Comput Syst Sci & Eng (2010) 1: 15–28

International Journal of
Computer Systems
Science & Engineering

Transactional risk-based decision making system in e-business interactions

Omar Khadeer Hussain, Tharam Dillon, Elizabeth Chang and Farookh Hussain

Digital Ecosystems and Business Intelligence Institute, Curtin University of Technology, Perth, Australia
Email: O.Hussain@cbs.curtin.edu.au

The credit crunch and economic crisis have demonstrated the need to properly understand, characterize and assimilate risk in business activities. Failure to do this has resulted in serious consequences to the users involved. So the analysis and management of risk is one of the important pre-requisites to ensure a successful outcome in a business activity in any domain. In this paper we propose an approach by which an interaction initiating user in the domain of e-business ascertains beforehand the level of transactional risk in the successful completion of its business activity and utilizes it to determine on an interaction. The proposed model considers the different sub-categories and characteristics of transactional risk and ascertains in numeric and semantic terms the different levels and severities of its occurrence. It then utilizes the determined analysis of transactional risk to recommend on an informed interaction-based decision to the interaction initiating user.

Keywords: Transactional Risk, Performance Risk, Financial Risk, Decision Making, Risk Propensity.

1. INTRODUCTION

Electronic business is rapidly becoming the preferred way of achieving outcomes in the growing technological world. Users all around the world are adopting this medium for carrying out their business activities. In return they get to complete their tasks in shorter periods of time, with increased flexibility and capability. An e-business architecture can be utilized to facilitate any type of business activity under its broad domain, the most popular being the e-marketplace where users collaborate with each other to achieve their desired outcomes. But like its predecessors, this architecture too does not provide any guarantee of always having a successful outcome. Users may also experience a negative situation, which signifies the non-achievement of their outcomes and the resultant consequences. So in order to enjoy the benefits of e-business paradigm users have to make informed interaction-based decisions. We define informed interaction-based decisions as those in which the user's interaction experience and benefits are maximized and any losses are minimized or alleviated. By making such decisions users can transform themselves into intelligent agents who can then act in a proactive way towards achieving their goals. To make an informed decision the notions of Security, Privacy, Trust and Risk play an important part. In the literature various approaches of decision-making have been proposed in the area of e-business. But most of those approaches ignore the notion of risk while doing so. In other words, they consider the notion of risk as a subset of trust, security and privacy; and consider that its impact in an e-business interaction can be alleviated or mitigated by the analysis of those concepts. But in reality this is not the case. Risk captures the 'negative' concepts that could be possible in an interaction and represents both the likelihood of failure as well as the consequences of failure of the interaction. This notion of risk will then provide a clear basis of decision making. Let us consider the simple example of a user engaging in an e-business interaction with another user, where there is a 20% chance of failure that would result in a loss of $10.

One might quite possibly engage in such an interaction. If on the other hand, the loss from such an interaction was $200,000, one would probably not engage at a 20% failure rate but would require a much lower failure rate say 0.01%, before being prepared to engage in such an interaction. This simple example illustrates that it is not just the probability of failure alone but the probability of failure taken together with the consequences that guides the decision to participate in an interaction. Such representation is characterized by the notion of risk and is not determined by the analysis of trust, security or privacy in the collaboration. So risk is one of the important concepts to analyze and consider while decision-making.

In this paper we propose a framework which quantifies and considers risk while decision-making in an e-business interaction. The proposed framework can be applied in any interaction in that domain where the financial resources are at stake. The paper is organized as follows. In Section 2 we briefly discuss the existing approaches from the literature and highlight the importance of considering risk while decision-making in e-business. In Section 3 we discuss our previous work of determining the sub-categories of risk for its assessment in the business interaction. In Section 4 and 5 we consider the determination of the numerical and linguistic level of transactional risk in an interaction. In Section 6 we propose a risk based recommender system in e-business interaction.

2. IMPORTANCE OF TRANSACTIONAL RISK WHILE DECISION-MAKING

Decision Making is a mental process that warrants a user to decide on its future course from the possible available ones. It is a problem solving approach based on the psychological and cognitive factors of the user, and requires it to analyze all the different available options against a set of indicators or needs and then base its decision on choosing the best among them. An e-business interaction is carried out for achieving a set of desired outcomes, so the decision-making process in such interactions should be based on maximizing the successful achievement of the desired outcomes. The main objective for the interaction initiating user during the decision-making process should be to decide whether it will achieve its desired outcomes and maximum benefits in interacting with that user. If it has to choose from a group, then during decision-making that particular user should be chosen with whom its interaction experience and benefits will be maximized. In such scenarios, security will help to determine and keep the collaboration platform safe from the intrusion of the outside disruptive forces. The notion of privacy will help to determine and keep the sensitive information of each user safe from un-authorized access. Trust will express the level of dependability of the interacting user on another user to achieve its outcomes. The notion of risk will express the consequences to the user as a result of failure of its collaboration. Although each of these concepts are related to the same business interaction, the analysis they provide is different and important at different time periods of the collaboration for making an informed interaction-based decision. The notion of security and privacy are important in the initial part of making an informed interaction-based decision, where the interacting user from a group selects those users to collaborate with who satisfy its perceptions of interacting in a safe environment. But such analysis is not enough on its own to make an informed interaction-based decision. To have a complete analysis, from the selected group that user should be chosen who has the best capability to commit to the desired outcomes of the business interaction. This representation is achieved by the combined analysis of trust and risk in the business interaction. The term risk in the previous sentence refers to a specific type of it.

There are different representations that are achieved by the analysis of risk according to the object of analysis in a business interaction. For example, the non-presence of the security mechanisms poses a risk to the successful completion of the business interaction. Similarly, the non-preservement of private information of the participants represents a threat. These types of risks are different from each other and can be classified into different categories, namely security risks and privacy risks respectively; and will be addressed by the analysis of concepts like security and privacy respectively. These types of risks are related to the initial considerations of decision-making in a business interaction. But another important representation of risk is required in the later part of decision-making. This type of risk gives an assessment of the level to which the interacting user will not achieve its desired outcomes in the business interaction and the level of consequences that it will experience as a result of that. This is due to the failure of the other user in committing to what was expected from it. That representation of risk is termed as the transactional risk; and it plays an important part during the later part of decision-making. In this paper by using the term risk we refer to the transactional risk. Although the importance of transactional risk while decision-making has been acknowledged by some researchers, they ignore it in lieu for trust while decision-making. In other words, they consider trust to be an authorative concept as compared to risk and base their decision on that. For example, Aberer et al. [1] consider the possibility of agent 'A' cheating in the interaction, but they do not take into consideration the transactional risk while decision making, which gives the degree and magnitude of loss in interacting with agent 'A' due to its cheating. Zheng et al. [2] consider the cost and utility function associated with an interaction while decision making, but they associate the cost with the 'rewards' of the consequences of the decision. They do not consider the notion of loss associated with the uncertainty in the interaction and the consequences of decision. Josang et al. [3] consider trust as the only factor in their approach which motivates an agent in the interaction. Although they consider the 'possible harm' and 'negative consequences', they do not quantify it in their model. Hassell [4] proposes a method whereby an agent decides to trust another agent by considering the neurological and socialization characteristics of its brain apart from just considering the 'level of belief' expressed by trust, but they fail to consider the importance of transactional risk and its impact on an agent's brain while decision making. Pearson et al. [5] proposes an approach of making trust-based decision which omits taking transactional risk into consideration. Wang and Lin [6] state that trust represents the extent to which a party can depend on the other with relative assurance, even though 'negative consequences' are possible. But they do not propose an approach by which the negative consequences are quantified and considered while decision making. Further in

[7], Wang and Lin propose an approach that differentiates transaction price of the interaction during trust evaluation. But this determination does not represent the level and degree of loss that can be experienced. Measuring the loss or its impact in the interaction is within the scope of transactional risk analysis, and hence it should be considered when making an informed interaction-based decision. To this effect, approaches have been proposed in the literature which assess risk in an interaction [8–17], but none of them do it by taking into consideration its required sub-categories and characteristics. So any framework of decision-making on such level of transactional risk does not give the required analysis to make an informed interaction-based decision. As mentioned in the previous section, transactional risk captures (a) the probability of failure of the interaction and (b) the consequences of failure of the interaction to the interacting user. So during its analysis it should be assessed according to these sub-categories. Further the characteristics of transactional risk that need to be considered while analysing these subcategories are its context specific, assessment criteria specific and time specific characteristics. Context specific nature takes into consideration the purpose for which the interaction is being carried out. Assessment Criteria specific takes into consideration the specific outcomes in the particular context and time specific characteristics take into consideration the dynamic nature of risk. In our previous work, we had proposed approaches by which each sub-category of transactional risk is determined. We will give a brief overview of those approaches in the next section. In this article, based on that analysis we will propose an approach whereby the user can analyse and quantify the level of transactional risk in an e-business interaction. We will then utilize the determined level of transactional risk to determine on an interaction.

3. ASSESSMENT OF THE SUB-CATEGORIES OF TRANSACTIONAL RISK IN E-BUSINESS INTERACTIONS

We term the two interacting users of the e-business interaction as the risk assessing agent and the risk assessed agent. Risk assessing agent is that user who wants to achieve the expectations and looks for a user to interact with. Risk assessed agent is that user who has the capability to provide the risk assessing agent with its expectations. Expectations are the collection of all the desired outcomes which the risk assessing agent wants to achieve in its interaction. We consider that before the interaction, the interacting agents negotiate with each other and decide on the common desired outcomes to be achieved, which are then termed as the expectations of the interaction. Performance risk represents the level to which the risk assessing agent will not achieve its expectations in forming an interaction with the risk assessing agent. In other words, it represents the incapability of the risk assessed agent in providing the risk assessing agent with its desired outcomes according to the formed assessment criteria. It is quite possible that the risk assessing agent's interaction with the risk assessed agent is in a point of time in the future. In such scenarios, it has to rely on the risk assessed agent's previous reputation in the assessment criteria of the expectations to determine its performance risk in the actual time period of its interaction. To achieve that we divide the time period of the interaction into two parts, namely pre-interaction start time phase and post-interaction start time phase. Pre-Interaction start time phase refers to the period of time before the risk assessing agent starts its interaction with the risk assessed agent, whereas Post-Interaction start time phase is that period of time, after the risk assessing agent starts and interacts with the risk assessed agent. To determine the performance risk, we proposed the Failure Scale and the FailureLevel. The Failure Scale, on the scale of 0–100% represents the different levels of failure that could be possible in an interaction. FailureLevel groups the different levels of failure on the Failure Scale according to their severity with a numerical value. To consider the dynamic nature of transactional risk, we consider that the risk assessing agent divides the time period of its interaction with the risk assessed agent (termed as the time space) in different non-overlapping 'time slots' and determine the FailureLevel of the risk assessed agent in each assessment criterion in each time slot, either by its past interaction history or soliciting recommendations. It then combines the FailureLevel of each assessment criterion according to its significance to determine the risk assessed agent's performance risk in that time slot. Once the performance risk in the pre-interaction start time slots has been determined, then the risk assessing agent can utilize it to determine the different levels of performance risk in each of the post-interaction start time slots. Utilizing that, the FailureLevel Curve (FLC) of the business interaction is plotted. The FailureLevel Curve as shown in Figure 1 quantifies and represents the different levels of performance risk of the risk assessed agent in committing to the expectations of its interaction. The detailed methodology by which the risk assessing agent determines the performance risk of the risk assessed agent according to its expectations in explained in Hussain et al. [18].

In an e-business interaction we consider that the risk assessed agent interacts with the risk assessing agent to give its desired outcomes in exchange of the pre-decided monetary financial value. These financial resources are decided between the interacting users while forming the expectations. So the impact or consequences to the risk assessing agent as a result of not achieving its desired outcomes is in those financial resources; and is determined by ascertaining the financial risk to it in its business interaction. The level of financial risk depends on two factors which are (a) the accurate investments which the risk assessing agent will have at stake in an interaction and (b) the variability to which it will invest its resources. To capture these factors we propose that the risk assessing agent determines the Amount Invested Curve (AIC). The Amount Invested Curve takes into consideration the different levels of investments in the time slots of the interaction and determines the accurate probability of an amount at stake throughout the interaction time period. According to the expectations, the risk assessing agent expects to achieve its desired outcomes in these resources. But due to the performance risk of the risk assessed agent and other uncertainties (non-dependant events) this might not be possible and the risk assessing agent may not achieve its expectations in the resources as decided in the expectations. To determine their effect, we propose that the risk assessing agent determines the Actual Factual Amount Invested Curve (AFAIC) of its business interaction. The AFAIC captures those uncertainties and represents

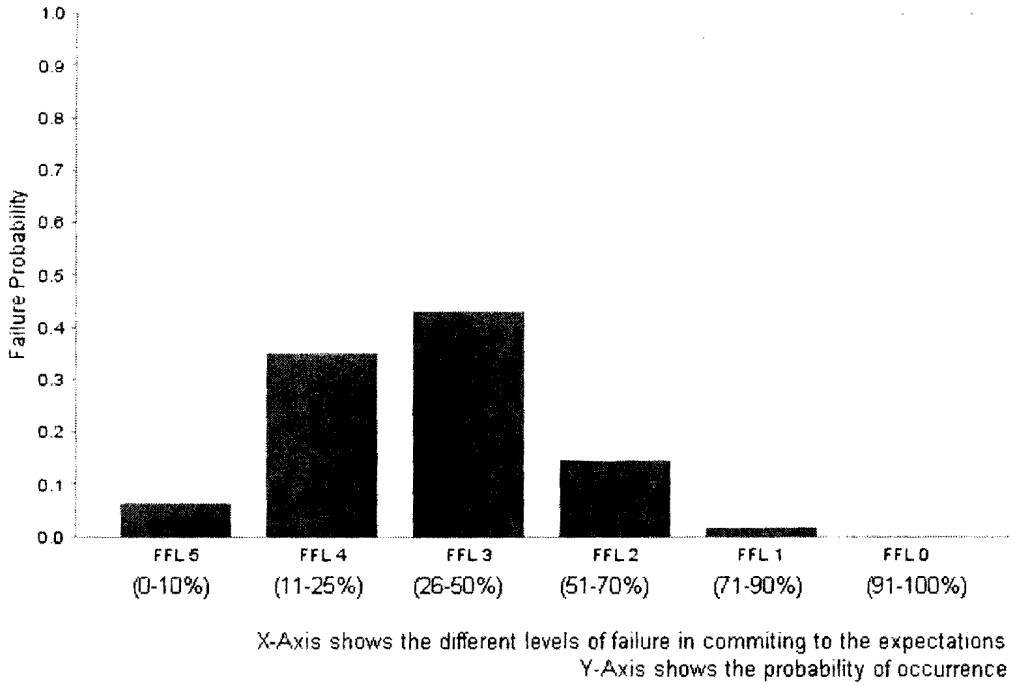

Figure 1 The FailureLevel Curve of the business interaction.

the actual resources with their probability that the risk assessing agent needs to keep at stake in the interaction as shown in Figure 2. Based on its maximum investment capacity (MIC), it can ascertain the 'Loss of Investment Probability' (LOIP) and the 'Possible Consequences of Failure' (PCF) to it in the interaction. Maximum investment capacity is that financial amount which was decided in the expectations. The 'Loss of Investment Probability' (LOIP) of the interaction gives the probability of the risk assessing agent not achieving the full benefit of its resources that it invests while interacting with a risk assessed agent as decided in the expectations. The 'Possible Consequences of Failure' (PCF) in a business interaction represents the additional degree/s of resources needed to be kept at stake in the interaction from what was decided in the expectations. The combination of these outcomes represents the financial risk in the interaction. The detailed methodology by which the risk assessing agent determines the financial risk to it in forming an interaction with the risk assessed agent is explained in Hussain et al. [19] and [20].

Once the sub-categories of transactional risk have been determined, they should be combined for ascertaining the level of transactional risk. In the next section we will propose a methodology by which the risk assessing agent determines the level of transactional risk and makes an interaction-based decision on that. It is logical that while determining the level of transactional risk there is uncertainty in the risk assessing agent's mind, as it is being determined in an interaction that is going to be held at a future period of time, in which nothing is certain. This uncertainty can be classified into two types: 'ambiguity' and 'vagueness'. We define ambiguity as that type of uncertainty which represents its inability to identify the concrete level/s or magnitudes of transactional risk in the interaction, whereas vagueness is defined as that type of uncertainty which represents its inability to identify the degree or likelihood to which those levels will occur in the interaction. To eliminate such types of uncertainty we propose that the risk assessing agent determines the magnitude of transactional risk in the interaction in a twofold process. The first part deals with ascertaining the numerical level of transactional risk and the second part deals with determining the linguistic level of transactional risk.

4. DETERMINING THE NUMERICAL LEVEL OF TRANSACTIONAL RISK

While ascertaining the numerical level of transactional risk, we consider the possibility distribution of the input variables and not their probability distribution. Possibility distribution allows the risk assessing agent to capture the different levels of risk along with their accurate magnitudes of occurrence over a future period of time. The risk assessing agent considers the effect of the FailureLevel Curve (FLC) of the risk assessed agent on the financial amounts that it has at stake to determine the Financial Risk in the business interaction. To avoid considering its effect again we propose that while determining the Transactional Risk it takes into consideration only two if its constituents, namely the loss of investment probability and the possible consequences of failure from the determined subcategories. The numerical magnitude of transactional risk in the interaction by using possibility theory is determined mathematically by a relation between:

$$\text{Transactional Risk} = \text{Possible Consequences of Failure} \oplus \text{Loss of Investment Probability}$$

The operator '$\oplus$' between the two inputs represents convolution. Universe of discourse (UoD) defines the scope or range to which the variable extends. The UoD of the input variables and the output variable is defined by the following sets:

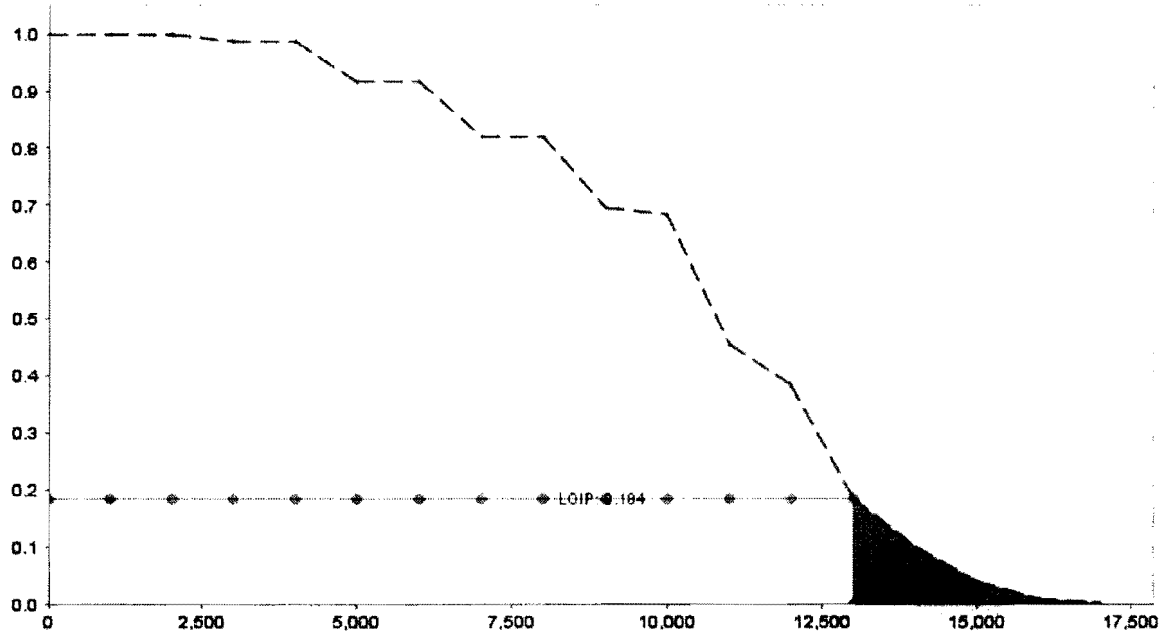

Figure 2 The Actual Factual Amount Invested Curve of the Interaction.

Possible Consequences of Failure (PCF)
= {0, 1, 2, 3..... 100} where each element has a unit of %.

Loss of Investment Probability (LOIP)
= {0, 1, 2, 3.....100} where each element has a unit of %.

Transactional Risk (TR)
= {0, 1, 2, 3.....100} where each element has a unit of %.

To obtain the possibility distribution of an input variable, the likelihood of occurrence of each element from its universe of discourse should be determined. This likelihood of occurrence of an element is termed the 'degree of evidence' of its outcome, represented by 'm (A)', where 'A' is an event or element from the universe of discourse of the input variable 'X'. From the universe of discourse, those elements with degree of evidence greater than zero are called the 'focal elements' for the particular input variable. These elements represent the sets from the UoD for that variable upon which the evidence of occurrence focuses and which furthermore will be utilized from that input variable to determine the magnitude of transactional risk in the interaction. The degree of evidence of an element from the UoD should be in the interval between [0, 1] and the cumulative sum of the degree of evidence of all the focal elements from the UoD should be equal to 1. From that the possibility of occurrence of an element 'A $_i$' of the input variable X can be determined from the focal elements of its UoD by [21, 22]:

$$\pi(Ai) = \sum_{j=1}^{n} m(Aj) \tag{1}$$

where: $m(A_j)$ represents the degree of evidence of 'Aj' from the focal elements of the input variable from its UoD, and which have been ordered such that $i < j$ and $\pi(A_i) \geq \pi(A_j)$.

Once the focal elements of the input variables (PCF and LOIP) along with their degree of evidence from their UoD have been determined, they must then be convolved to determine the transactional risk in the interaction. The focal elements of the output variable function from its defined universe of discourse are determined in the convolution process. The convolution of the possibility distributions is the artesian product of the input variables [23]. The convolution of the focal elements from the input UoD (X and Y) is done by taking their artesian products and is represented by:

$$\text{PCF} \oplus \text{LOIP} = \{<x, y> : \text{ where } x \in \text{ PCF and } y \in \text{LOIP}\} \tag{2}$$

where: $<x, y>$ denotes the tuple which represents the artesian product of the input focal elements from their UoD.

The possibility distribution of the focal elements of the resultant output variable as the result of the convolution of the inputs variables is represented by [23]:

$$\pi(u) = \max\{\min[\pi_{\text{PCF}}(x), \pi_{\text{LOIP}}(y)]\} \tag{3}$$

where: u is the focal element of the output function determined as the artesian product of the inputs $f(x, y)$,

$\pi(u)$ is the possibility of focal element 'u' from the output universe of discourse.

The above equation gives the possibility of occurrence of the focal elements of the magnitude of transactional risk in the interaction due to the convolution of the focal elements of the inputs, the possible consequences of failure and the loss of investment probability.

To explain with an example the process of determining the level of transactional risk in an interaction, let us consider that a risk assessing agent 'A' wants to interact with a logistics company

to transfer its goods from Perth to Melbourne. There are various possible logistics companies for it to choose from; and agent 'A' to make an informed decision based on the level of transactional risk present in interaction with each of them. Let us consider that agent 'A' according to its expectations and maximum investment capacity of $ 13,000 determines the level of performance risk and financial risk in forming an interaction with agent 'B' as shown in Figure 1 and 2 respectively. From that it has to determine the level of transactional risk in its interaction with the logistics company 'B'. To determine the focal elements and the possibility distribution of the PCF in the interaction, the risk assessing agent from its maximum investment capacity should determine the levels of extra financial resources that it has to keep at stake while interacting with the risk assessed agent. The steps to be followed are:

- It should determine the probability mass function (PMF) of the AFAIC in interacting with the risk assessed agent. The PMF of the AFAIC shows the probability of an amount that the risk assessing agent has to keep at stake throughout the duration of interacting with the risk assessed agent.
- It should then determine the point on the PMF of the AFAIC which represents its maximum investment capacity in the interaction, which is termed as 'x'.
- From point 'x', the risk assessing agent on a scale of 0–100 should determine the degrees of extra financial resources that it has to keep at stake or the levels of its un-served investment in the interaction.
- From the UoD for the PCF, the focal elements should be chosen according to the measure of step size on the AFAIC of the levels of un-served investment in the interaction.
- The risk assessing agent should then determine the degree of evidence (m (A)) of each focal element, which represents the level of un-served investment in the interaction. This is determined by taking into consideration the PMF of the particular financial amount from the AFAIC and then converting it to possibility distribution.
- Based on the degree of evidence calculated for each focal element from the UoD, the possibility distribution of the PCF can be determined by using equation 1.
- The LOIP of the interaction in contrast to the PCF is a single crisp value in the range of [0–1], which shows the ordinate on the AFAIC at the end of its maximum investment capacity in the interaction. But in order to utilize a unified and comparable numerical scale to the two inputs, the range of the LOIP is normalized in the range between 0–100.
- Hence, the ordinate of the AFAIC at point 'x' is taken as the focal element from its UoD to represent the LOIP in the interaction. The degree of evidence of the focal element is taken as 1.

Once the focal elements and their degree of evidence for each input variable have been determined, the risk assessing agent should then convolve them to determine the focal elements of transactional risk in the interaction from its UoD by using equation 2. The possibility of occurrence of the focal elements of transactional risk in the interaction can then be determined by using equation 3. In the current example, the level of transactional risk to the risk assessing agent 'A' in forming an interaction with the risk assessed agent 'B' is as shown in Figure 3. The resultant graph will give the risk assessing agent with different levels of transactional risk along with the possibility of occurrence of those levels.

5. DETERMINING THE LINGUISTIC LEVEL OF TRANSACTIONAL RISK

Our motive for incorporating the fuzzy inference system is for the risk assessing agent to ascertain semantically the level of transactional risk in interacting with a risk assessed agent. Fuzzy inference systems are mathematical objects modeling the vagueness present in the natural language when the described phenomena do not have sharply defined boundaries. They were developed to incorporate the concept of partial truth characterized by the fuzziness of the data which yields a more accurate mathematical representation of the perception of truth than that of crisp sets [24].

A fuzzy inference system models the vague inputs in terms of semantics and transforms them into a mathematical representation of the data to map its output semantics. To achieve this, data is transformed from crisp values to fuzzy sets by using the defined predicates. A fuzzy set or predicate is a linguistic phrase that is used as a semantic label for representing a part of the variable, which best matches its description. The predicates for a variable should be defined such that they cover the whole universe of discourse or the scope in which the variable extends. Once the predicates have been defined for a variable, then the membership function for each of the predicates in that variable should be defined so that they cover its scope or its range of universe of discourse. The membership function is used to transform each crisp input into a fuzzy variable, by utilizing the predicates and then determining the degree of qualification or the membership value of the crisp input to those predicates. As mentioned previously, the universe of discourse (UoD) for the inputs PCF and LOIP and output TR ranges from {0, 1, 2,. . ., 100} where each element has a unit of %. To classify different fuzzy sets for each variable, we divide the universe of discourse such that there are 6 predicates in each of them. Those predicates are: 'Extremely Low', 'Low' 'Low Medium', 'Medium High', 'High' and 'Extremely High'. The range of a predicate varies for each variable according to the severity of the value in its context. The membership function for each variable is represented by the trapezoidal curve such that its shape is as shown in Figure 4–6.

To transform a focal element 'x' of an input linguistic variable to the defined fuzzy sets in it, the risk assessing agent has to determine the possibility to which that element 'x' corresponds with the defined predicates of that input variable. This is done by considering the overlap between the degree of evidence of the input value 'x', with the degree of membership to which 'x' corresponds to a particular predicate. The possibility that the fuzzy set or predicate 'A' of an input variable will occur based on the degree of evidence of input 'x' is given by [24]:

$$\Pi(A) = \max\{\min[\pi(x), \mathrm{DOM}_A(x)]\}. \quad (4)$$

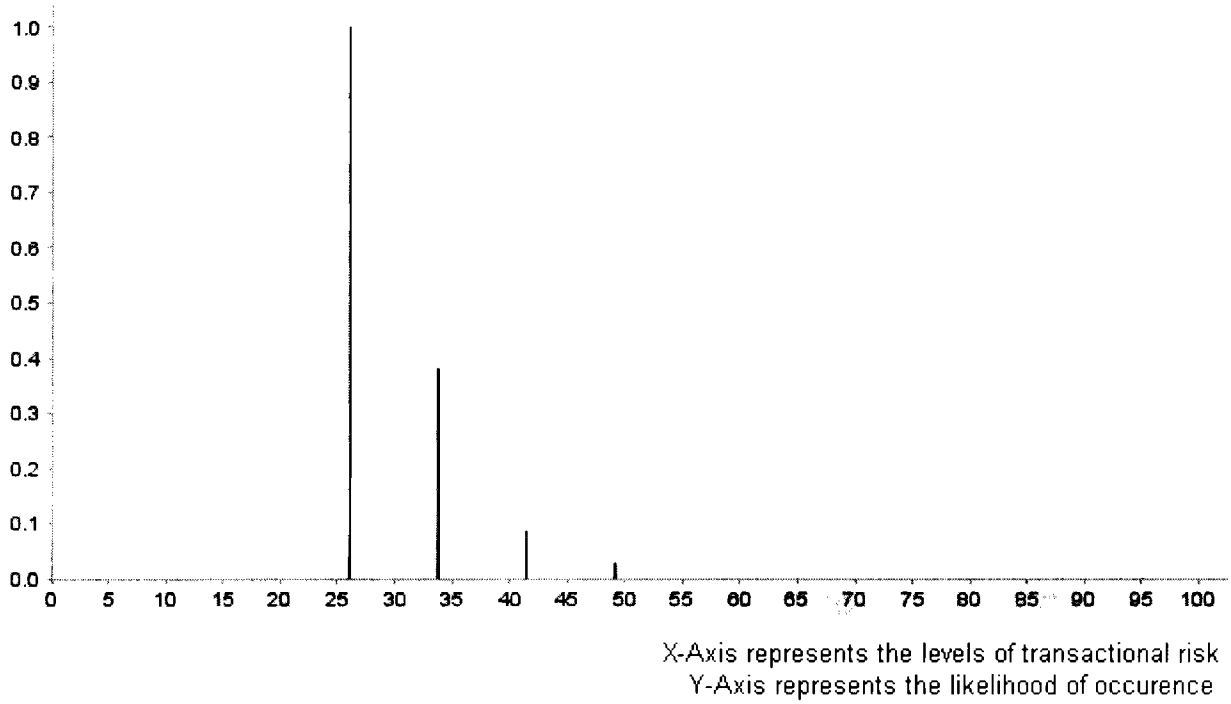

Figure 3 The Numerical Level of Transactional Risk in an Interaction.

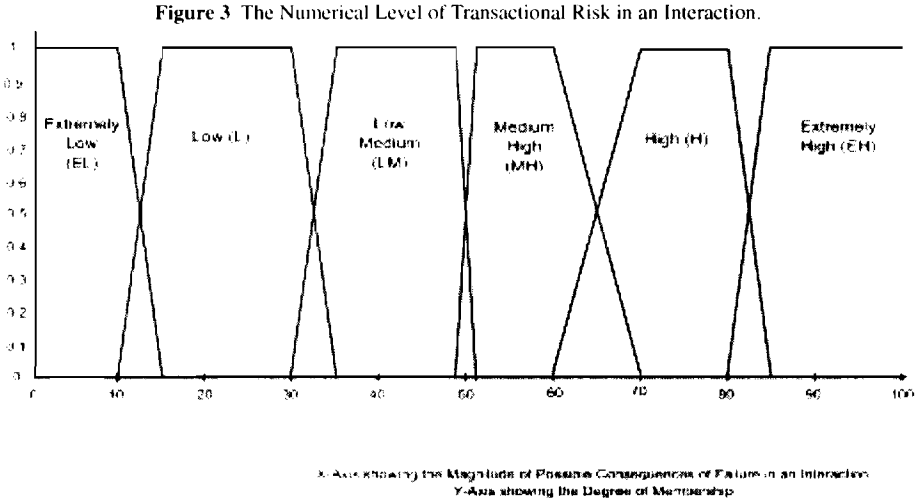

Figure 4 Membership function of the input: Possible Consequences of Failure.

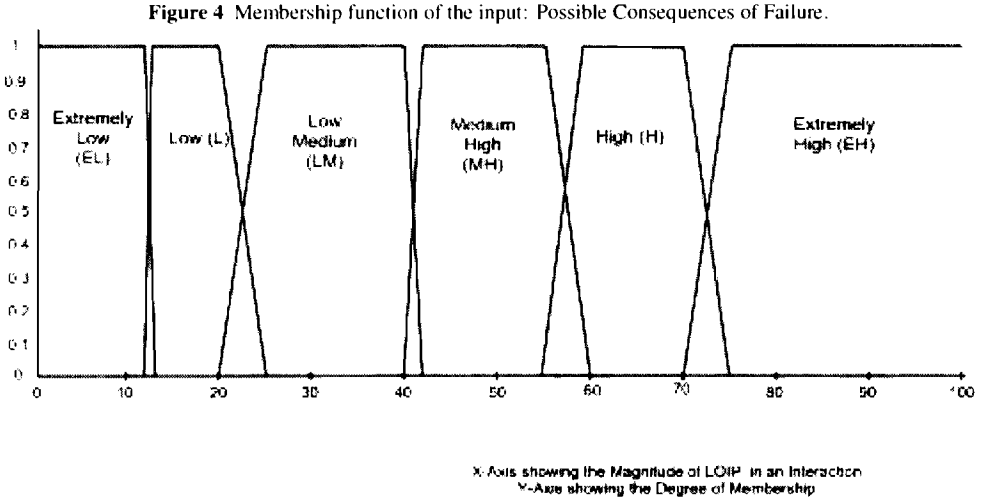

Figure 5 Membership function of the input: Loss of Investment Probability.

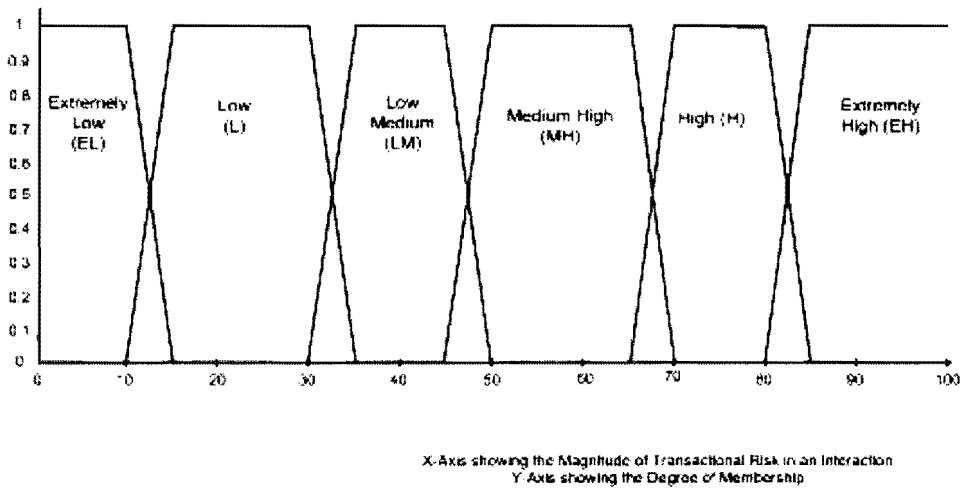

Figure 6 Membership function of the output: Transactional Risk in the Interaction.

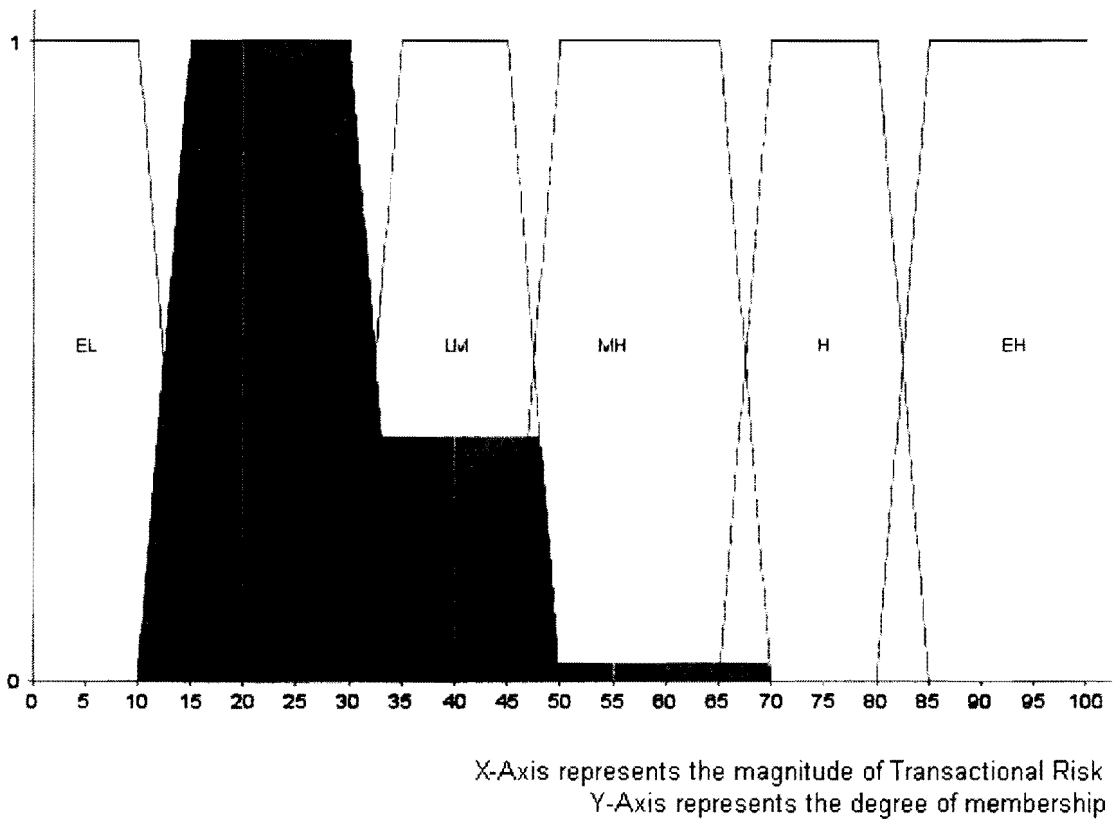

Figure 7 The Linguistic Level of Transactional Risk in an Interaction.

Equation 4 is repeated for each focal element 'x' of an input variable to determine the possibility of occurrence of a fuzzy set or predicate in its UoD. Once all the focal elements of the inputs have been transformed to their corresponding fuzzy sets, they must then be processed in the inference engine of the fuzzy system which consists of fuzzy rules to draw a conclusion on the UoD of the output linguistic variable. The rules which we use in our model are of the IF-THEN structure. The left hand side of the rule is called the conditional part and the right hand side is called as the implication part of the rule. The implication part of the rule gives the level of transactional risk in the interaction based on the computations performed by the inference engine, according to the inputs given to it. We utilize the logic AND operator to consider the intersection between the input fuzzy sets, while implicating the magnitude of risk present in the interaction by utilizing the input fuzzy sets. In our fuzzy inference model, there are two inputs (PCF and LOIP) which are further defined by 6 predicates. Hence, the total number of homogenous rules in our system will be: $6 \times 6 = 36$. The rules of our fuzzy inference model to ascertain the linguistic level of transactional risk are as shown in Table 1.

The output of the fuzzy inference system will be determined by the degree or strength to which each rule fires. The rules use the possibility of the fuzzy set of each input as the weight-

- Risk Taking (RT): 'Risk Taking' is defined as that attitude of the risk assessing agent where it is indifferent to any level of transactional risk and is ready to interact with a risk assessing agent, no matter what level of transactional risk is present in the interaction.

These broad categories cover the different ranges which represents the risk assessing agent's attitude while decision-making. In terms of accepting the levels of transactional risk the risk attitudes of the risk assessing agent is in the order of, RA < RN < RT. It is possible that the risk propensity level of the risk assessing agent might not always be a crisp value which corresponds totally to a given level, but might overlap across the different possible levels. To take such scenarios into account, we propose using a fuzzy inference system to (a) capture the fuzziness of the risk attitude of the risk assessing agent and (b) ascertain its impact on the level of transactional risk and recommend its decision. The operation of the fuzzy recommender system in making this decision can be classified and divided into two parts, the learning part and the computation part. In the learning part, the recommender system 'learns' about the tendency of the risk assessing agent in taking risk in the interaction, and in the computation part, it utilizes the determined tendency of the risk assessing agent in computing the recommended risk-based decision in forming an interaction with the risk assessed agent/s.

Fuzzy Inference Model for Recommending a Risk-based Decision

To capture the fuzziness in the risk propensity of the risk assessing agent, we define the universe of discourse (UoD) for that variable in the range of 1–5; {1, 2, 3, 4, 5} where each element represents a numeric value and is unit-less. To classify different fuzzy sets for the input variable 'Risk Propensity' of the risk assessing agent we divide the universe of discourse into 3 predicates, 'Risk Averse', 'Risk Neutral' and 'Risk Taking' as shown in Figure 8. We aim to determine the accurate risk propensity of the risk assessing agent against a set of psychological questions, whose results are then quantified between the range of 1–5. We do not discuss those set of questions in this paper.

The second input of the fuzzy inference system is the Level of Transactional risk as shown in Figure 6.

The fuzzy inference system based on the inputs given to it computes an output specifying the Recommended Risk-based Decision (RRD). We consider a range of 0–10; {0, 1, 2,. . ., 10} as the universe of discourse (UoD) while determining the recommended risk-based decision output. As our aim is to develop a fuzzy inference system which assists the risk assessing agent in deciding on an interaction with a risk assessed agent, the fuzzy sets for the output variable are defined such that there are two predicates in them. They are 'Proceed' (P) and 'Don't Proceed' (DP) which represents the two possibilities for the risk assessing agent to consider while decision making in an interaction. So the membership function for the output 'Recommended Risk-based Decision in the Interaction' is defined as an intersection of straight lines spread over the universe of discourse for the fuzzy variable, as shown in Figure 9.

Once the input variables have been transformed into fuzzy sets by using their defined membership function, they must then be processed in the inference engine to determine the impact of the risk propensity of the risk assessing agent on the transactional risk in interacting with the risk assessed agent. In the next sub-section, we define the rules for the fuzzy inference system, which recommends a decision output to the risk assessing agent in forming an interaction with a risk assessed agent.

Defining the Rules for Fuzzy Risk-based Decision Recommender Model

As mentioned earlier, with the change in the risk propensity levels the way how the risk assessing agent perceives the transactional risk in an interaction varies. To clarify with an example, a risk assessing agent having a risk propensity nature of Risk Averse (RA) = 1, will analyze the risk in interacting with a risk assessed agent to be acceptable or not in a different way, as compared to the same risk assessing agent if its risk propensity nature might have been a combination of Risk Averse (RA) and Risk Neutral (RN) levels. To take into consideration the intermediate values of the risk assessing agent's risk propensity on the level of transactional risk in the interaction, in Table 2 we define by using fuzzy rules the acceptable levels of transactional risk by the risk assessing agent in interacting with a risk assessed agent, according to the various levels of its risk propensity. Furthermore, while defining the fuzzy rules, if the risk assessing agent's risk propensity is a combination of different attitudes, then we consider the maximum risk attitude (MRA) of the risk assessing agent and based on that determine the maximum level of acceptable transactional risk (MARL) in the interaction. As mentioned earlier, the nature of the risk taking attitude of the risk assessing agent in the interaction is in the order of: RA < RN < RT. Hence, if a risk assessing agent's risk propensity nature is a combination of levels RA and RN with DOM 0.4 and 0.6 respectively, then the maximum risk attitude or risk propensity nature of the risk assessing agent is RN = 0.6. Based on this risk propensity level by using fuzzy rules, the recommender system should determine the maximum level of transactional risk which it can term as acceptable.

It is highly possible that there is more than one fuzzy set or predicate of transactional risk present in interacting with a risk assessed agent. For example, let us consider that a risk assessing agent 'A' determines the level of transactional risk in interacting with agent 'B' as a combination of three predicates: MH = 1, H = 0.1818 and EH = 0.0909. In order for determining on an interaction, the recommender system should consider each predicate of transactional risk and then analyze whether or not it is acceptable to the risk assessing agent according to its risk attitude or risk propensity in the interaction. Three possibilities arise here according to the risk propensity nature of the risk assessing agent 'A':

- the levels of transactional risk in the interaction are totally acceptable to the risk assessing agent;
- the levels of transactional risk in the interaction are totally unacceptable to the risk assessing agent;
- the level/s of transactional risk in the interaction is/are partially acceptable to the risk assessing agent.

For example, if we consider a risk assessing agent's 'A' risk propensity nature to be as RT = 1, then from Table 2 the MARL according to its risk propensity is EH = 1. Based on that, the determined levels of transactional risk in interacting with agent 'B' (MH = 1, H = 0.1818, and EH = 0.0909) are totally acceptable

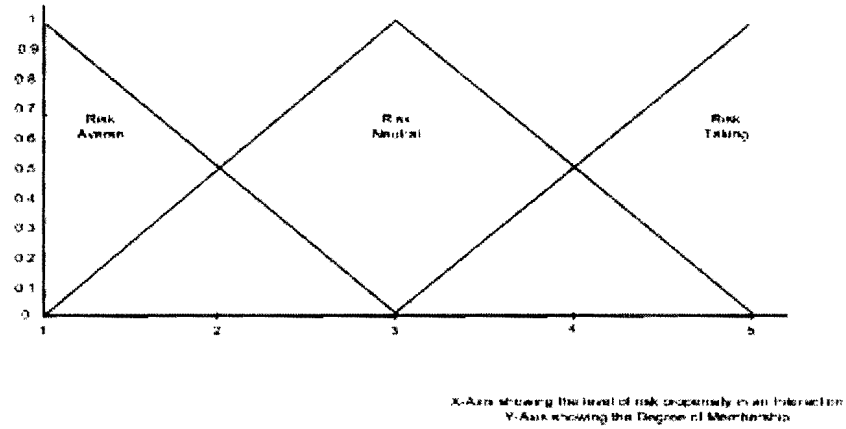

Figure 8 Membership function for the input: Risk Propensity.

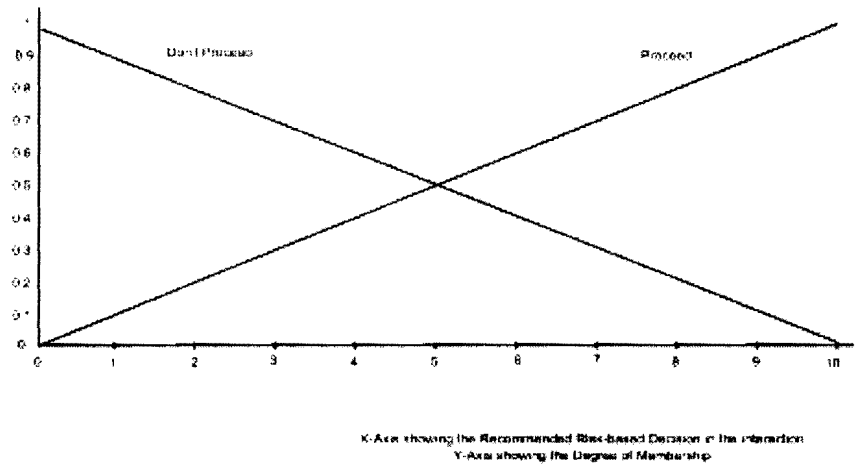

Figure 9 Membership function for the output: Recommended Risk-based Decision.

to the risk assessing agent. Similarly, if the risk propensity of the risk assessing agent is RA = 1, then all the levels of transactional risk in the interaction with agent 'B' are beyond its maximum acceptable level. When the risk assessing agent's risk propensity is RN = 0.6 and RT = 0.4, then it partially accepts the level of transactional risk in the interaction with agent 'B'. In each case, the recommended output (RRD) from the fuzzy recommender system to the risk assessing agent varies according to the level of its acceptance of the transactional risk in the interaction.

In order for the fuzzy recommender system to consider such cases, we introduce a variable called 'Possible to Proceed in the Interaction at this stage' (Poss). A binary value of either 1 or 0 is assigned to this variable for each predicate of transactional risk. The assigned value depends on whether that predicate of transactional risk (CRL) along with its magnitude or occurrence (DOM) is acceptable to the risk assessing agent or not, according to its current risk propensity (CRA). A value of 1 affirms the above condition whereas the value of 0 suggests otherwise. The output of the Poss variable applies only to that predicate of transactional risk. If there are more than one predicate of transactional risk, then the recommender system for each of them should determine the value for the variable Poss according to each predicate of its risk propensity. The risk propensity of the risk assessing agent is represented by three fuzzy sets as shown in Figure 8, and the transactional risk in the interaction is represented by six fuzzy sets as shown in Figure 6. Hence, the total number of homogeneous rules to be defined for the fuzzy inference system to assist in decision making is: $6 \times 3 = 18$, as shown in Table 3. The rules that we use to define the fuzzy model are of the IF-THEN-ELSE structure. The two inputs to the fuzzy system which form the LHS of the rules are combined together with the logic 'AND' operator for the inference part to give the RHS of the rule; which is accepted if the 'Poss' value is true, otherwise the 'ELSE' operator is considered.

The fuzzy system determines the value for the variable 'Poss' in Table 4 for each of the 'CRL' being considered, by taking into consideration the 'MRA' of the risk assessing agent and then comparing if the 'CRL' is less than or equal to the 'MARL'. If this is the case, then the value of 'Poss' in Table 3 at that 'CRL' will be 1 otherwise it will be 0.

Once the fuzzy rules of Table 3 have been evaluated, then they must be aggregated and defuzzified in order to obtain a crisp value on the output membership function. For aggregating the output of the rules we utilize the Root Sum Square (RSS) method. The RSS method determines the square of each rule output which corresponds to a predicate in the output membership function and then sums them up to find its centroid. In our case, as there are two predicates in the output membership function, the aggregation output of all the rules for each predicate is determined by:

Table 2 Defining the fuzzy rules to determine the maximum acceptable level of transactional risk according to the risk propensity of the risk assessing agent.

	MRA		MARL
If	RA = 1	then	EL = 1
If	RN = 0.1	then	L = 0.2
If	RN = 0.2	then	L = 0.4
If	RN = 0.3	then	L = 0.6
If	RN = 0.4	then	L = 0.8
If	RN = 0.5	then	L = 1
If	RN = 0.6	then	LM = 0.2
If	RN = 0.7	then	LM = 0.4
If	RN = 0.8	then	LM = 0.6
If	RN = 0.9	then	LM = 0.8
If	RN = 1	then	LM = 1
If	RT = 0.1	then	MH = 0.34
If	RT = 0.2	then	MH = 0.67
If	RT = 0.3	then	MH = 1
If	RT = 0.4	then	H = 0.34
If	RT = 0.5	then	H = 0.67
If	RT = 0.6	then	H = 1
If	RT = 0.7	then	EH = 0.34
If	RT = 0.8	then	EH = 0.67
If	RT = 0.9	then	EH = 0.99
If	RT = 1	then	EH = 1

Table 3 Defining the rules for the fuzzy recommended risk-based decision model.

	CRL		CRA		RRD		Poss		RRD
If	EL	And	RA	then	P	if	1	else	DP
If	L	And	RA	then	P	if	1	else	DP
If	LM	And	RA	then	P	if	1	else	DP
If	MH	And	RA	then	P	if	1	else	DP
If	H	And	RA	then	P	if	1	else	DP
If	EH	And	RA	then	P	if	1	else	DP
If	EL	And	RN	then	P	if	1	else	DP
If	L	And	RN	then	P	if	1	else	DP
If	LM	And	RN	then	P	if	1	else	DP
If	MH	And	RN	then	P	if	1	else	DP
If	H	And	RN	then	P	if	1	else	DP
If	EH	And	RN	then	P	if	1	else	DP
If	EL	And	RT	then	P	if	1	else	DP
If	L	And	RT	then	P	if	1	else	DP
If	LM	And	RT	then	P	if	1	else	DP
If	MH	And	RT	then	P	if	1	else	DP
If	H	And	RT	then	P	if	1	else	DP
If	EH	And	RT	then	P	if	1	else	DP

$$\mu \text{ 'Proceed'} = \sqrt{\sum (P)}^{2}$$

$$\mu \text{ 'Don't Proceed'} = \sqrt{\sum (DP)^2}.$$

The determined values for each predicate from the aggregation process are then plotted on the output membership function, to ascertain the range of the output. Defuzzifying the range by utilizing the centre of gravity or centroid method gives the scalar output of the fuzzy inference system. This value when plotted on the output fuzzy set represents the recommended risk-based decision from the fuzzy inference model to the risk assessing agent. In the current interaction scenario, if the risk assessing agent 'A' determines its risk propensity value as 2.4, then the quantified fuzzy sets of its risk propensity are RA = 0.3 and RN = 0.7. Based on that, the range of output by the fuzzy system is shown in Figure 10. The centroid of the range is 9.3; which qualifies to the fuzzy sets Proceed and Don't Proceed with strength of 93.114% and 6.886% respectively. This output shows that not all levels of transactional risk present in forming an interaction with agent 'B' are acceptable to agent 'A' and there are some levels which are beyond its acceptable level of transactional risk.

Table 4 Determining the value for the variable 'Poss'.

	MRA		CRL ≤		Poss		Poss
If	RA = 1	And	EL = 1	then	1	else	0
If	RN = 0.1	And	L = 0.2	then	1	else	0
If	RN = 0.2	And	L = 0.4	then	1	else	0
If	RN = 0.3	And	L = 0.6	then	1	else	0
If	RN = 0.4	And	L = 0.8	then	1	else	0
If	RN = 0.5	And	L = 1	then	1	else	0
If	RN = 0.6	And	LM = 0.2	then	1	else	0
If	RN = 0.7	And	LM = 0.4	then	1	else	0
If	RN = 0.8	And	LM = 0.6	then	1	else	0
If	RN = 0.9	And	LM = 0.8	then	1	else	0
If	RN = 1	And	LM = 1	then	1	else	0
If	RT = 0.1	And	MH = 0.34	then	1	else	0
If	RT = 0.2	And	MH = 0.67	then	1	else	0
If	RT = 0.3	And	MH = 1	then	1	else	0
If	RT = 0.4	And	H = 0.34	then	1	else	0
If	RT = 0.5	And	H = 0.67	then	1	else	0
If	RT = 0.6	And	H = 1	then	1	else	0
If	RT = 0.7	And	EH = 0.34	then	1	else	0
If	RT = 0.8	And	EH = 0.67	then	1	else	0
If	RT = 0.9	And	EH = 0.99	then	1	else	0
If	RT = 1	And	EH = 1	then	1	else	0

If there is more than one agent from whom agent 'A' has to determine on an interaction, then by utilizing the proposed approach it can ascertain the different level/s of transactional risk in forming an interaction with them and then utilize their risk attitude to determine on an interaction with them. Based on such analysis it can make an informed decision of its future course of interaction with a risk assessed agent. It is quite possible that none or some of the risk assessed agents might not come with the 100% Proceed value. In such cases, the determined analysis will help the risk assessing agent to ascertain the magnitude to which the determined level of transactional risk is unacceptable to it and then carry out the process of risk management accordingly. This is our future work.

7. CONCLUSION

Risk is an important factor for the interaction initiating agent to consider while decision making in e-business interaction. By

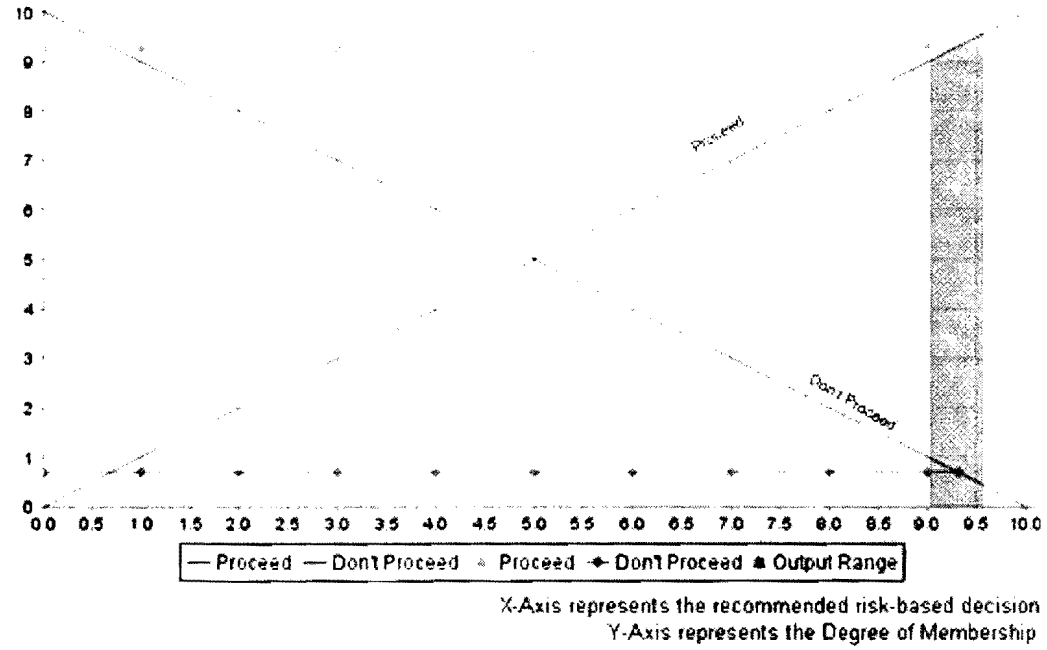

Figure 10 The Recommended Risk-based Decision (RRD) in agent 'A' forming an interaction with agent 'B'.

analyzing the level of risk in an e-business interaction, the initiating agent can ascertain the level of failure and financial loss that it can experience in its business activity. Such an analysis cannot be determined by the assessment of either trust or security in this domain. In this paper, we extended our previous work and proposed a methodology by which the interaction initiating agent determines the numerical and linguistic level of transactional risk in forming an interaction with the other user. Our proposed approach utilizes possibility theory and fuzzy inference system to determine the different numeric and linguistic levels of transactional risk respectively in an interaction. This will help the interaction initiating agent to alleviate the ambiguity and vagueness that is present in its mind before decision-making. We then proposed a fuzzy inference system that captures the risk propensity or risk attitude of the interaction initiating agent and then quantifies its effect on the determined linguistic level of transactional risk. By utilizing the determined analysis, it can make an informed interaction-based decision which in turn would help it to maximize its interaction experience and expected benefits. Our future work is to consider the determined un-acceptable levels of transactional risk in the business activity and then propose an approach for risk management by which they can be alleviated or minimized.

REFERENCES

1. Karl Aberer and Z. Despotovic, "Managing trust in a Peer-2-Peer Information System," in *Proceedings of the Tenth International Conference on Information and Knowledge Management (CIKM'01)*, Atlanta, Georgia, USA, 2001, pp. 310–317.
2. Xiaoqing Zheng, Zhaohui Wu, Huajun Chen, and Y. Mao, "A Scalable Probabilistic Approach to Trust Evaluation," in *Fourth International Conference on Trust Management (iTrust'06)*, Pisa, Italy, 2006, pp. 423–438.
3. Audun Jøsang, Claudia Keser, and T. Dimitrakos, "Can We Manage Trust?," in *Third International Conference on Trust Management (iTrust 2005)*, Rocquencourt, France, 2005, pp. 93–107.
4. Lewis Hassell, "Affect and Trust," in *Third International Conference on Trust Management (iTrust'05)*, France, 2005, pp. 131–145.
5. Siani Pearson, Marco Casassa Mont, and S. Crane, "Persistent and Dynamic Trust: Analysis and the Related Impact of Trusted Platforms," in *Third International Conference on Trust Management (iTrust'05)*, France, 2005, pp. 355–363.
6. Yan Wang, Duncan S. Wong, Kwei-Jay Lin, and V. Varadharajan, "Evaluating transaction trust and risk levels in peer-to-peer e-commerce environments," *Information Systems and E-Business Management*, vol. 6, pp. 25–48, January 2008.
7. Yan Wang, Kwei-Jay Lin, Duncan S. Wong, and V. Varadharajan, "The Design of A Rule-based and Event-driven Trust Management Framework," in *IEEE International Conference on e-Business Engineering (ICEBE'07)*, Hong Kong, 2007, pp. 97–104.
8. Li Xiong and L. Liu, "A Reputation-Based Trust Model for Peer-to-Peer eCommerce Communities," in *International Conference on E-Commerce Technology (CEC'03)*, IEEE, Ed. Newport Beach, California, USA 2003, pp. 275–284.
9. Nathan Griffiths, "Enhancing peer-to-peer collaboration using trust," *Expert Systems with Applications*, vol. 31, pp. 849–858, November 2006.
10. Brian J. Corbitt, Theerasak Thanasankit, and Han Yi, "Trust and e-commerce: a study of consumer perceptions," *Electronic Commerce Research and Applications*, vol. 2, pp. 203–215, 2003.
11. M. Wojcik, Jan H. P. Eloff, and H. S. Venter, "Trust Model Architecture: Defining Prejudice by Learning," in *Third International Conference on Trust, Privacy & Security in Digital Business (TrustBus'06)*, vol. Vol 4083 Krakow, Poland: LNCS 2006, pp. 182–191.
12. Juan Xu, Zhixue Liu, and Y. Li, "Integrating Processes of Logistics Outsourcing Risk Management in e-Business," in *IEEE/WIC/ACM International Joint Conference on Web Intelligence and Intelligent Agent Technology* Hong Kong, 2006, pp. 544–547
13. Wenshuan Xu, Yunwei Xin, and G. Lu, "A Trust Framework for Pervasive Computing Environments," in *2007 International Conference on Wireless Communications, Networking and Mo-*

bile Computing (WiCOM'07), Shanghai, China, 2007, pp. 2222–2225.

14. Rashid Hafeez Khokhar, David A. Bell, Jiwen Guan, and Q. Wu, "Risk Assessment of E-Commerce Projects Using Evidential Reasoning " in *Third International Conference on Fuzzy Systems and Knowledge Discovery (FSKD'06)*, Xi'an, China, 2006, pp. 621–630.
15. Daniel Cvrcek and K. Moody, "Combining Trust and Risk to Reduce the Cost of Attacks," in *Third International Conference on Trust Management (iTrust'05)*, vol. LNCS 3477 Paris, France: Springer, 2005, pp. 372–383.
16. Colin English, Waleed Wagealla, Paddy Nixon, Sotirios Terzis, Helen Lowe, and A. McGettrick, "Trusting Collaboration in Global Computing Systems " in *The First International Conference on Trust Management (iTrust'03)*, Heraklion, Crete, Greece, 2003, pp. 136–149.
17. Gang Xie, Jin-long Zhang, and Kin Keung Lai, "Web-Based Risk Avoidance Group Decision Support System in Software Project Bidding " in *International Conference on Web Intelligence and Intelligent Agent Technology* Hong Kong, 2006, pp. 180–183.
18. Omar K. Hussain, Elizabeth Chang, Farookh K. Hussain, and Tharam S. Dillon, "Determining the Failure Level for Risk Analysis in an e-commerce Interaction," in *Advances in Web Semantics: A state-of-the Art Semantic Web*, E. C. Tharam S. Dillon, Robert Meersman, and Katia Sycara, Ed.: Springer, 2008.
19. Omar Hussain and Tharam Dillon, "Ascertaining the Financial Loss from Non-dependable Events in Business Interactions by using the Monte Carlo method," in *The Fourth International Conference on Availability, Reliability and Security (ARES'09)*, Fukuoka, Japan 2009, pp. 406–411.
20. Omar Hussain, Tharam Dillon, Elizabeth Chang, and Farookh Hussain, "Determining the Net Financial Risk for Decision Making in Business Interactions," in *The IEEE 23rd International Conference on Advanced Information Networking and Applications (AINA-09)*, Bradford, 2009, pp. 822–829.
21. Didier Dubois and H. Prade, "Possibility theory, Probability Theory and Multiple-Valued Logics: A Clarification," *Annals of Mathematics and Artificial Intelligence*, vol. 32, pp. 35–66, 2001 2001.
22. Didier Dubious, Henri Prade, Henri Farreny, Roger Martin-Clouaire, Claudette Testemale, and E. F. Harding, *Possibility Theory: An Approach to Computerized Processing of Uncertainty*. New York: Plenium Press, 1988.
23. John L. Darby, "Estimating Terrorist Risk with Possibility Theory," 2004.
24. Riza C. Berkan and S. L. Trubatch, *Fuzzy Systems Design Priciples*. New York: IEEE Press, 1997.
25. E. H. Mamdani, "Applications of Fuzzy Set Theory to Control Systems: A Survey," in *Fuzzy Automata and Decision Processes*, North-Holland, New York, 1977, pp. 1–13.
26. Sim B. Sitkin and L. R. Weingart, "Determinants of Risky Decision-Making Behavior: A Test of the Mediating Role of Risk Perceptions and Propensity," *Academy of Management Journal*, vol. 38, pp. 1573–1592, December 1995.
27. Paul Andreassen, "The Psychology of Risk: A Brief Primer," The Levy Economics Institute 1993.