems can contribute a very important role in SCM. Many of research have examined the relationship between SCM and IT range from surveys to case studies and simulations. The proposed expert system in this research can be used in making decision about all professional contracts regarding insurance coverage or other recommendations. The implementation of the proposed system in this study leads to the improvement of projects execution.

- For an optimal implementation of the project, subindices of three indices should be entered to the working memory/temporary memory of the system, and the system should make comments about the fourth index due to the knowledge in the knowledge rule. In other words, the necessary recommendations should be given about outcomes of the subindices of the fourth index to the user.
  Four main indices are as follows:
- Specifications of the present contract;
- The present project risks;
- Conditions of the suitable contractor among list of the authorized contractors;
- Appropriate conditions of the organization for optimal execution of the project.
- In terms of insurance coverage, this system can evaluate the insurance coverage necessity for all professional contracts and consequently help improve SCM in the relevant industry. These insurances can include life insurance, automobile insurance, professional liability insurance of physicians, and other types of insurances in the world. This goal can be achieved by making partial changes to the user interface.
- In the further studies, by changing/modifying other parts of the system such as knowledge rule base, user interface, and working memory, system could be changed so that:
- Accuracy of the system will increase by adding new criteria or weighing each of the subindices. In this regard, increase in the number of subindices or change in fuzzy membership functions due to weighing will change laws and results of executing system.
- One can produce a new system with the same production performance by changing programming language and information bank management with this difference that it is given to others as open-ended text to extend it to other usages.
- A program should be designed and implemented for production and storage of all rules with very high number at the beginning of work so that it can create and store all rules including all possible combined states of inputs in knowledge bank. The advantage of this practice is to use this program as a component for all expert systems and the number of the input indices and also the number of combined input states is high.

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