A methodology to quantify failure for risk-based decision support system in Digital Business Ecosystems

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

Digital Ecosystems and Business Intelligence Institute, Curtin University of Technology, Perth, Australia
Email: omar.hussain@postgrad.curtin.edu.au, {elizabeth.chang, farookh.hussain, tharam.dillon}@cbs.curtin.edu.au

Abstract

In digital business ecosystem architecture it is rational for the trusting agent to analyse the possible risk according to its demand before interacting with a probable trusted agent. Doing so would assist the trusting agent in its decision process and would also give the trusting agent a hint of the direction in which the interaction might head. The possible risk in an interaction is a combination of the probability of failure and the possible consequences of failure of an interaction. In this paper, we propose a methodology by which the trusting agent determines the probability of failure in interacting with a probable trusted agent. The determined probability of failure by the trusting agent is according to the specific demand of its future interaction with the probable trusted agent.

Keywords: Criteria, FailureLevel, Trusting agent, Trusted agent.

1. Introduction

The development of the internet has provided users with numerous mechanisms for conducting or facilitating e-commerce interactions [1]. The terms 'trusting agent' and 'trusted agent' define the two agents participating in an interaction. The former refers to the instigator of the interaction while the latter refers to the agent accepting the request. In other words, this is the agent with whom the trusting agent interacts with to achieve its desired outcomes. The significance of the trusting agent to analyse the possible risk before initiating an interaction with a probable trusted agent is substantial. The trusting agent, by analysing the possible risk beforehand, could gain an idea of whether it will achieve its desired outcomes from the interaction or not. Based on this, it can safeguard its resources.

Risk analysis is important in the study of behaviour in e-commerce because there is a whole body of literature based in rational economics that argues that the decision to buy is based on the risk-adjusted cost-benefit analysis [2]. Thus, it commands a central role in any discussion of e-commerce that is related to a transaction. The need to distinguish between the likelihood and magnitude of risk is important as they represent different concepts. For example, the likelihood of selling an item on the web decreases as the cost of the product increases and vice versa. The likelihood of a negative outcome might be the same in both transactions but the magnitude of loss will be greater in the higher cost transaction. Risk plays a central role in deciding whether to proceed with a transaction or not. It can broadly be defined as an attribute of decision making that reflects the variance of its possible outcomes. The Australian and New Zealand Standard on Risk Management, AS/NZS 4360:2004, states that Risk Identification is the heart of Risk Management [3]. Therefore the trusting agent, by identifying and analysing the possible risk beforehand in interacting with a probable trusted agent, can make an informed decision of whether to interact with that particular agent or not. Alternatively it can choose an agent to interact with from the set of probable trusted agents.

Digital Business Ecosystems is a new concept that is emerging worldwide as an innovative approach to support the adoption and development of information and communication technologies. Digital ecosystems transcend the traditional rigorously defined collaborative environments from centralized or distributed or hybrid models into an open, flexible, domain clustered, and demand-driven interactive environment. A digital ecosystem is a new-networked architecture and collaborative environment that addresses the weakness of client-server, peer-to-peer, grid and web services. It is a self-organizing digital infrastructure aimed at creating a digital environment for networked organizations that supports the cooperation, knowledge sharing, development of open and adaptive technologies and the evolutionary business models [4-6]. It can also be defined as a system which is loosely coupled, agent-based collaborative environment where every specie is proactive and responsive and acts for its own benefit or profit. A business ecosystem is the network of buyers, suppliers and makers of related products or services plus the socio-economic environment. An agent in a Digital Ecosystem can be a client and a server at the same time. They may offer their service to others as a server and request help as a client. The communication and collaboration is through swarm intelligence. Unlike traditional environments, digital ecosystems are self-organizing systems which can form different architectural models through swarm intelligence. A demand driven business ecosystem interaction implies that the trusting agent wants to achieve certain desired outcomes in its future interaction and in order to achieve that it should select a trusted agent who can fulfil its demand. In doing that, it is possible the trusting agent has to decide and choose a trusted agent to interact with among a set of probable trusted agents. The trusting agent can analyse the possible risk according to its demand and can ease the decision making process of which agent to interact with. The possible risk in an interaction is a combination of:

- The probability of failure in achieving the outcome; and
- The possible consequences of failure.

As a step towards analysing the possible risk in an interaction beforehand, in this paper, we propose and develop a methodology by which the trusting agent can determine the probability of failure in interacting with a probable trusted agent to achieve its demand. This paper is organised in seven sections. In section 2, we discuss the definitions of Risk defined in the literature and highlight the need to analyze the possible Risk before initiating an interaction. In section 3, we propose the methodology of determining the probability of failure of an interaction. From section 4 to section 6 we explain the proposed methodology with an example and finally in section 7, we conclude the paper.

2. Related Work

In this section we will discuss about the existing work in the literature related to Risk in an interaction. In the literature Risk has been defined in different ways by different researchers. To summarize some of those definitions, March and Shapira [7] define Risk more by the magnitude of the value of the outcome rather than by taking its likelihood. This paradigm of Risk is more common in business transactions. Luhmann [8] defines Risk in a transaction where the possible damage might be more than the advantage sought. This type of perception is more common in finance and investments where the expected returns are high. Mayer, Davis and Schoorman [9] conclude that Risk is present in the transaction only if the negative outcome outweighs the positive outcome at the end of the transaction. In contrast to this definition, Rousseau et al [10] measure Risk as the potential negative consequence and probability of failure. Sztompka [11] defines Risk as the probability of the loss of the resources invested. Grazioli and Wang [12] views Risk as the consumers' perception of the uncertainty and adverse consequences of engaging in an activity. Cheung and Lee [13] define Risk as having two dimensions; one related to the uncertainty or probability of loss notion and the other related to a consequence of the importance of the notion of loss. Jarvenpaa et al [14] define Risk in Information Systems by using items reflecting its likelihood such as too much uncertainty, how to characterize a decision to proceed with a transaction.

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The above mentioned definitions of Risk though have been defined in different context but they all emphasize on the probability of failure and the possible loss in an interaction. This loss varies according to the context in which it is being discussed. In the context of a financial e-interaction the possible loss is to the resources of the trusting agent involved in the interaction.

There is still confusion in the relationship between Trust and Risk. As Mayer et al [9] suggest 'it is unclear whether Risk is an antecedent to trust'. It is a well known fact that Risk & Trust are dependent on each other, but it is still unclear whether Risk is an antecedent to Trust or an outcome of Trust. Different arguments can be given to this. It can be said that in an interaction Risk creates an opportunity for Trust which leads to Risk taking. In this case Risk is an antecedent to Trust. But it can also be said that when the interaction is done based on the level of Trust, then there is a low amount of Risk in it. In this case Risk is an outcome of Trust. Risk can also provide a moderating relationship between Trust and the behaviour of the Peer in an interaction. For example the effect of Trust on the behaviour is different when the level of Risk is low and different when the Risk is high. Similarly Risk can have a mediating relationship on Trust. For example the existence of Trust reduces the perception of Risk which in turn improves the behaviour in the interaction and willingness to engage in the interaction.

It is important to comprehend the difference between Trust and Risk as they are two different terms that express different concepts, but they complement each other [15]. Risk evaluation involves the trusting agent to determine beforehand the probability of failure and the subsequent possible consequences of failure to its resources in interacting with the probable trusted agent. On the other hand trust evaluation measures the belief that the trusting agent has in a probable trusted agent in attaining its desired outcomes if it interacts with it. The trust evaluation is done by the trusting agent either by considering its own experience or by considering the other agents recommendations but this does not take into account the amount of resources invested in the interaction. A lot of work has been done in the literature to determine and evaluate the trust in an interaction [21-30]. We will not be discussing it here as our aim in this paper is not trust evaluation, where as it is to determine one aspect towards risk evaluation, namely determining the probability of failure of the interaction. As mentioned before the inclusion of Risk in the study of behaviour of e-commerce transaction is important because there is a large volume of literature based in rational economics that argues that the decision to proceed with the transaction is based on the Risk adjusted cost benefit analysis and analyzing Risk in the transaction is really important with the widespread use and incursion of the Internet in our day to day life, particularly with the advent of business and e-commerce transactions in digital business ecosystem domain.

Through the above discussion, it is evident that Risk measurement, prediction and management is indeed needed before initiating an e-commerce interaction in a digital business ecosystem domain. We need a Risk management tool which complies with Australian and New Zealand Standard on Risk Management AS/NZS 4360:2004 and that helps in analyzing and evaluating the risk. In order to achieve that, we defined risk in the context of e-commerce transactions conducted in digital business ecosystem domain as 'the likelihood that the trusted agent might not act as expected according to the trusting agent's expectations in a given context and at a particular time once the interaction begins, resulting in the loss of dollars and the resources involved in the interaction'. Context represents the high level nature of the trusting agent's interaction with the trusted agent [16]. It can be decomposed into several detail aspects called as the criteria. Criteria is defined as the demand or the set of factors which show specifically what the trusting agent wants in its interaction with the trusted agent in the particular context.

In order to ascertain the possible risk in an interaction, the probability of failure and the possible consequences of failure of an interaction must be quantified. To quantify and represent semantically the probability of failure of an interaction, we define the term 'FailureLevel' and the 'Failure scale'. 'FailureLevel' (FL) is defined as the numerical value that is assigned by the trusting agent to the trusted agent after interacting with it, which shows the level of failure of the interaction on the Failure scale. The Failure scale as shown in Figure 1 has 7 different probable levels of failure that could be present in the interaction, with level 0 representing the highest level of failure and level 5 representing the lowest level of failure.

Semantics of Failure Level	Probability of Failure	FailureLevels	Star Rating
Unknown		- 1	Not Displayed
Total Failure	91 - 100 % Probability of Failure	0	Not Displayed
Extremely High	71 – 90 % Probability of Failure	1	From ⭐ to ⭐
Largely High	51 – 70 % Probability of Failure	2	From ⭐⭐ to ⭐⭐
High	26 – 50 % Probability of Failure	3	From ⭐⭐⭐ to ⭐⭐⭐
Significantly Low	11- 25 % Probability of Failure	4	From ⭐⭐⭐⭐ to ⭐⭐⭐⭐
Extremely Low	0 – 10 % Probability of Failure	5	From ⭐⭐⭐⭐⭐ to ⭐⭐⭐⭐⭐

Figure 1 showing the Failure scale

The trusting agent assigns a FailureLevel to the trusted agent after interacting with it by assessing the level of un-commitment in the trusted agent's actual behaviour in the interaction as compared to the expected behaviour. In other terms, this is the in-capability of the trusted agent to complete the interaction according to the expected behaviour. *Expected behaviour* is defined as that behaviour which the trusted agent was supposed to commit to in completing the interaction [16]. This expected behaviour is defined by the trusting agent before starting its interaction with the trusted agent and is according to the criteria of its interaction. The actual behaviour is the commitment that the trusted agent showed or behaved in the interaction. Hence, the FailureLevel that the trusting agent assigns to the trusted agent after the interaction is by assessing the un-committed behaviour of the trusted agent according to the criteria of its interaction. The methodology by which the trusting agent sets the criteria and later assesses and assigns a FailureLevel to the trusted agent after interacting with it, depending on the level of its un-committed behaviour in the interaction is defined in Hussain, Chang, Hussain and Dillon [17].

By utilising this methodology, the trusting agent assigns a failure level to the trusted agent after completing its interaction with it. For risk analysis before initiating an interaction, a trusting agent has to determine the probability of failure and the possible consequences of failure before starting an interaction with the probable trusted agent. The determined probability of failure of the interaction by the trusting agent should be strictly according to the criteria of its future interaction with the probable trusted agent. Further, it is likely that the trusting agent, before initiating an interaction, might have to select an agent to interact with from a set of possible trusted agents. If the trusting agent does not have an interaction history with any of the possible trusted agents in the context of its future interaction then it is difficult for it to decide which particular agent to interact with. One way by which the trusting agent can ease its decision making process is by determining the possible level of risk beforehand. To achieve that, in this paper, we propose a methodology of determining the probability of failure (FailureLevel) of an interaction beforehand as a step towards risk analysis of an interaction.

In the next sections, we define the process by which the trusting agent can determine the FailureLevel in interacting with a probable trusted agent before initiating an interaction with it.

3. Determining the FailureLevel of an Interaction

The FailureLevel of an interaction is the extent to which the trusting agent ascertains that it might not achieve its desired outcomes in interacting with a probable trusted agent. The trusting agent can determine the FailureLevel in interacting with a probable trusted agent beforehand, by analysing the trusted agent's in-capability to complete the interaction according to the expected behaviour of its future interaction. By considering the expected behaviour, the trusting agent is analysing the FailureLevel in interacting with a probable trusted agent according to the criteria of its future interaction. The possible interaction of the trusting agent with the probable trusted agent is in the future state of time. Hence, for risk analysis, the trusting agent has to determine the FailureLevel in interacting with the probable trusted agent in the future. In order to achieve that, we propose that the trusting agent analyse the FailureLevel in interacting with a probable trusted agent in two stages. They are:

1. Pre-interaction start time phase
2. Post-interaction start time phase

Pre-interaction start time phase refers to the period of time before the trusting agent starts its interaction with the probable trusted agent, whereas *Post-interaction start time phase* is the period of time after the trusting agent starts and interacts with the probable trusted agent. The trusting agent has to determine the FailureLevel in interacting with a probable trusted agent in that future state of time, i.e. in the post-interaction start time phase. In order for the trusting agent to determine the FailureLevel in interacting with a probable trusted agent in the post-interaction start time phase, it should know its FailureLevel according to the specific context and criteria as that of its future interaction, in the pre-interaction start time phase. Based on the FailureLevel achieved for the probable trusted agent in the pre-interaction start time phase, the trusting agent can predict the FailureLevel of the probable trusted agent in the post-interaction start time phase.

We will explain the process of determining the FailureLevel in interacting with a probable trusted agent in each time phase in the next sub-sections.

3.1 Determining the FailureLevel in Pre-Interaction Start Time Phase

The trusting agent can determine the FailureLevel in interacting with a probable trusted agent in the pre-interaction start time phase either:

a) By considering its past interaction history with the probable trusted agent in the same context and criteria as that of its future interaction with it; or
b) By soliciting recommendations from other agents and determining the in-capability of the trusted agent to complete the interaction according to the criteria of its future interaction with it.

If the trusting agent has a past interaction history with a probable trusted agent in the same context and criteria as that of its future interaction, then it can determine the FailureLevel of the probable trusted agent in the pre-interaction start time phase by analysing those past interactions. As mentioned in the literature, risk varies according to the time and context of the interaction. Hence, if the trusting agent's past interactions with the probable trusted agent were long ago as compared to its future interaction or if they are in a different context as compared to its future interaction, then those past interactions cannot be utilised to determine the FailureLevel of the probable trusted agent. In such a case, the trusting agent has to solicit for recommendations to determine the FailureLevel of the particular trusted agent in the pre-interaction start time phase. As mentioned by Carter and Ghorbani, reputation can be relied on in the event of total ignorance [18]. But the reputation of a probable trusted agent shows its capability to complete the interaction. In order for the trusting agent to

determine the FailureLevel of an interaction it should determine the in-capability of the probable trusted agent to complete the interaction according to its expectations.

To achieve that, we propose the trusting agent should first determine the reputation of the probable trusted agent in the pre-interaction start time phase according to the context and criteria of its future interaction with it on the failure scale. By doing so, the trusting agent knows the capability of the probable trusted agent to complete the interaction according to the criteria of its future interaction on the failure scale. It can then determine the probability of failure in interacting with that particular probable trusted agent by ascertaining the difference between what it expects in the interaction and how far the probable trusted agent can fulfil it according to its reputation. The value achieved gives the probability of failure of the interaction according to the criteria of its future interaction with it. The FailureLevel is achieved by mapping the probability of failure of the interaction to the failure scale.

In order to determine the reputation of the probable trusted agent, the trusting agent solicits for recommendations in the context of its future interaction. The agents who have had previous interaction history with the probable trusted agent in the particular context reply back with their recommendations. We term the agents replying back with the recommendations as the *Recommending agents*. The trusting agent on getting the recommendations should classify them according to the criteria of its future interaction and then assimilate them to determine the reputation of the probable trusted agent on the failure scale. It would be difficult for the trusting agent to understand the meaning of the recommendations and later assimilate them, if each agent when solicited for, gives its recommendation in its own format. So, we propose that the recommending agents should communicate their recommendation in a standard format called as the *Risk set*. Doing so would help the trusting agent to understand each element of the recommendation easily and to assimilate it properly. The format of the Risk set is:

{TP1, TP2, Context, PFL, FFL, FL, (Criteria, Commitment level), Cost, Start time, End time, RRP}

Where:

TP1: is the trusting agent in the interaction who is also the recommending agent while giving recommendation.

TP2: is the trusted agent in the interaction.

Context: represents the context of the interaction.

PFL: stands for 'Previous FailureLevel'. This represents the FailureLevel of the trusted agent determined by the recommending agent before interacting with it and according to its expected behaviour, in the pre-interaction time phase of its interaction.

FFL: stands for 'Future FailureLevel'. This represents the FailureLevel of the trusted agent determined by the recommending agent, before interacting with it and according to its expected behaviour, in the post-interaction start time phase of its interaction.

FL: stands for 'FailureLevel'. This represents the actual FailureLevel of the interaction on the failure scale. This is determined by the recommending agent after interacting with the trusted agent by assessing the level of un-commitment in the trusted agent's actual behaviour with respect to its expected behaviour.

(Criteria, Commitment level): Criteria represent the demand or factors on which the recommending agent interacted with the trusted agent and later assigned it with the 'FailureLevel' after its interaction. These criteria are necessary to mention while giving recommendations, so that a trusting agent who solicits recommendations knows the criteria on which this particular trusted agent has been assigned the recommended 'FailureLevel'. In this way it can consider only those recommendations which are of interest to it according to the criteria of its future interaction. Commitment level specifies whether the particular criterion was fulfilled by the trusted agent or not. A value of either 0 or 1 assigned here is based on its commitment. A value of 0 signifies that the criterion was not fulfilled by the trusted agent according to the expected behaviour whereas a value of 1 signifies that the criterion was fulfilled according to the expected behaviour. Further explanation is given in Table 1

Cost: represents the cost of the interaction.
Start Time: is the time at which the recommending agent started the interaction with the trusted agent.
End time: is the time at which the interaction of the recommending agent ended with the trusted agent.
RRP: is the Riskiness value of the recommending agent while giving recommendations. This value determines whether the agent is trustworthy or not while giving recommendations.

Commitment Level	Semantics of the Value
0	The trusted agent did not commit to the criterion as it was expected from it according to the expected behaviour
1	The trusted agent committed to the criterion exactly according to the expected behaviour

Table 1 Showing the Commitment level of each criterion

Once the trusting agent receives all the recommendations for a probable trusted agent, it should assimilate those in order to determine the reputation and subsequently the FailureLevel of that probable trusted agent in the pre-interaction start time phase according to the criteria of its future interaction with it. Some factors to be considered by the trusting agent while assimilating the recommendations are:

3.1.1 Trustworthiness of the Recommendations

There is a possibility of the recommending agents giving un-trustworthy or incorrect recommendations. In order to avoid such recommendations while determining the reputation of the probable trusted agent, we propose that the trusting agent should first determine whether the recommendation is trustworthy or not, before assimilating it. We adopt the methodology mentioned by Chang, Dillon and Hussain [19] of classifying the recommendations according to their trustworthiness. To summarise that methodology, an agent whose Riskiness value while giving recommendation (RRP) is in the range of (-1, 1) is said to be a trustworthy recommending agent. An agent whose RRP while giving recommendations is beyond this range is said to be giving un-trustworthy recommendations and, hence, an un-trustworthy recommending agent. Further, Chang et al. [19] mentions that the trusting agent should consider recommendations from only trustworthy and unknown recommending agents and omit the ones from the un-trustworthy recommending agents in order to determine the reputation of the probable trusted agent correctly.

3.1.2 Time Based FailureLevel Assessment

We define risk as the likelihood that the probable trusted agent will not act as expected by the trusting agent resulting in the failure of the interaction and loss of resources involved in it. This 'likelihood' varies throughout the transaction depending on the behaviour of the probable trusted agent and, therefore, it is dynamic. As mentioned in the literature too, risk is dynamic and varies according to time. It is not possible for an agent to have the same impression of a trusted agent throughout that it had at a particular time. Hence the trusting agent should take into account this dynamic nature of risk while doing risk analysis in its future interaction with a probable trusted agent. In order to incorporate and consider its dynamic nature, we propose that the trusting agent should determine the FailureLevel in interacting with a probable trusted agent in regular intervals of time to ascertain it correctly according to that particular interval of time. Further by doing so the trusting agent can give more weight or importance to those recommendations which are in the recent intervals of time to its future interaction with the trusted agent as compared to those which are in far recent ones, while determining the FailureLevel of that trusted agent. We will define some terms by which the recommendations can be classified according to time.

We quantify the level of failure on the failure scale in interacting with a probable trusted agent in a given context and at a given time 't' which can be either at the current, past or future time with the metric *FailureLevel*. But for better understanding we represent the FailureLevel of a probable trusted agent according to the time phase to which they correspond to. For example, if a FailureLevel for a probable trusted agent is determined in the pre-interaction start time phases then we represent it by the metric 'PFL' which stands for 'Previous FailureLevel'. Similarly, if the FailureLevel for the probable trusted agent is determined in the post-interaction start time phases we represent it by 'FFL' which stands for 'Future FailureLevel'.

We define the total boundary of time which the trusting agent takes into consideration to determine the FailureLevel (previous or future) of a probable trusted peer as the *time space*.

It is not possible for the trusting agent to assess and determine the FailureLevel of a probable trusted agent correctly if the time space is of a long duration. As mentioned earlier, risk varies according to time and it is possible that in a time space the probable trusted agent's FailureLevel might not be the same throughout. Hence, we propose that the total time space is divided into different non-overlapping parts and the trusting agent assess the FailureLevel of the probable trusted agent in each of those parts. These different non-overlapping parts are called as *time slots*.

The time at which the trusting agent or any other agent giving recommendation deals with the probable trusted agent in the time slot is called as *time spot*.

The trusting agent should first decide about the total time space over which it is going to analyze the FailureLevel of a probable trusted agent. Within the time space, the trusting agent should determine the duration of each time slot. Once it knows the duration of each time slot it can determine the number of time slots in the given time space and subsequently analyze the FailureLevel of the probable trusted agent in each time slot, may it be either in past or future.

For explanation sake, let us suppose that a trusting agent wants to interact with a probable trusted agent for a period of 14 days. This is the post-interaction start time phase. Before initiating the interaction, the trusting agent wants to determine the level of failure of the interaction as a first step towards risk analysis. To achieve that, the trusting agent wants to assess the reputation of the probable trusted agent, to determine its FailureLevel from a period of 14 days prior to starting an interaction with it. This is the pre-interaction start time phase. Hence, the total period of time which the trusting agent takes into consideration to determine the FailureLevel (PFL and FFL) of the probable trusted agent is of 28 days. This time space is a combination of pre and post interaction start time phase. Further, the trusting agent wants to analyse the FailureLevel of the probable trusted agent on a weekly basis. The total time space is 28 days and the time slot is of 7 days. The number of time slots in this time space will be 4.

By dividing the time space into different time slots, the trusting agent can give more weight or importance to those recommendations which are near to the time spot of its interaction with a probable trusted agent while determining its FailureLevel in the pre-interaction start time phase.

3.1.3 Criteria of the Recommendations

As mentioned earlier, the recommending agents when solicited for recommendations for a probable trusted agent in a particular context reply back with the FailureLevel (FL) that they assigned to that trusted agent in that particular context as their recommendation, in the form of Risk set. The recommendation from a recommending agent for the probable trusted agent is according to the criteria of its interaction. Criteria are the factors against which the un-committed behaviour of the trusted agent was assessed by the recommending agent and subsequently assigned with a FailureLevel.

It is possible that a trusting agent soliciting for recommendations to ascertain the FailureLevel of a probable trusted agent in a particular context, might have different criteria in its future interaction with it as compared to those of the

recommending agents, who had interacted previously with the same trusted agent, in the same context. To explain with an example, two trusting agents 'A' and 'B' might have different criteria in their interaction with the same trusted agent 'D' in the same context, and the FailureLevel they assign to the trusted agent 'D' after their interaction is according to their own individual criteria. If at a later stage, a future trusting agent 'E' solicits for recommendations about the probable trusted agent 'D' from agents 'A' and 'B' in the same context as their previous interaction, then they reply back with the FailureLevel (FL) that they had assigned to the trusted agent 'D' in the form of Risk set as their recommendation. But the FailureLevel recommended by the recommending agents 'A' and 'B' for the probable trusted agent 'D' is according to the criteria of their individual interaction. It is extremely possible that these recommendations might not be of any use to the future trusting agent 'E' in ascertaining the FailureLevel of the probable trusted agent 'D', as it might have a different set of criteria in its future interaction as compared to those of the recommending agents, even though the context remains the same. If this is the case then the reputation and subsequently the FailureLevel determined by the trusting agent 'E', for the trusted agent 'D' by assimilating these recommendations in the pre-interaction start time phase, is incorrect and not according to the criteria of its future interaction with it. Based on these values, the trusting agent 'E' cannot determine correctly the FailureLevel in interacting with the probable trusted agent 'D' in the post-interaction start time phase according to the criteria of its future interaction. Hence, the trusting agent 'E', while assimilating the recommendations should consider and take only those recommendations whose criteria are of interest to it in its future interaction.

All these factors have to be considered by the trusting agent before it assimilates the recommendations to determine the reputation and the FailureLevel of a probable trusted agent in the pre-interaction start time phase, according to the context and criteria of its future interaction with it. In the next sections, we will propose a methodology by which the trusting agent can assimilate the recommendations after classifying them according to its trustworthiness, time and criteria.

3.1.4 Assimilating the Recommendations to determine the FailureLevel in Pre-Interaction time start phase

To explain the process of assimilating the recommendations in order to ascertain the reputation and subsequently the FailureLevel of a probable trusted agent in the pre-interaction start time phase, let us consider the following example of a trusting agent 'E' wanting to interact with a logistic company in the context of transporting its goods. The criteria that the trusting agent wants in its interaction are C1, C2 and C3. The possible agents to interact with, are agents 'D' and 'Z' who are willing to fulfil the trusting agent's request. These agents are the set of probable trusted agents from which the trusting agent has to decide and choose one of them to interact with. The trusting agent 'E' does not have any past interaction history with any of the probable trusted agents and in order to make an informed decision, it decides to analyse the possible risk that could be present in interacting with each of them. In order to ascertain the probability of failure in dealing with each probable trusted agent, agent 'E' solicits for recommendations to determine the reputation and subsequently the FailureLevel of each probable trusted agent in the pre-interaction start time slots according to the context and criteria of its future interaction with them. The agents, who had previous interaction history with the probable trusted agents and in the same context of question, reply back with their recommendations, in the form of Risk set. The trusting agent should then classify and consider only those recommendations whose criterions are of interest to it in its future interaction with the probable trusted agents.

As discussed before, it is possible that the recommendations which the trusting agent gets for a probable trusted agent in a pre-interaction time slot, might not be strictly according to the criteria of its future interaction, or might reflect partially the criteria composing its future interaction with the probable trusted agent. Further it is possible that there might be more than one recommendation in a criterion of interest to the trusting agent in a particular time slot. Hence to utilize these types of recommendations we propose that in each pre-interaction time slot, the trusting agent should determine the reputation and subsequently the FailureLevel of the probable trusted agent, according to each criterion of its future interaction with it, by assimilating the recommendations of that criterion. It can then combine the FailureLevel of each criterion in a time slot to determine a crisp FailureLevel of the trusted agent in that time slot. By doing so the trusting agents considers all the recommendations of interest that it gets for a particular criterion in a time slot, for a probable trusted agent.

The reputation of a particular trusted agent 'P' in criterion 'C' (Rep$_{PC}$) can be determined by assimilating the trustworthy and unknown recommendations by using the following formulae:

Reputation value of the trusted agent 'P' in criterion 'C' (Rep$_{PC}$) =

$$(*((*\frac{1}{N} (\sum_{i=1}^{N} RRP_i \oplus \text{Commitment Level}_c)) + (*\frac{1}{K} (\sum_{l=1}^{K} RRP_l \oplus \text{Commitment Level}_c))))$$

$$+$$

$$(*((*\frac{1}{J} (\sum_{o=1}^{J} \text{Commitment Level}_c)) + (*\frac{1}{M} (\sum_{q=1}^{M} \text{Commitment Level}_c)))) \qquad \dots.. \text{Equation 1}$$

Where:
RRP$_i$ is the Riskiness value of the trustworthy recommending agent 'i' whose recommendation is in the recent time slot of the trusting agent's future interaction,
RRP$_l$ is the Riskiness value of the trustworthy recommending agent 'l' whose recommendation is in the far recent time slot of the trusting agent's future interaction,
Commitment level$_c$ is the level of commitment by the trusted agent in the particular criterion 'c' as recommended by the recommending agent in its recommendations,
N and K are the number of trustworthy recommendations classified according to the recent and far recent time slots respectively,
J and M are the number of unknown recommendations classified according to the recent and far recent time slots respectively,
   and   are the variables attached to the parts of the equation which give more weight to recommendations which are in the recent time slot as compared to the far recent ones . In general   >   and   +   = 1,
   and   are the variables attached to the parts of the equation which will give more weight to the recommendation from the trustworthy recommending agents as compared to those from the unknown recommending agents. In general   >   and   +   = 1.

The reputation value of the probable trusted agent 'P' in a criterion 'C' is determined in two parts as shown in equation 1. The first part of the equation calculates the reputation value of the probable trusted agent 'P' in the criterion 'C' by taking the recommendations of the trustworthy recommending agents. The second part calculates the reputation value of the same probable trusted peer 'P' in the same criterion by taking the recommendations of the unknown recommending agents. The recommendations from the un-trustworthy recommending agents are left out and not considered. In order to give more importance to the recommendations from the trustworthy recommending agents as compared to ones from the unknown recommending agents, variables are attached to the two parts of the equation. These variables are represented by   and   respectively. It depends upon the trusting agent as to how much weight it wants to assign each type of recommendation. Further, the reputation value determination of the probable trusted agent 'P' in a criterion 'C' by taking the trustworthy and unknown recommendations too is done in two parts according to the time slot of the recommendations. We propose that the trusting agent gives more weight to the recommendations which are in the recent time slot of its interaction as compared to the far recent time slot ones. Those weights are represented by the variables   and   respectively.

The RRP of the trustworthy recommending agent is also considered while assimilating its recommendation. As shown in equation 1 the RRP of the trustworthy recommending agent is adjusted with the adjustment operator '$\oplus$' to its recommendation. This takes into consideration the accurate recommendation from the trustworthy recommending agent according to its trustworthiness. The rules for the adjustment operator '$\oplus$' are:

$$a \oplus b = \begin{cases} a + b, & \text{if } 0 \le (a + b) \le 1 \\ 1, & \text{if } (a + b) > 1 \\ 0, & \text{if } (a + b) < 0 \end{cases}$$

It is possible that in a time slot, the trusting agent may not get any recommendation for the probable trusted agent 'P' in a criterion 'C', thus preventing it from determining the trusted agent's reputation in that criterion by assimilating the recommendations. In such a case, we propose that the trusting agent should assume a value of '0' as the reputation of the probable trusted agent for that criterion 'C' (Rep_{PC}) in that time slot. It is because the trusting agent determines the reputation of the probable trusted agent in a criterion, to ascertain its capability to complete the criterion. And if there is no recommendation for the probable trusted agent in a time slot for a criterion, then for doing a sensible Risk analysis, the trusting agent should assume that the trusted agent is incapable to complete the criterion in that time slot. Hence it should assign the probable trusted agent a value of '0' as its reputation in that criterion.

After determining the reputation of the probable trusted agent 'P' in a criterion 'C' (Rep_{PC}) the trusting agent should map it to the failure scale (FS) to determine its capability to complete the criterion, on it. As mentioned earlier, the levels between 0 and 5 on the failure scale represent varying degree of levels of failure. Hence for risk analysis, the reputation of the probable trusted agent in a criterion should be mapped on the range of (0, 5) on the failure scale, as it is within these levels that its capability to complete the criterion has to be ascertained on the failure scale, according to its reputation. In order to represent the reputation of the probable trusted agent 'P' in a criterion 'C' (Rep_{PC}), on the failure scale (FS), it should be multiplied by 5. Hence Rep_{PCFS}:

$$Rep_{PCFS} = ROUND (Rep_{PC} * 5) \qquad \qquad \dots\dots\text{Equation 2}$$

Once the trusting agent determines the reputation of a probable trusted agent against a criterion on the failure scale, it can then ascertain the probability of failure to achieve that particular criterion according to its expected behaviour in interacting with that probable trusted agent, by determining the difference between what it expects from the trusted agent in the criterion, and how far the probable trusted agent can fulfil it according to its reputation. The trusting agent expects the probable trusted agent to complete the criterion according to its expected behaviour. This expectation of the trusting agent can be quantified with a value of 5 on the failure scale. This value represents the lowest probability of failure of the criterion and expresses the total commitment by the probable trusted agent, according to the expected behaviour. The probability of failure to achieve a criterion 'C' in interacting with the probable trusted agent 'P' can then be determined by:

$$\text{Probability of Failure}_{CP} = \left(\frac{5 - Rep_{PCFS}}{5} \right) \cdot 100 \qquad \qquad \dots\dots\text{Equation 3}$$

The determined probability of failure to achieve criterion 'C' in interacting with probable trusted agent 'P' will be on a scale of 0-100%. Determining the FailureLevel (PFL) for the probable trusted agent 'P' in criterion 'C' on the Failure scale (PFL_{PCFS}) according to the probability of failure of the criterion:

$$PFL_{PCFS} = LEVEL (\text{Probability of Failure}_{CP}) \qquad \qquad \dots\dots\text{Equation 4}$$

When the trusting agent determines the FailureLevel of the probable trusted agent in each criterion of its interaction in a time slot, then it can determine its crisp FailureLevel in that time slot according to those criteria, by weighing the individual FailureLevel of each criterion according to its significance. All criteria of an interaction will not be of equal importance or significance. The significance of each criterion might depend on the degree to which it influences the

successful outcome of the interaction according to the trusting agent. The levels of significance for each criterion (Sc) are shown in table 2 below.

Significance level of the Criterion (Sc)	Significance Rating and Semantics of the level
1	Minorly Significant
2	Moderately Significant
3	Largely Significant
4	Majorly Significant
5	Highly or Extremely Significant

Table 2 showing the significance level of each criterion

The crisp FailureLevel of the probable trusted agent 'P' in a pre-interaction start time slot 't-1' (PFL_{Pt-1}) is then determined by weighing its FailureLevel to complete the criterions in that time slot with the significance of each criterion. Hence:

$$PFL_{Pt-1} = ROUND \left(\frac{1}{\sum\limits_{n=1}^{z} S_{Cn}} \left(\sum\limits_{n=1}^{z} S_{Cn} * PFL_{PCnFS} \right) \right)$$ .....Equation 5

Where:
S_{Cn} is the significance of the criterion 'Cn';
PFL_{PCnFS} represents the FailureLevel of the trusted agent 'P' in criterion 'C_n' on the Failure scale; and
z   is the number of criterions in the interaction.

It should be noted that the determined crisp FailureLevel of the probable trusted agent 'P' determined in the pre-interaction phase time slots by assimilating the recommendations should be set to 0 if it is less than 0, as the failure levels on the Failure scale ranges from 0 to 5. Extending the previous example, when the trusting agent 'E' determines the FailureLevel (PFL) of the probable trusted agents 'D' and 'Z' in the pre-interaction start time slots according to the criteria of its future interaction with them, it can utilise these respective values of each agent to predict and ascertain the future FailureLevel (FFL) in interacting with them in the time slots of the post-interaction start time phase. The FailureLevel determined for each probable trusted agent in the post-interaction start time phase will be strictly according to the criteria of the trusting agent's future interaction with them. In the next section, we will propose the concept of determining the future FailureLevel of a probable trusted agent on the failure scale in the post-interaction start time phase.

3.2 Determining the FailureLevel in Post-Interaction Start Time Phase

In order for the trusting agent to determine the FailureLevel (FFL) of a probable trusted agent in the post interaction start time phase, it should know its FailureLevel according to the specific context and criteria as that of its future interaction, from the beginning of the time space till the time spot of its interaction, i.e. till pre-interaction start time phase. Based on the determined FailureLevel (PFL) till that time by using the above methodology, the trusting agent can predict the future FailureLevel (FFL) in interacting with the probable trusted agent in the post-interaction start time phase. Hence the trusting agent in order to determine the future FailureLevel of the probable trusted agent at time 't+1' should consider all its FailureLevels from the beginning of the time space till time 't'. The trusting agent determines the FailureLevel (PFL) of a probable trusted agent in the pre-interaction start time phase strictly according to the criteria of its future interaction with it, and hence the future FailureLevel (FFL) determined by utilizing these previous levels, too is strictly according those

criteria.

We propose that the trusting agent while determining the future FailureLevel (FFL) of a probable trusted agent in the post-interaction start time phase should determine the magnitude of each level of failure within the domain of (0, 5) on the Failure scale rather than determining a crisp FailureLevel as it does in the Pre-Interaction start time phase. This is due to the fact that the future FailureLevel (FFL) of a probable trusted agent at time 't+1' is predicted by considering its FailureLevels till time 't'. This might not give an accurate conclusion as compared to the one obtained in the pre-interaction start time phase where the trusting agent determines the FailureLevel in interacting with a probable trusted agent by either considering its past interaction history with it or by assimilating recommendations. Hence to overcome that we propose that the trusting agent should determine the magnitude of each level of failure on the Failure scale in the post-interaction start time phase.

Our method of determining the future FailureLevel (FFL) for a probable trusted agent at time 't+1' is by taking its FailureLevels from the beginning of the time space till time 't' and utilize the Gaussian Distribution to determine the probability of the future FailureLevel (FFL) being any level on the Failure scale (FS). As mentioned, the Failure scale ranges from (-1, 5), with -1 denoting Unknown level of Failure. So the future FailureLevel of a probable trusted agent in the post-interaction start time phase is determined in the domain of (0, 5) on the Failure scale. Within this domain there are six possible levels of failure on the Failure scale.

To determine the trusted agent's future FailureLevel at time 't+1' within each range on the Failure scale (FS), let us suppose that the trusting agent has determined the FailureLevel of the probable trusted agent in each time slot from the time space of its interaction till time 't'. Those FailureLevel of the probable trusted agent from the time space till time 't' are represented as:

$$\{PFL_1, PFL_2, PFL_3 \ldots PFL_K\}$$

where k is the number of time slots.

The mean FailureLevel (μ_{PFL}) is calculated as:

$$\mu_{PFL} = \frac{1}{K} \sum_{i=1}^{K} PFL_i \qquad \ldots..\text{Equation 6}$$

Accordingly the unbiased Sample Variance (σ^2) is:

$$\sigma^2 = \frac{1}{K-1} \sum_{i=1}^{K} (PFL_i - \mu_{PFL})^2 \qquad \ldots..\text{Equation 7}$$

The future FailureLevel in interacting with a probable trusted agent peer is denoted as FFL. Since FFL ~ (μ, ^{2}), then for any random variable FFL according to Gaussian distribution [20] the probability of FFL in a given domain of (0, 5) can be determined according to equation 8.

$$P\ (a<FFL \le b) = \frac{1}{\sqrt{2\,\Pi}\,\sigma} \int_{\frac{a-\mu}{\sigma}}^{\frac{b-\mu}{\sigma}} e^{\frac{-t2}{2}}\ dt$$

.....Equation 8

The probability of FFL of a probable trusted agent in a post-interaction start time slot is determined for each level within the domain of (0, 5) on the Failure scale. Doing so would give an indication to the trusting agent of the magnitude of each level of failure present in interacting with the probable trusted agent. Further by representing the future FailureLevel (FFL) in interacting with the probable trusted agent in each time slot in the post-interaction start time phase by busbars of the different possible levels of failure, the trusting agent would get a better indication how the probable trusted agent might behave in the interaction.

The proposed concepts in this paper will be understood and its significance can be determined more clearly when we explain it in the next section by taking an example.

4. Determining the FailureLevel of the probable Trusted Agents by an Example

To demonstrate the proposed concept of determining the FailureLevel in interacting with a probable trusted agent beforehand with a real world example, let us simulate an interaction between Alice and a logistic company. Let us suppose that Alice wants to interact with a logistic company on the context of transporting its goods worth $ 15,000 over the period of time from 15/06/2006 to 21/06/2006. There are two logistic companies who can fulfil Alice's needs. They are logistic company 'D' and 'E'. These two companies are the set of probable trusted agents from which Alice has to decide and choose one of them to interact with. Further in this example we will term the logistic company 'D' and 'E' as agent 'D' and agent 'E' respectively. For simplicity we also term the context of the interaction as 'C'. The criteria that Alice wants in its interaction are C1 and C2.

Let us consider that Alice had interacted successfully previously with agent 'E', but in a different context and it does not have any previous interaction history with the probable trusted agent 'D' in any context. Hence, to make an informed decision of choosing with which agent to interact with, Alice decides to analyse the possible risk that could be present in interacting with each of them. In order to achieve that, Alice has to determine the probability of failure (FailureLevel) and the possible consequences of failure in interacting with each of the probable trusted agents. In this paper, we will discuss about only determining the FailureLevel in interacting with the probable trusted agents.

To determine the future FailureLevel (FFL) in interacting with each probable trusted agent in the post-interaction start time phase, Alice decides to analyse the FailureLevel (PFL) in interacting with each probable trusted agent from a period of 3 weeks prior to the time spot of its interaction with them, i.e. from 25/05/2006 to 14/06/2006. This is the pre-interaction start time phase. The interaction of Alice with any agent is from 15/06/2006 to 21/06/2006. This is the post-interaction start time phase. Subsequently, the total time space in which Alice will be analysing and determining the FailureLevel in interacting with the probable trusted agents is from 25/05/2006 to 21/06/2006. This time space is the combination of pre- and post-interaction start time phase. Alice divides the time space into four different non-overlapping time slots, each of 7 days to determine the FailureLevel of each probable trusted agent in each of them. The time spot of Alice's interaction with any probable trusted agent is 15/06/2006 and, hence, Alice has to:

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- Determine the FailureLevel (PFL) in interacting with each probable trusted agent in the pre-interaction start time phase, i.e. from 25/05/2006 till 14/06/2006 by determining their reputation and then ascertaining their in-capability to complete the interaction according to its future criteria, and

- By predicting the future FailureLevel (FFL) of each probable trusted agent in the time space of 15/06/2006 to 21/06/2006 to determine the FailureLevel in the post-interaction start time phase.

Figure 2, below, shows the division of the time space according to the time slots.

Figure 2 showing the division of the time space

To determine the reputation of agent 'D' and 'E' in time slots t-3 till t-1, Alice solicits for recommendations and assimilates them according to the criteria of its future interaction with them. Based on the reputation achieved, Alice then determines the FailureLevel of each probable trusted agent in each time slot, by ascertaining their in-capability to complete the interaction according to its expectations. Let us assume that Alice gives a weight of 0.9 to trustworthy recommendations and a weight of 0.1 to un-known recommendations, i.e. and respectively while determining the reputation of the probable trusted agent. Further, let us assume that it gives a weight of 0.6 to the recommendations, which are in the recent time slot of its interaction, and a weight of 0.4 to the far recent recommendations, i.e. and respectively. Alice considers the time slot of 08/06/2006 to 14/06/2006 as the recent time slot to its interaction and any other time slot previous to this time slot as the far recent ones.

5. Determining the FailureLevel in interacting with Agent 'D'

5.1 Determining the FailureLevel of agent 'D' in pre-interaction time phase

Let us suppose that the recommendations that the trusting agent Alice gets for agent 'D' in the form of Risk set are:

From agent 'F':
{Agent 'F', Agent 'D', Context 'C', 4, 4, 3, ((C1, 1) (C3, 0)), 1000, 26/05/2006, 30/05/2006, -0.6}
From agent 'G':
{Agent 'G', Agent 'D', Context 'C', 4, 3, 5, ((C2, 0) (C6, 1)), 500, 27/05/2006, 28/05/2006, UNKNOWN}
From agent 'H':
{Agent 'H', Agent 'D', Context 'C', 3, 3, 3, ((C1, 1) (C2, 1) (C9, 0)), 15500, 05/06/2006, 07/06/2006, 0.8}
From agent 'I':
{Agent 'I', Agent 'D', Context 'C', 3, 3, 3, ((C9, 1) (C2, 1)), 2500, 02/06/2006, 05/06/2006, 1.6}
From agent 'J':
{Agent 'J', Agent 'D', Context 'C', 1, 1, 0, ((C1, 1) (C2, 1) (C10,1)), 500, 09/06/2006, 10/06/2006, 0.6}
From agent 'K':
{Agent 'K', Agent 'D', Context 'C', 2, 1, 0, ((C1, 1) (C2, 0)), 3500, 11/06/2006, 13/06/2006, UNKNOWN}

As mentioned earlier, a recommendation whose RRP is in the range of (-1, 1) is said to be a trustworthy recommending agent. Classifying the recommendations for agent 'D' according to their trustworthiness and representing them according to their criteria and the time slot of the trusting agent's division of the time space in table 3:

Trustworthy Recommendations		Un-Known Recommendations		Un-Trustworthy Recommendations	
Agent 'F' C1(1), C3(0)	Time slot: t-3	Agent 'G' C2(0), C6(1)	Time slot: t-3	Agent 'I' C9(1), C2(1)	Time slot: t-2
Agent 'H' C1(1), C2(1), C9(0)	Time slot: t-2	Agent 'K' C1(1), C2(0)	Time slot: t-1		
Agent 'J' C1(1), C2(1), C10(1)	Time slot: t-1				

Table 3. Classifying the recommendations for agent 'D'

5.1.1 Determining the FailureLevel of agent 'D' in time slot t-3

Assimilating the recommendations to determine the reputation and the FailureLevel of agent 'D' according to the criterions C1, C2 and C3 in the time slot t-3.

➤ **FailureLevel of agent 'D' in criterion C1 in time slot t-3:**

There is only one recommendation for agent 'D' in criterion C1 from trustworthy recommending agent 'F', in the far recent time slot of its interaction. Hence determining reputation of agent D in criterion C1 from equation 1:
$Rep_{DC1} = (0.9 *((0.6*(0)) + (0.4 * (-0.6 \oplus 1)))) + (0.1* ((0.6*(0)) + (0.4 *(0)))) = \mathbf{0.144}$
Representing the reputation on the Failure scale by using equation 2:
$Rep_{DC1FS} = ROUND (0.144 * 5) = 1$

Determining the probability of failure of criterion C1 in interacting with agent 'D' by using equation 3:

Probability of Failure $_{C1D} = (\frac{5-1}{5}) . 100 = 80\%$

Determining the FailureLevel of agent 'D' in criterion 'C1' on the Failure scale by using equation 4:

$\text{PFL}_{\text{DC1FS}} = \text{LEVEL } (80 \%) = 1$

> ➤ **FailureLevel of agent 'D' in criterion C2 in time slot t-3:**

There is one recommendation for agent 'D' in criterion C2 from an unknown recommending agent 'G' in time slot t-3. Hence determining $\text{Rep}_{\text{DC2}} =$

$\text{Rep}_{\text{DC2}} = (0.9 * ((0.6*(0)) + (0.4 * (0)))) + (0.1* ((0.6*(0)) + (0.4 *(0)))) = 0$

Representing the reputation on the Failure scale by using equation 2:

$\text{Rep}_{\text{DC2FS}} = \text{ROUND } (0 * 5) = 0$

Determining the probability of failure of criterion C2 in interacting with agent 'D' by using equation 3:

Probability of Failure $_{\text{C2D}} = (\dfrac{5-0}{5}) * 100 = 100\%$

Determining the FailureLevel of agent 'D' in criterion C2 on the Failure scale by using equation 4:

$\text{PFL}_{\text{DC2FS}} = \text{LEVEL } (100 \%) = 0$

> ➤ **Determining a crisp FailureLevel of agent 'D' in time slot t-3:**

Once the FailureLevel of each criterion has been determined in a time slot, then they must be combined to determine a crisp FailureLevel in that particular time slot. Let us consider that Alice assigns a significance value of 5 to each criterion of its future interaction. Using equation 5 to determine the FailureLevel of agent 'D' according to the significance of the criterions in time slot t-3:

$\text{PFL}_{\text{Dt-3}} = \text{ROUND } (\dfrac{1}{10} ((5*1) + (5*0)))$

$\text{PFL}_{\text{Dt-3}} = \text{ROUND } (0.5)$

$\textbf{PFL}_{\textbf{Dt-3}} = \textbf{1}$

Hence, in the pre-interaction start time slot t-3, the FailureLevel of agent 'D' ($\text{PFL}_{\text{Dt-3}}$) is 1 on the Failure scale.

5.1.2 Determining the FailureLevel of agent 'D' in time slot t-2

> ➤ **FailureLevel of agent 'D' in criterion C1 in time slot t-2:**

There are two recommendations for agent 'D' for criterion C1 from agents 'H' and agent 'I'. But agent 'I' is an untrustworthy recommending agent. Hence its recommendation will not be considered by Alice. Determining $\text{Rep}_{\text{DC1}} =$

$\text{Rep}_{\text{DC1}} = (0.9 * ((0.6*(0)) + (0.4 * (0.8 \oplus 1)))) + (0.1* ((0.6*(0)) + (0.4 *(0)))) = 0.36$

Representing the reputation on the Failure scale by using equation 2:

$\text{Rep}_{\text{DC1FS}} = \text{ROUND } (0.36 * 5) = 2$

Determining the probability of failure of criterion C1 in interacting with agent 'D' by using equation 3:

Probability of Failure $_{\text{C1D}} = (\dfrac{5-2}{5}) . 100 = 60\%$

Determining the FailureLevel of agent 'D' in criterion C1 on the Failure scale by using equation 4:

$\textbf{PFL}_{\textbf{DC1FS}} = \textbf{LEVEL } (\textbf{60} \%) = \textbf{2}$

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➤ FailureLevel of agent 'D' in criterion C2 in time slot t-2:

There is only one recommendation for agent 'D' to consider for criterion C2 from agent 'H'. Determining Rep_{DC2}

$\text{Rep}_{DC2} = (0.9 *((0.6*(0)) + (0.4 * (0.8 \oplus 1)))) + (0.1* ((0.6*(0)) + (0.4 *(0)))) = \textbf{0.36}$

Representing the reputation on the Failure scale by using equation 2:

$\text{Rep}_{DC2FS} = \text{ROUND} (0.36 * 5) = 2$

Determining the probability of failure of criterion C2 in interacting with agent 'D' by using equation 3:

Probability of Failure $_{C2D} = (\dfrac{5-2}{5}) \cdot 100 = 60\%$

Determining the FailureLevel of agent 'D' in criterion C2 on the Failure scale by using equation 4:

$\textbf{PFL}_{DC2FS} = \textbf{LEVEL (60 \%) = 2}$

➤ Determining a crisp FailureLevel of agent 'D' in time slot t-2:

Using equation 5 to determine the FailureLevel of agent 'D' in time slot t-2:

$\text{PFL}_{Dt-2} = \text{ROUND} (\dfrac{1}{10} ((5*2) + (5*2)))$

$\text{PFL}_{Dt-2} = \text{ROUND} (2)$

$\textbf{PFL}_{Dt-2} = \textbf{2}$

Hence, in the pre-interaction start time slot t-2, the FailureLevel of agent 'D' (PFL_{Dt-2}) is 2 on the Failure scale.

5.1.3 Determining the FailureLevel of agent 'D' in time slot t-1

➤ FailureLevel of agent 'D' in criterion C1 in time slot t-1:

There are two recommendations for agent 'D' for criterion C1 in time slot t-1 from agent 'J' and agent 'K' in the recent time slot of its future interaction. Determining Rep_{DC1}

$\text{Rep}_{DC1} = (0.9 *((0.6*(0.6 \oplus 1)) + (0.4 * (0)))) + (0.1* ((0.6*(1)) + (0.4 *(0)))) = \textbf{0.60}$

Representing the reputation on the Failure scale by using equation 2:

$\text{Rep}_{DC1FS} = \text{ROUND} (0.60 * 5) = 3$

Determining the probability of failure of criterion C1 in interacting with agent 'D' by using equation 3:

Probability of Failure $_{C1D} = (\dfrac{5-3}{5}) \cdot 100 = 40\%$

Determining the FailureLevel of agent 'D' in criterion C1 on the Failure scale by using equation 4:

$\textbf{PFL}_{DC1FS} = \textbf{LEVEL (40 \%) = 3}$

➤ FailureLevel of agent 'D' in criterion C2 in time slot t-1:

There are two recommendations for agent 'D' for criterion C2 in time slot t-1 from agent 'J' and agent 'K'. Determining

$\text{Rep}_{DC2} = (0.9 *((0.6*(0.6 \oplus 1)) + (0.4 * (0)))) + (0.1* ((0.6*(0)) + (0.4 *(0)))) = \textbf{0.54}$

Representing the reputation on the Failure scale by using equation 2:

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Rep_{DC2FS} = ROUND (0.54 * 5) = 3

Determining the probability of failure of criterion C2 in interacting with agent 'D' by using equation 3:

Probability of Failure $_{C2D}$ = ($\frac{5-3}{5}$) . 100 = 40%

Determining the FailureLevel of agent 'D' in criterion C2 on the Failure scale by using equation 4:

PFL_{DC2FS} = LEVEL (40 %) = 3

> **Determining a crisp FailureLevel of agent 'D' in time slot t-1:**

Using equation 5 to determine the FailureLevel of agent 'D' in time slot t-1:

PFL_{Dt-1} = ROUND ($\frac{1}{10}$ ((5*3) + (5*3)))

PFL_{Dt-1} = ROUND (3)

PFL_{Dt-1} = 3

Hence, in the pre-interaction start time slot t-1, the FailureLevel of agent 'D' (PFL_{Dt-1}) is 3 on the Failure scale.

Once Alice determines the FailureLevel in interacting with the probable trusted agent 'D' in the pre-interaction start time phase till the time spot of its interaction, it should then determine the future FailureLevel in interacting with it in the post-interaction start time as explained in the next section.

5.2 Determining the FailureLevel of agent 'D' in post-interaction time phase

Determining the FailureLevel of agent 'D' in time slot t1 by using the methodology defined in section 3:

FailureLevel of the probable trusted agent 'D':
In time slot 25/05/2006 to 31/05/2006 (PFL_{Dt-3}): **1**
In time slot 01/06/2006 to 07/06/2006 (PFL_{Dt-2}): **2**
In time slot 08/06/2006 to 16/06/2006 (PFL_{Dt-1}): **3**

Determining the mean FailureLevel (μ_{PFL}) by using equation 6:
μ_{PFL} = 2

Accordingly, the Sample Variance (^{2}) calculated from equation 7 is:
^{2} = 1
= 1

As mentioned earlier, the trusting agent should determine the magnitude of each level of failure on the Failure scale while determining the FFL in interacting with a probable trusted agent in the post-interaction start time phase. Using equation 8 to determine the probability of the future FailureLevel (FFL) of agent 'D' in each range of the Failure scale in time slot t1:

P $(0 < FFL < 0.4)$ = 0.032 = 3.20 %

Similarly,

P $(0.5 < FFL < 1.4)$ = 0.2075 = 20.75%

P $(1.5 < FFL < 2.4)$ = 0.3565 = 35.65%

$$P\left(2.5 < FFL < 3.4\right) = 0.2277 = 22.77\%$$
$$P\left(3.5 < FFL < 4.4\right) = 0.0586 = 5.86\ \%$$
$$P\left(4.5 < FFL < 5\right) = 0.0049 = 0.49\ \%$$

Representing in figure 3 the probability of occurrence of each failure level:
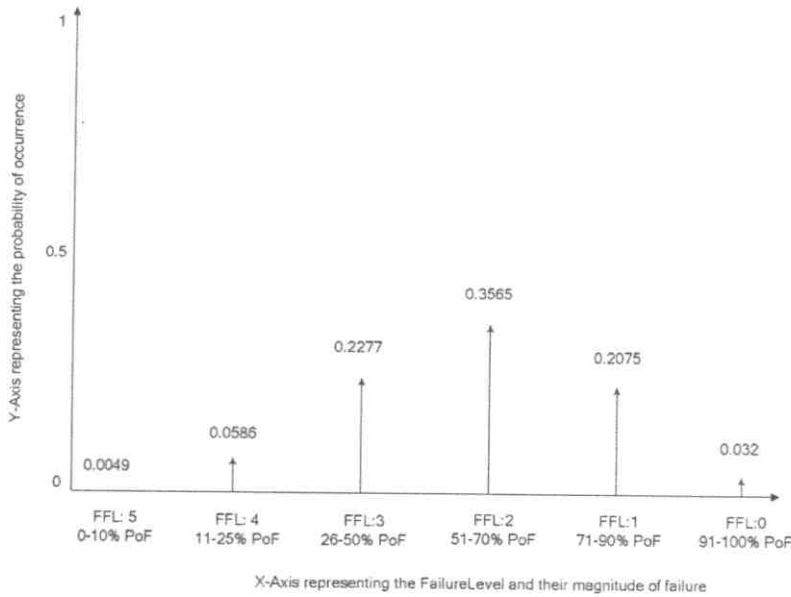

Figure 3 showing the probability of occurrence of each level of failure in interacting with agent 'D' in time slot t1

The above graph shows the magnitude of occurrence of each level of failure in interacting with the probable trusted agent 'D' in the time slot t1. The trusting agent, by having a look at this graph, can analyse and get a better indication of how the probable trusted agent 'D' will behave in the interaction.

6. Determining the FailureLevel in interacting with Agent 'E'

6.1 Determining the FailureLevel of agent 'E' in pre-interaction time phase

In order to determine the reputation and the FailureLevel of agent 'E' in the pre-interaction start time phase, Alice solicits for recommendations from other agents in the context of its future interaction with it. Let us suppose that the recommendations that it gets for agent 'E' in the form of Risk set are:

From agent 'G':
{Agent 'G', Agent 'E', Context 'C', 3, 4, 4, ((C1, 1) (C2, 1) (C4, 0)), 200, 30/05/2006, 31/05/2006, 0.9}
From agent 'H':

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{Agent 'H', Agent 'E', Context 'C', 5, 5, 5, ((C8, 1) (C9, 1)), 1200, 25/05/2006, 29/05/2006, 0.4}
From agent 'J':
{Agent 'J', Agent 'E', Context 'C', 5, 5, 4, ((C1, 0) (C2, 1) (C3, 1) (C6, 0)), 2500, 05/06/2006, 07/06/2006, 0.21}
From agent 'K':
{Agent 'K', Agent 'E', Context 'C', 2, 2, ((C1, 1) (C2, 1) (C3, 1) (C8, 0)), 1, 100, 02/06/2006, 04/06/2006, UNKNWON}
From agent 'L':
{Agent 'L', Agent 'E', Context 'C', 5, 5, 5, ((C2, 0) (C6, 1) (C7, 1), 1547, 10/06/2006, 13/06/2006, 0}
From agent 'I':
{Agent 'I', Agent 'E', Context 'C', 4, 4, 3, ((C9, 1) (C2, 1)), 520, 10/06/2006, 13/06/2006, 1.9}
From agent 'M':
{Agent 'M', Agent 'E', Context 'C', 5, 5, 5, ((C2, 0) (C5, 1)), 750, 13/06/2006, 14/06/2006, UNKNOWN}

Classifying the recommendations for agent 'E' according to their trustworthiness and representing them according to their criteria and the time slot of the trusting agent's division of the time space in table 4:

Trustworthy Recommendations	Un-Known Recommendations	Un-Trustworthy Recommendations
Agent 'G' Time slot: t-3 C1(1), C2(1), C4(0)	Agent 'K' Time slot: t-2 C1(1), C2(1), C3(1), C8(0)	Agent 'I' Time slot: t-1 C9(1),C2(1)
Agent 'H' Time slot: t-3 C8(1), C9(1)	Agent 'M' Time slot: t-1 C2(0), C5(1)	
Agent 'J' Time slot: t-2 C1(0), C2(1), C3(1), C6(0)		
Agent 'L' Time slot: t-1 C2 (0), C6(1), C7(1)		

Table 4. Classifying the recommendations for agent 'E'

6.1.1 Determining the FailureLevel of agent 'E' in time slot t-3

Assimilating the recommendations to determine the reputation and the FailureLevel of agent 'E' according to the criterions C1, C2 and C3 in the time slot t-3.

➤ **FailureLevel of agent 'E' in criterion C1 in time slot t-3:**

There is only one recommendation for agent 'E' in time slot t-3 according to the criteria of the trusting agent's future interaction. Hence, determining reputation of agent E in criterion C1 from equation 1:

$Rep_{EC1} = (0.9 *((0.6*(0)) + (0.4 * (0.9 \oplus 1)))) + (0.1* ((0.6*(0)) + (0.4 *(0)))) = \mathbf{0.36}$

Representing the reputation on the Failure scale by using equation 2:

$Rep_{EC1FS} = ROUND (0.36 * 5) = 2$

Determining the probability of failure of criterion C1 in interacting with agent 'E' by using equation 3:

Probability of Failure $_{C1E} = (\frac{5-2}{5}) \cdot 100 = 60\%$

Determining the FailureLevel of agent 'E' in criterion 'C1' on the Failure scale by using equation 4:

$PFL_{EC1FS} = LEVEL\ (60\ \%) = 2$

> **FailureLevel of agent 'E' in criterion C2 in time slot t-3:**

There is one recommendation for agent 'E' in criterion C2 from a trustworthy recommending agent 'G' in time slot t-3. Hence, determining $Rep_{EC2} =$

$Rep_{EC2} = (0.9\ *((0.6*(0)) + (0.4\ *\ (0.9\ \oplus\ 1)))) + (0.1*\ ((0.6*(0)) + (0.4\ *(0)))) = \mathbf{0.36}$

Representing the reputation on the Failure scale by using equation 2:
$Rep_{EC2FS} = ROUND\ (0.36\ *\ 5) = 2$

Determining the probability of failure of criterion C2 in interacting with agent 'E' by using equation 3:

Probability of Failure $_{C2E\ =\ (}\dfrac{5-2}{5}\ )\ *\ 100\ = 60\%$

Determining the FailureLevel of agent 'E' in criterion C2 on the Failure scale by using equation 4:
$\mathbf{PFL_{EC2FS} = LEVEL\ (60\ \%) = 2}$

> **Determining a crisp FailureLevel of agent 'E' in time slot t-3:**

Using equation 5 to determine the FailureLevel of agent 'E' according to the significance of the criterions in time slot t-3:

$PFL_{Et-3} = ROUND\ (\dfrac{1}{10}\ ((5*2) + (5*2)))$

$PFL_{Et-3} = ROUND\ (2)$
$\mathbf{PFL_{Et-3} = 2}$

Hence, in the pre-interaction start time slot t-3, the FailureLevel of agent 'E' (PFL_{Et-3}) is 2 on the Failure scale.

6.1.2 Determining the FailureLevel of agent 'E' in time slot t-2

> **FailureLevel of agent 'E' in criterion C1 in time slot t-2:**

There is a recommendation apiece for agent 'E' in criterion C1 from agents 'J' and agent 'K' who are trustworthy and unknown recommending agents respectively. Determining $Rep_{EC1} =$

$Rep_{EC1} = (0.9\ *((0.6*(0)) + (0.4\ *\ (0.21\ \oplus\ 0)))) + (0.1*\ ((0.6*(0)) + (0.4\ *(1)))) = \mathbf{0.1156}$

Representing the reputation on the Failure scale by using equation 2:
$Rep_{EC1FS} = ROUND\ (0.1156\ *\ 5) = 1$

Determining the probability of failure of criterion C1 in interacting with agent 'E' by using equation 3:

Probability of Failure $_{C1E\ =\ (}\dfrac{5-1}{5}\ )*\ 100 = 80\%$

Determining the FailureLevel of agent 'E' in criterion C1 on the Failure scale by using equation 4:
$\mathbf{PFL_{EC1FS} = LEVEL\ (80\ \%) = 1}$

> **FailureLevel of agent 'E' in criterion C2 in time slot t-2:**

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There are two recommendations for agent 'E' to consider for criterion C2 from agents 'K' and agent 'J'. Determining
$Rep_{EC2} = (0.9 *((0.6*(0)) + (0.4 * (0.21 \oplus 1)))) + (0.1* ((0.6*(0)) + (0.4 *(1)))) = \textbf{0.40}$
Representing the reputation on the Failure scale by using equation 2:
$Rep_{EC2FS} = ROUND (0.40 * 5) = 2$

Determining the probability of failure of criterion C2 in interacting with agent 'E' by using equation 3:

Probability of Failure $_{C2E} = (\dfrac{5-2}{5}) . 100 = 60\%$

Determining the FailureLevel of agent 'E' in criterion C2 on the Failure scale by using equation 4:

$\textbf{PFL}_{EC2FS} = \textbf{LEVEL (60 \%) = 2}$

➢ Determining a crisp FailureLevel of agent 'E' in time slot t-2:

Using equation 5 to determine the FailureLevel of agent 'E' in time slot t-2:
$PFL_{Et-2} = ROUND (\dfrac{1}{10} ((5*1) + (5*2)))$
$PFL_{Et-2} = ROUND (1.5)$
$\textbf{PFL}_{Et-2} = \textbf{2}$

Hence, in the pre-interaction start time slot t-2, the FailureLevel of agent 'E' (PFL_{Et-2}) is 2 on the Failure scale.

6.1.3 Determining the FailureLevel of agent 'E' in time slot t-1

➢ FailureLevel of agent 'E' in criterion C1 in time slot t-1:

There is no recommendation for agent 'E' in criterion C1 in time slot t-1. Hence $Rep_{EC1} =$
$\textbf{Rep}_{EC1} = \textbf{0}$
Representing the reputation on the Failure scale by using equation 2:
$Rep_{EC1FS} = ROUND (0 * 5) = 0$

Determining the probability of failure of criterion C1 in interacting with agent 'E' by using equation 3:

Probability of Failure $_{C1E} = (\dfrac{5-0}{5}) . 100 = 100\%$

Determining the FailureLevel of agent 'E' in criterion C1 on the Failure scale by using equation 4:
$\textbf{PFL}_{EC1FS} = \textbf{LEVEL (100 \%) = 0}$

➢ FailureLevel of agent 'E' in criterion C2 in time slot t-1:

There are two recommendations for agent 'E' for criterion C2 in time slot t-1 from agent 'L' and agent 'M'. Determining
$Rep_{EC2} = (0.9 *((0.6*(0 \oplus 0)) + (0.4 * (0)))) + (0.1* ((0.6*(0)) + (0.4 *(0)))) = \textbf{0}$
Representing the reputation on the Failure scale by using equation 2:
$Rep_{EC2FS} = ROUND (0 * 5) = 0$

Determining the probability of failure of criterion C2 in interacting with agent 'E' by using equation 3:

Probability of Failure $_{C2E} = (\frac{5-0}{5}) \cdot 100 = 100\%$

Determining the FailureLevel of agent 'E' in criterion C2 on the Failure scale by using equation 4:

PFL$_{EC2FS}$ = LEVEL (100 %) = 0

➤ Determining a crisp FailureLevel of agent 'E' in time slot t-1:

Using equation 5 to determine the FailureLevel of agent 'E' in time slot t-1:

$PFL_{E_{t-1}}$ = ROUND $(\frac{1}{10}$ ((5*0) + (5*0)))

$PFL_{E_{t-1}}$ = ROUND (0)

PFL$_{E_{t-1}}$ = 0

Hence, in the pre-interaction start time slot t-1, the FailureLevel of agent 'E' (PFL$_{E_{t-1}}$) is 0 on the Failure scale.

The trusting agent after determining the FailureLevel (PFL) of the probable trusted agent 'E' till the time spot of the interaction, should then determine the FFL in interacting with it in the post-interaction start time phase.

6.2 Determining the FailureLevel of agent 'E' in post-interaction time phase

Determining the FailureLevel of agent 'E' in time slot t1 by using the methodology defined in section 3:

FailureLevel of the probable trusted agent 'E':
In time slot 25/05/2006 to 31/05/2006 (PFL$_{E_{t-3}}$): **2**
In time slot 01/06/2006 to 07/06/2006 (PFL$_{E_{t-2}}$): **2**
In time slot 08/06/2006 to 16/06/2006 (PFL$_{E_{t-1}}$): **0**

Determining the mean FailureLevel (μ_{PFL}) by using equation 6:

μ_{PFL} = 1.33

Accordingly the Sample Variance (^{2}) calculated from equation 7 is:
^{2} = 1.33
 = 1.154

Using equation 8 to determine the probability of the future FailureLevel (FFL) of agent 'E' in each range of the Failure scale in time slot t1:

P $(0 < FFL < 0.4) = 0.0726 = 7.26 \%$
Similarly,
P $(0.5 < FFL < 1.4) = 0.285 = 28.50\%$
P $(1.5 < FFL < 2.4) = 0.2264 = 22.64\%$
P $(2.5 < FFL < 3.4) = 0.1195 = 11.95\%$
P $(3.5 < FFL < 4.4) = 0.0262 = 2.62 \%$
P $(4.5 < FFL < 5) = 0.0024 = 0.24 \%$

Representing the probability of occurrence of a failure level against it in the form of a graph in figure 4:
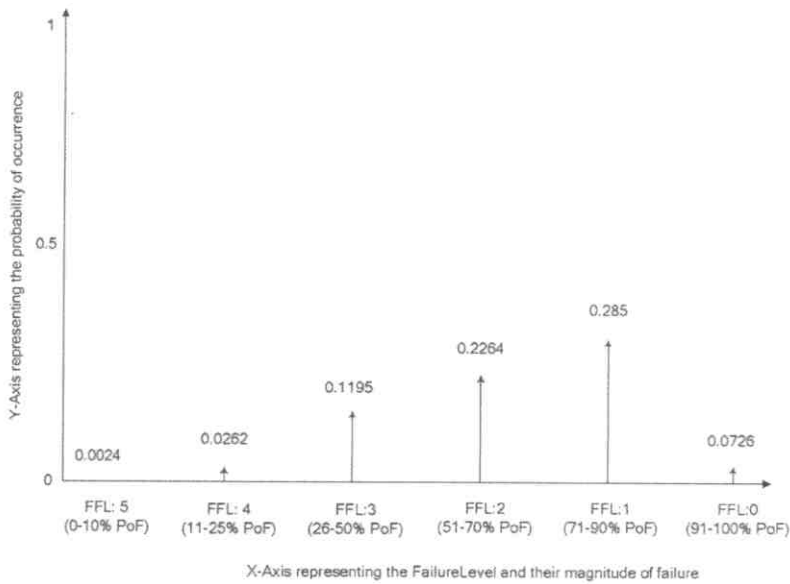

Figure 4 showing the probability of occurrence of each level of failure in interacting with agent 'E' in time slot t1

The above graph shows magnitude of occurrence of each level of failure in interacting with the probable trusted agent 'E' in the time slot t1.

It is highly possible that the trusting agent might have more than one time slot in the post-interaction time phase in its interaction with a probable trusted agent. In such a case for risk analysis, it has to determine the FailureLevel (FFL) in interacting with the probable trusted agents in each of the post-interaction start time slots. To achieve that, we propose the trusting agent after determining the magnitude of occurrence of each level of failure, in interacting with a probable trusted agent in a post-interaction time slot, should take the level with the highest probability of occurrence as the FailureLevel of that probable trusted agent for that particular time slot. Taking our example, if Alice has to determine the FailureLevel of the probable trusted agents 'D' and 'E' in two time slots (t1 and t2) of the post-interaction time phase, then it can take the FailureLevel (FFL) of agent 'D' and agent 'E' for time slot t1, as '2' and '1' respectively on the failure scale, as these are the individual levels with the highest probability of occurrence in that time slot. It can then use the methodology defined in section 3.2 and consider the time slots from 't-3' till 't1' while determining the FailureLevel of each probable trusted agent in time slot t2.

The trusting agent, Alice, by analysing the magnitude of occurrence of each level of failure on the Failure scale in interacting with each probable trusted agent can get a better indication of which probable trusted agent to interact with. In order for Alice to analyse the possible risk in interacting with the probable trusted agents, it should also determine the possible consequences of failure in interacting with them apart from determining the probability of failure of the interaction (FailureLevel). In this paper, we limit ourselves in determining the FailureLevel of the interaction.

7. Conclusion

In this paper we highlighted a problem that is common in an e-commerce interaction carried out in a digital ecosystem domain. It is possible that the trusting agent might have to decide and choose an agent to interact with from a set of probable trusted agents. It can ease its decision making process by analyzing the possible level of Risk that could be present in interacting with each of them according to the demand of its interaction. Analyzing the possible level of Risk gives the trusting agent an indication of the probability of failure of the interaction (FailureLevel) and the possible consequences of failure to its resources. In this paper we proposed a methodology by which the trusting agent can determine the FailureLevel beforehand in interacting with a probable trusted agent. The determined FailureLevel is strictly according to the criteria of the trusting agent's future interaction with the probable trusted agent. Further in the paper we explained the proposed methodology by taking a real world example.

References

[1] H. Chan, R. Lee, T.S. Dillon and E. Chang, 'E-Commerce and its Applications', 1ª edition, John Wiley and Sons, Ltd, (2002).

[2] S. Greenland, 'Bounding analysis as an inadequately specified methodology', Risk Analysis vol. 24, no. 5, pp. 1085-1092, (2004).

[3] D. F. Cooper, 'The Australian and New Zealand Standard on Risk Management, AS/NZS 4360:2004', Tutorial Notes: Broadleaf Capital International Pty Ltd, Available: http://www.broadleaf.com.au/tutorials/Tut_Standard.pdf, (2004).

[4] Technologies for Digital Ecosystems, Available: http://www.digital-ecosystems.org/, Retrieved on 6 October 2006

[5] G.I. Doukidis, N. Mylonopoulos and N. Pouloudi, 'Social and economic transformation in the digital era', Idea Group International, ISBN: 1591402670, (2003).

[6] P.J. Denning, R.M. Metcalfe and M. Robert, 'Beyond calculation: The next fifty years of computing', (edited) Springer ISBN: 0387985883, (1998).

[7] J.G. March and Z. Shapira, 'Managerial perspective on risk and risk taking', Management Science, vol. 33, no. 11, pp. 1404-1418, (1987).

[8] N. Luhmann, 'Familiarity, confidence, trust: Problems and alternatives', Making and Breaking Cooperative Relations, Basil Blackwell, New York, USA, (1988).

[9] R.C. Mayer, J.H. Davis and F.D. Schoorman, 'An interactive model for organizational trust', Academy of Management Review, vol. 20, no. 3, pp.709-734, (1995).

[10] D.M. Rousseau, S.B. Sitkin, R.S. Burt and C. Camerer, 'Not so different after all: A cross-discipline view of trust', Academy of Management Review, vol. 23, no. 3, pp. 391-404, (1998).

[11] P. Sztompka, 'Trust: A sociological theory', Cambridge University Press, Cambridge, U.K., (1999).

[12] S. Grazioli and A. Wang, 'Looking without seeing: Understanding unsophisticated consumers success and failure to detect Internet deception', Proceedings of the International Conference on Information Systems, New Orleans, USA, pp 193-204, (2001).

[13] C. Cheung and M.K.O. Lee, 'Trust in Internet shopping: A proposed model and measurement instrument', Proceedings of the 6th Americans Conference on Information Systems, pp 681-689, (2000).

[14] S.L. Jarvenpaa, N. Trctinsky and M. Vitale, 'Consumer trust in an Internet store: A Cross Cultural Validation', Journal of Computer Mediated Communication, vol. 5, no. 2, pp 1-35, (1999).

[15] D. Gefen, V.S. Rao and N. Tractinsky, 'The conceptualization of trust and their relationship in electronic commerce: The need for clarification', Proceedings of the 36th Hawaii International Conference on System Sciences, Hawaii, pp 192-201, (2003).

[16] F.K. Hussain, E.Chang, and T.S. Dillon, 'Classification of trust in peer-to-peer (P2P) communication', International Journal of Computer Science and Engineering, vol. 19, no. 2, pp 59-73, (2004).

[17] O.K. Hussain, E. Chang, F.K. Hussain and T.S. Dillon, 'A methodology for risk measurements in e-transactions', Special Issue of International Journal of Computer System, Science and Engineering, CRL Publishing Ltd, 17-31, (2006).

[18] J. Carter and A.A. Ghorbani, 'Towards a formalization of Trust' Web Intelligence and Agent Systems, Vol. 2, No. 3, pp. 167-183, (2004).

[19] E. Chang, T. Dillon, F. K. Hussain, 'Trust and Reputation for Service-Oriented Environments: Technologies for Building Business Intelligence and Consumer Confidence', 1st edition, John Wiley and Sons Ltd, ISBN: 0-470-01547-0, (2006).

[20] N.A. Weiss, 'A Course in Probability', Pearson Education, Inc., USA, ISBN 0-201-77471-2, (2005).

[21] Y. Wang and V. Varadharajan, 'A Time-based Peer Trust Evaluation in P2P E-commerce Environments', The Fifth International Conference on Web Information Systems Engineering (WISE'04), Brisbane, Australia, Springer-Verlag, LNCS Vol. 3306, pp.730-735, (2004).

[22] Y. Wang and V. Varadharajan, 'Two-phase Peer Evaluation in P2P E-commerce Environments', Proceedings of the 2005 IEEE International Conference on e-Technology, e-Commerce and e-Service (EEE'05), Hong Kong, China, pp.654-657, (2005).

[23] J. C. Fan, 'Trust and Electronic Commerce - A Test of an E-Bookstore', Proceedings of the IEEE International Conference on e-business Engineering (ICEBE '06), Shanghai, China, pp.110-117, (2006).

[24] M. Wojcik, J.H.P. Eloff and H.S. Venter, 'Trust Model Architecture: Defining Prejudice by Learning', Proceedings of the third International Conference on Trust, Privacy and Security in Digital Business (TRUSTBUS '06), krakow, Poland, Sringer-Verlag, LNCS Vol. 4083, pp182-191, (2006).

[25] C. Su, H. Zhang, F. Bi, 'P2P-based Trust Model for E-Commerce', Proceedings of the IEEE International Conference on e-business Engineering (ICEBE '06), Shanghai, China, pp. 118-122, (2006).

[26] E. Koutrouli, A. Tsalgatidou, 'Reputation-Based Trust Systems for P2P Applications: Design Issues and Comparision Framework', Proceedings of the third International Conference on Trust, Privacy and Security in Digital Business (TRUSTBUS '06), krakow, Poland, Sringer-Verlag, LNCS Vol. 4083, pp 152-161, (2006).

[27] H. Chein and R. Lin, 'Identity-based Key Agreement Protocol for Mobile Ad-hoc Networks Using Bilinear Pairing', Proceedings of the IEEE International Conference on Sensor Networks, Ubiquitous, and Trustworthy Computing -Vol 1 (SUTC'06), Taichung, Taiwan, pp. 520-529, (2006).

[28] F. K. Hussain, E. Chang, T.Dillon, 'Trustworthiness and CCCI Metrics for Assigning Trustworthiness', International Journal of Computer Science Systems and Engineering, Volume 19(2); 173-189, (2004).

[29] F. Cornelli, E. Damiani, S.C. Vimercati, S. Paraboschi and P. Samarati, 'Choosing Reputable Servents in a P2P Network', Proceedings of the International WWW Conference (11), Honolulu, Hawaii, USA, (2002).

[30] M. Morzy and J. Jezierski, 'Cluster-Based Analysis and Recommendation of Sellers in Online Auctions' Proceedings of the third International Conference on Trust, Privacy and Security in Digital Business (TRUSTBUS '06), krakow, Poland, Sringer-Verlag, LNCS Vol. 4083, pp 172-181, (2006).