Determining the Failure Level for Risk Analysis in an e-Commerce Interaction

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Abstract. Before initiating a financial e-commerce interaction over the World Wide Web, the initiating agent would like to analyze the possible Risk in interacting with an agent, to ascertain the level to which it will not achieve its desired outcomes in the interaction. By analyzing the possible risk, the initiating agent can make an informed decision of its future course of action with that agent. To determine the possible risk in an interaction, the initiating agent has to determine the probability of failure and the possible consequences of failure to its resources involved in the interaction. In this chapter as a step towards risk analysis, we propose a methodology by which the initiating agent can determine beforehand the probability of failure in interacting with an agent, to achieve its desired outcomes.

Keywords: Risk assessing agent, Risk assessed agent, FailureLevel and Failure scale.

1 Introduction

The development of the internet has provided its users with numerous mechanisms for conducting or facilitating e-commerce interactions. It has also provided its users with various functionalities which will facilitate the way e-commerce interactions are carried out. But along with the provision of the increased functionalities for facilitating e-commerce interactions, also comes the fear of loss or the fear of not achieving what is desired in an interaction. This fear of loss or not achieving what is desired is termed as 'Risk' in the interaction. The terms 'risk assessing agent' and 'risk assessed agent' defines the two agents participating in an interaction. The former refers to the one initiating the interaction, while the latter refers to the agent accepting the request. In other words, this is the agent with whom the risk assessing agent interacts with to achieve its desired outcomes. The significance of the risk assessing agent to analyze the possible risk before initiating an interaction with a risk assessed agent is substantial. The risk assessing agent, by analyzing 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 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 the possible outcomes of the interaction.

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Risk & Trust complement what the risk assessing agent needs in order to make an informed decision of its future course of action with a risk assessed agent. But there is still confusion in the relationship between them. As Mayer et al [1] suggest 'it is unclear whether Risk is an antecedent 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 agent 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. But it is important to understand that, although risk and trust are two terms that complement each other while making an informed decision, they express different concepts which cannot be replaced with each other. Further it is important to comprehend the difference between each concept while analyzing them. Risk analysis involves the risk assessing agent to determine beforehand the probability of failure and the subsequent possible consequences of failure to its resources in interacting with a risk assessed agent. On the other hand, trust analysis measures the belief that the risk assessing agent has in a risk assessed agent in attaining its desired outcomes, if it interacts with it. This analysis does not take into account the resources that the risk assessing agent is going to invest in the interaction. A lot of work has been done in the literature to determine and evaluate the trust in an interaction [6-14].

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 an interaction. The need to distinguish between the likelihood and magnitude of risk is important as they represent different concepts. Magnitude shows the severity of the level of risk, whereas the likelihood shows the probability of its occurrence. 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 interactions, but the magnitude of loss will be greater in the higher cost interaction. Hence these two characteristics must be considered by the risk assessing agent while analyzing the possible risk in interacting with a risk assessed agent. Previous methods in the literature analyze risk by just considering the probability of failure of the interaction. However, in our approach apart from considering the probability of failure of the interaction, we also consider the possible consequences of failure while ascertaining the possible risk in an interaction. It should be noted that this is the first attempt in the literature to model and analyze risk by using the two aforesaid constituents in e-commerce interactions.

In this chapter, we propose a methodology to determine semantically one aspect of risk evaluation, namely determining the probability of failure of the interaction. We propose to determine the probability of failure in the interaction according to the

magnitude or severity of failure, and the likelihood of its occurrence. The methodology is explained in the next sections.

2 Defining the Failure Scale

The risk assessing agent can determine the probability of failure in interacting with a risk assessed agent, by ascertaining its in-capability to complete the interaction according to the context and criteria of its future interaction with it. Context of the interaction defines the purpose or scenario for which the interaction is to be carried out [3], or it is a broad representation of the set of all coherently related functionalities, which the risk assessing agent is looking to achieve, or desires to achieve while interacting with a risk assessed agent. Subsequently in a context, there might be a number of different related functionalities which comes under it, and if a risk assessing agent wants to interact with a risk assessed agent in a particular context, then it is highly possible that it might want to achieve only certain functionalities, in the particular context and not all the available functionalities in it. So we term those desired functionalities that the risk assessing agent wants to achieve while interacting with a risk assessed agent in a particular context, as the 'assessment criteria' or 'criteria' or 'desired outcomes'. In other terms 'assessment criteria' represents the certain desired functionalities that the risk assessing agent wants to achieve specifically while interacting with a risk assessed agent, in the particular context. Hence it is logical to say that the risk assessing agent when ascertaining the possible risk in interacting with a risk assessed agent in a context, should determine it according to the specific criteria of its future interaction with it, which comes under that particular context.

We assume that before initiating the interaction, the risk assessing agent communicates with the risk assessed agent about the context, criteria or the desired outcomes that it wants to achieve in its interaction with it, and decide on the quantitatively expressed activities in the expected or mutually agreed behaviour [3]. These set of quantitatively expressed activities are termed as the 'expectations' of the risk assessing agent, which the risk assessed agent is expected to adhere to. So we propose that while determining the probability of failure in an interaction, the risk assessing agent should ascertain it according to the 'expectations' of its future interaction with a risk assessed agent.

In an interaction there might be various degrees of failure according to their severity. Subsequently, it would be more expressive and understandable if the levels of failure are expressed according to their severity, rather than being expressed by using just two superlatives or extremes, such as "High" or "Low". Hence, before determining the probability of failure in an interaction, it is first necessary to ascertain the different possible levels of failure possible in an interaction according to their severity, so that while determining the probability of failure of an interaction the risk assessing agent can determine the severity of failure and the probability of occurrence of that failure in interacting with a risk assessed agent according to its expectations for a given period of time.

To represent semantically the different levels of failure possible in an interaction according to their severity, we propose a 'Failure scale'. The Failure scale represents

seven different varying degrees of failure according to their severity which could be possible in an interaction, while interacting with a risk assessed agent. We term each degree of failure on the Failure scale, which corresponds to a range of severity of failure as 'FailureLevel' (FL). We propose that the risk assessing agent while determining the probability of failure according to its severity and probability of occurrence, in interacting with a risk assessed agent, ascertains its FailureLevel on the Failure scale. FailureLevel quantifies the possible level of failure according to its severity on the failure scale, in interacting with the risk assessed agent. The risk assessing agent determines the FailureLevel in interacting with a risk assessed agent by ascertaining its in-capability to complete the interaction according to its expectations.

Semantics of Failure Level	Probability of Failure	FailureLevel
Unknown	-	-1
Total Failure	91-100 %	0
Extremely High	71-90 %	1
Largely High	51-70 %	2
High	26-50 %	3
Significantly Low	11-25 %	4
Extremely Low	0-10 %	5

Fig. 1. The Failure scale

To represent the varying degrees of failure according to their severity, we make use of seven different FailureLevel on the failure scale. The failure scale as shown in Figure 1 represents 7 different varying levels of failure according to their severity, which could be possible in an interaction. The failure scale is utilized by the risk assessing agent when it has to determine beforehand either direct interaction based probability of failure or reputation based probability of failure of an interaction. Each level on the failure scale represents a different degree or the magnitude of failure. The domain of the failure scale ranges from [-1, 5]. The domain on the failure scale is defined as the possible set of values from which a FailureLevel is assigned to the risk assessed agent, according to the severity of failure present in interacting with it. The reason for us to choose this domain for representing the FailureLevel of the risk assessed agent is that it is expressive, and the semantics of the values are not lost; as compared to the approach proposed by Wang and Lin [13]. The authors in that approach represent the possible risk in an interaction within a domain of [0, 1]. This domain for representation is not much expressive as either:

1. Any value which comes in between gets rounded off to its nearest major value. By doing so, the semantics and severity which the actual value represents is either lost or gets compromised, or;
2. If rounding off is not used then there might be number of values between this range, which gets difficult to interpret them semantically.

So in our method we use a domain which is more expressive and which can represent different levels of failure according to their severity, thus alleviating the above mentioned disadvantages. In our domain even when rounding is used, the representation of the severity of the level of failure does not get effected, as it gets

rounded off to its nearest value which is of the same level of severity. Hence the features of the domain of the failure scale are:

- One level is used to represent the state of ignorance in the probability of failure (Level -1).
- Two levels to represent the high probability of failure in an interaction (FailureLevel 0 and 1). Out of those two levels, one represents the greater level of high probability of failure and the other represents the lesser level of high probability of failure in an interaction.
- Two levels to represent the medium probability of failure in an interaction (Level 2 and 3). From those levels, one represents the higher level of medium probability of failure and the other level represents the lower level of medium probability of failure in the interaction.
- Two levels to represent low probability of failure in an interaction (Level 4 and 5). One level represents the higher level of low probability of failure and the other level represents the lower level of low probability of failure in the interaction.

Hence the domain that we propose for the Failure scale ranges from [-1, 5], with -1 representing the level of failure as 'Unknown' and the levels from 0 to 5 representing decreasing severity of failure. In order to express each level of failure on the Failure scale semantically we have defined the semantics or meanings associated with each FailureLevel. We explain them below:

2.1 Defining the Semantics of the Failure Scale

- **Unknown**

The first level of the failure scale is termed as *Unknown Failure* and its corresponding FailureLevel is -1. This level suggests that the level of failure in interacting with the risk assessed agent is unknown.

Semantics: This level can only be assigned by the recommending agent to the risk assessed agent if it does not have any past interaction history with it, in the context and criteria in which it is communicating its recommendation. Hence we propose that, the recommending agent instead of recommending any random FailureLevel in the range of (0, 5) on the Failure scale, recommends the level -1 to the risk assessing agent soliciting for recommendations. An important point to note is that all new agents in a network begin with this value, and hence a FailureLevel of -1 is assigned to the risk assessed agent, when there are no precedents that can help to determine its FailureLevel.

- **Total Failure**

The second level of the failure scale is defined as *Total Failure* and its corresponding FailureLevel value is 0. A FailureLevel value of 0 suggests that the probability of failure in interacting with the risk assessed agent is between 91-100 %.

Semantics: This level on the failure scale suggests that at a given point of time and in the given criteria the risk assessed agent is totally or completely unreliable to complete the desired outcomes of the risk assessing agent. In other terms it will not

complete the interaction according to the expectations at all and acts fraudulently in the interaction, thus resulting in total failure for the risk assessing agent in achieving its desired outcomes. The FailureLevel of 0 expresses the highest level of failure possible in an interaction.

- **Extremely High**

Extremely High is the third level on the failure scale with the corresponding FailureLevel value of 1. This level denotes that there is 71-90 % probability of failure in interacting with the risk assessed agent.

Semantics: This level on the failure scale depicts that at a given point of time and in the given criteria the risk assessed agent is unreliable most of the times to commit to the expectations of the risk assessing agent. In other terms it will deviate from the desired criteria most of the times, hence resulting in extremely high level of failure in the interaction accordingly.

- **Largely High**

The fourth level of the failure scale is termed as *Largely High* level of failure. The corresponding FailureLevel value of this level is 2. This level depicts that there is a 51-70 % probability of failure in interacting with the risk assessed agent.

Semantics: A FailureLevel of 2 on the failure scale indicates that there is significant high level of failure in the interaction, as the risk assessed agent at that given point of time will not commit to a greater extent to its expectations.

- **High**

The fifth level on the failure scale is termed as *High* level of failure and it is shown by a FailureLevel value of 3. This level outlines that there is 26-50 % probability of failure in the interaction.

Semantics: A FailureLevel value of 3 on the failure scale assigned to a risk assessed agent suggests that at that particular point of time, the risk assessed agent is unable to complete the interaction to a large extent according to its expectations, hence resulting in high level of failure in the interaction.

- **Significantly Low**

The sixth level on the failure scale is defined as *Significantly Low* level of failure with a corresponding FailureLevel value of 4. This level depicts that there is 11-25 % probability of failure in the interaction.

Semantics: This level on the failure scale suggest that at a given point of time the risk assessed agent can complete MOST but not ALL of the criterions of its expectations. A FailureLevel of 4 on the failure scale indicates that the risk assessed agent assigned with this value can be relied on to a greater extent in that time, to commit to the expectations of the interaction, thus resulting in significantly low failure level in the interaction.

- **Extremely Low**

Extremely Low is the seventh and the last level of the failure scale represented by the FailureLevel value of 5. This level shows that there is 0-10 % probability of failure in the interaction.

Semantics: This level on the failure scale implies that at a given point of time, the risk assessed agent can fully be relied upon to complete the interaction according to its expectations, hence minimizing the probability of failure in an interaction. The probability of failure in interacting with the risk assessed agent, if any will be minimal. A FailureLevel of 5 expresses the lowest level of failure possible in an interaction.

3 Determining the FailureLevel of an Interaction

As mentioned earlier, for risk analysis the risk assessing agent has to determine beforehand the FailureLevel and the possible consequences of failure in interacting with a risk assessed agent. The risk assessing agent can determine the FailureLevel in interacting with a risk assessed agent beforehand, by analyzing its in-capability to complete the interaction according to its expectations. The possible interaction of the risk assessing agent with the risk assessed agent is in the future state of time. Hence, for risk analysis, the risk assessing agent has to determine the FailureLevel in interacting with the risk assessed agent in that future state of time. In order to achieve that, we propose that the risk assessing agent analyze and determines the FailureLevel in interacting with a risk assessed 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 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. For risk analysis the risk assessing agent has to determine the FailureLevel in interacting with a risk assessed agent in this period of time, i.e. in the post-interaction start time phase. However, as this time phase is in the future state of time, the risk assessing agent can only determine it by using some prediction methods. So we propose that the risk assessing agent should first ascertain the FailureLevel of the risk assessed agent according to the specific context and criteria as that of its future interaction, in the pre-interaction start time phase. Based on those achieved levels, the risk assessing agent can determine its FailureLevel, in the post-interaction start time phase. The determined FailureLevel of the risk assessed agent in the post-interaction time phase depicts the probability of failure in interacting with it, in that time phase, according to the context and criteria of the risk assessing agent's future interaction with it.

3.1 Time Based FailureLevel Analysis

We define the perceived risk in the domain of financial e-commerce transaction 'as the likelihood that the risk assessed agent will not act as expected by the risk

assessing agent resulting in the failure of the interaction and loss of resources involved in it' [4]. This 'likelihood' varies throughout the transaction depending on the behaviour of the risk assessed 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 risk assessed agent throughout, which it had at a particular time. Hence the risk assessing agent should take into account this dynamic nature of risk while doing risk analysis in its interaction with a risk assessed agent. In order to incorporate and consider this dynamic nature, we propose that the risk assessing agent should determine the FailureLevel in interacting with a risk assessed agent in regular intervals of time. By doing so, it ascertains the correct FailureLevel of the risk assessed agent, according to its incapability to complete criterions of its future interaction, in each particular interval of time, thus considering its dynamic nature while doing risk analysis. We will define some terms by which the total time can be divided into different separate intervals.

We quantify the level of failure on the failure scale in interacting with a risk assessed 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 risk assessed agent according to the time phase in which it is determined and hence corresponds to. For example, if the FailureLevel for a risk assessed agent is determined in the pre-interaction start time phase, then we represent it by the metric 'PFL' which stands for '*Previous FailureLevel*'. Similarly, if the FailureLevel for the risk assessed agent is determined in the post-interaction start time phase, then we represent it by 'FFL' which stands for '*Future FailureLevel*'. We define the total boundary of time which the risk assessing agent takes into consideration to determine the FailureLevel (previous or future) of a risk assessed peer as the *time space*. But, as mentioned earlier, risk varies according to time and if the time space is of a long duration, then the FailureLevel of the risk assessed agent might not be the same throughout. Hence we propose that the risk assessing agent divides the time space into different non-overlapping parts and it assess the FailureLevel of the risk assessed agent in each of those parts, according to its incapability to complete the criterions of its future interaction in that time slot, to reflect it correctly while doing risk analysis. These different non-overlapping parts are called as *time slots*. The time at which the risk assessing agent or any other agent giving recommendation deals with the risk assessed agent in the time space is called as *time spot*. The risk assessing agent should first decide about the total time space over which it is going to analyze the FailureLevel of a risk assessed agent. Within the time space, the risk assessing 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 risk assessed agent in each time slot, may it be either in past or future.

For explanation sake, let us suppose that a risk assessing agent wants to interact with a risk assessed agent for a period of 10 days from 01/02/2007 till 10/02/2007. This is the post-interaction start time phase. Before initiating the interaction, the risk assessing agent wants to determine the probability of failure of the interaction as a first step towards risk analysis. To achieve that, the risk assessing agent wants to determine the FailureLevel of the risk assessed agent according to the criteria of its future interaction with it, from a period of 30 days prior to starting an interaction with

it, i.e. from 02/01/2007 till 31/01/2007. This is the pre-interaction start time phase. Hence, the total period of time which the risk assessing agent takes into consideration to determine the FailureLevel (PFL and FFL) of the risk assessed agent is of 40 days. This time space is a combination of pre and post interaction start time phase. Further, the risk assessing agent wants to analyze the FailureLevel of the risk assessed agent in a time interval basis of 5 days. The total time space is of 40 days and each time slot is of 5 days. The number of time slots in this time space will be 8 as shown in Figure 2.

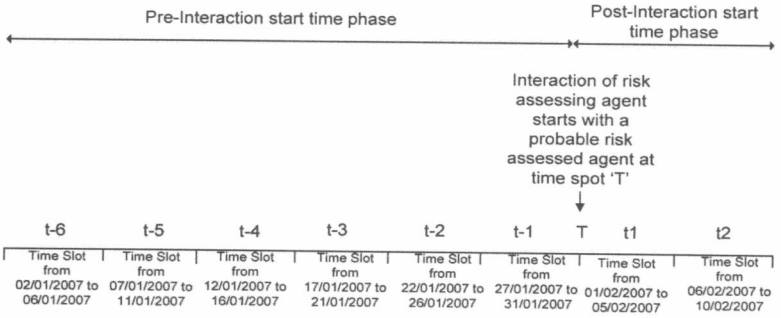

Fig. 2. Showing the division of the time space

Hence the risk assessing agent by determining the FailureLevel of the risk assessed agent in different time slots within the time space of its interaction is considering its accurate dynamic level of failure, according to its in-capability to complete the criterions in each of those time slots, thus reflecting it while doing risk analysis. The process for the risk assessing agent to ascertain the FailureLevel of the risk assessed agent in a time slot of its time space varies according to the time phase it comes in. We will briefly discuss the process by which the risk assessing agent can ascertain the FailureLevel of the risk assessed agent according to the expectations of its interaction with it, in each time slot of its time space depending upon the time phase it is in.

Scenario 1: The risk assessing agent determining the FailureLevel of the risk assessed agent in a time slot before the time spot of its interaction i.e. in the pre-interaction start time phase.

The risk assessed agent can determine the FailureLevel (PFL) of the risk assessed agent according to the expectations of its future interaction with it, in a time slot which is in the pre-interaction state time phase by considering either:

- its previous interaction history with it (if any) in the expectations of its future interaction, (direct past interaction-based probability of failure); or
- in the case of ignorance, then soliciting for recommendations from other agents and assimilating them according to the expectations of its future interaction, (reputation-based probability of failure).

A detailed explanation of how to determine the FailureLevel of the risk assessed agent in a time slot by using either direct past-interaction history or by soliciting recommendation from other agents is given in Section 4.

Scenario 2: The risk assessing agent determining the FailureLevel of the risk assessed agent in a time slot after the time spot of its interaction i.e. in the post-interaction start time phase.

Case 2.1: If the time spot and the duration of the interaction (post-interaction start time phase) is limited to the time slot in which the risk assessing agent is at present as shown in Figure 3, then it can determine the FailureLevel (FFL) of the risk assessed agent for the period of time in the post-interaction phase, by either considering its past-interaction history with the risk assessed agent (if any), or by soliciting recommendations from other agents.

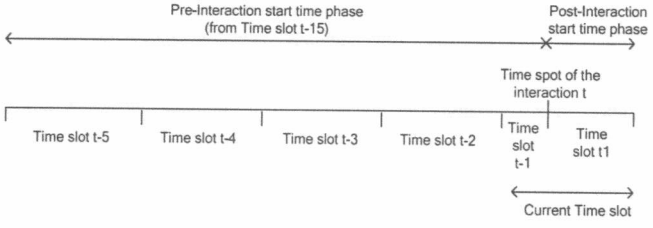

Fig. 3. The time spot and post-interaction phase of the interaction limited to the current period of time

The risk assessing agent can consider its past interaction history with the risk assessed agent only if it is in the same time slot, with the same expectations which had the same significance attached to each assessment criterion as for its future interaction with it. If this is the case, then the risk assessing agent can utilize the FailureLevel (AFL) that it had determined for the risk assessed agent in its past interaction as its FailureLevel (FFL) in the current interaction. This is based on the assumption made by Chang et al. [3] who state that the behavior of the risk assessed agent remains the same in a time slot, and subsequently the risk assessing agent can utilize the FailureLevel of the risk assessed agent from its past interaction if it is in the same expectations, significance and time slot of its future interaction as its FailureLevel (FFL) in that time slot. However, if the risk assessing agent does not have a past interaction history with the risk assessed agent in the expectations and in the time slot of its future interaction, or it has a past interaction history in the partial expectations in the time slot of its future interaction, then in such cases the risk assessing agent can solicit recommendations about the risk assessed agent from other agents for that particular time slot in the assessment criterion or criteria of its interest from its expectations, in which it does not have a past interaction history with it, and then assimilate them along with its past-interaction history (if any in the partial expectations) to determine the FailureLevel (FFL) of the risk assessing agent in the post-interaction start time phase. A detailed explanation of how to determine the FailureLevel of the risk assessed agent in a time slot by either using direct past-interaction history and/or by soliciting recommendation from other agents is given in Section 4.

It may be the case that the risk assessing agent may neither have any past interaction history nor obtains any recommendations from other agents for the risk

assessed agent against all the assessment criteria of its expectations in the current time slot of its interaction. In such cases, the risk assessing agent should determine the FailureLevel (FFL) of the risk assessed agent in the current time slot by using the methodology proposed in case 2.2.

Case 2.2: If the time spot or duration of the interaction (post-interaction start time phase) begins or extends to a future point in time from the current time slot in which the risk assessing agent is at present as shown in Figure 4, then it should utilize the determined FailureLevel of the risk assessed agent from the beginning of the time space till the current time slot to predict and determine the future FailureLevel (FFL) of the risk assessed agent in each of the post-interaction start time slots. A detailed explanation of how to determine the FailureLevel of the risk assessed agent in future time slots is given in Section 5.

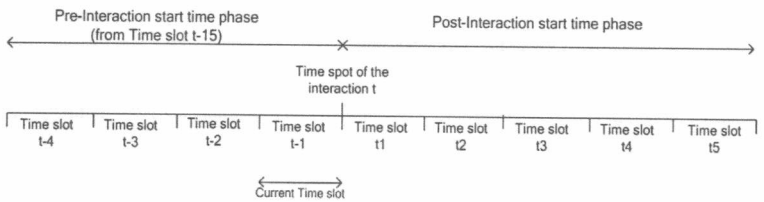

Fig. 4. The time spot and the post-interaction start time phase of the interaction extending to a future point in time

A point to be considered by the risk assessing agent while utilizing the FailureLevel of the risk assessed agent in the previous time slots to determine its FailureLevel during the time of its interaction, is that it should give more importance to the fresh status of the risk assessed agent (represented by its FailureLevel), which is in the time slots near or closest to the time spot of its interaction with it as compared with those which are in the less recent time slots from the time spot of its interaction. This takes into consideration the fact mentioned by Chang et al. [3] that 'recency is important' when utilizing the past values of an agent in order to determine its value/s in the future. They state that it is important for the risk assessing agent to weigh those values of the risk assessed agent obtained in the recent interactions or time slots more heavily among the values that it considers for it in the previous time slots, so as to avoid modeling its behavior in the future that may no longer be relevant according to the expectations of its future interaction. Hence, the prediction method should weigh the recent FailureLevel values of the risk assessed agent more heavily as compared to its FailureLevel values in the far recent time slots, progressively reducing the effect of the older FailureLevel values in order to take into consideration its fresh status while determining its FailureLevel value/s over a future period of time. We represent the weight to be given to the status of the risk assessed agent in a time slot before the time spot of the interaction by the variable 'w'. The weight (w) to be given to each time slot of the pre-interaction start time phase is represented in Figure 5 and is determined by:

$$w = \begin{cases} 1 & \text{if } m \leq \Delta t \\ e^{\frac{-((n+\Delta t)-m)}{N}} & \text{if } m > \Delta t \end{cases} \quad (1)$$

where, 'w' is the weight or the time delaying factor to be given to the status of the risk assessed agent,

'n' represents the current time slot,

'm' represents the time slot for which the weight of adjustment is determined,

'Δt' represents the time slots from the time spot of the interaction in which the risk assessing agent will give more importance to the fresh status of the risk assessed agent,

'N' is the term which characterizes the rate of decay.

We consider that the risk assessing agent among the 15 time slots of the pre-interaction start time phase, gives more importance to the FailureLevel of the risk assessed agent in the five time slots previous to the time spot of its interaction as compared to the other time slots, in order to consider the fresh status of the risk assessed agent while utilizing it to ascertain its FailureLevel in the future period of time. For the importance to be given to the status or FailureLevel of the risk assessed agent in the other time slots of the pre-interaction start time phase, the weight to be adjusted to it is a progressively declining value determined by using equation 1.

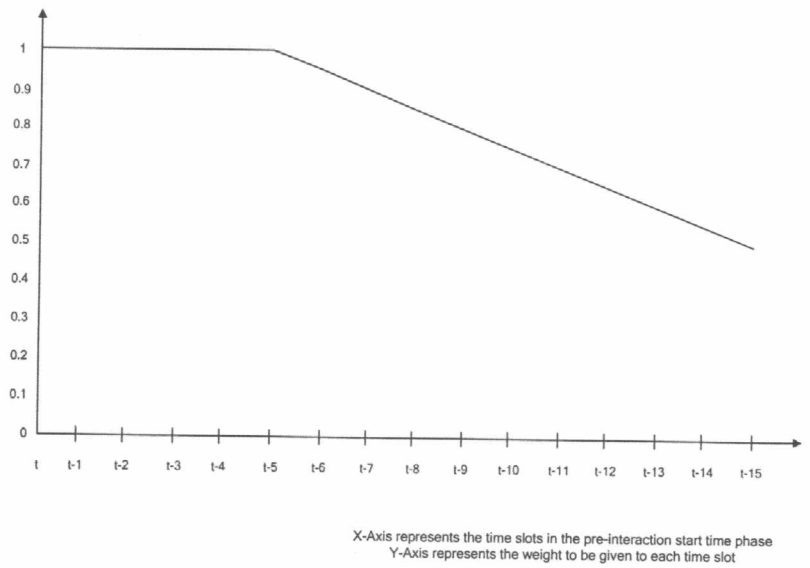

Fig. 5. The weight given to each time slot of the pre-interaction start time phase

To summarize the proposed methodology for the division of time in order to consider the dynamic nature of perceived risk while ascertaining the level of failure in an interaction:

- The risk assessing agent determines the 'time space' of its interaction over which it wants to analyze the FailureLevel of the risk assessed agent while ascertaining the performance risk in interacting with it.

- The time space is divided into different 'time slots' and then broadly divided into two phases, the pre-interaction start time phase and post-interaction start time phase according to the 'time spot' of the interaction.
- The risk assessing agent ascertains the FailureLevel of the risk assessed agent in each time slot of the pre-interaction time phase by either considering its past-interaction history with it or by soliciting recommendations from other agents.
- If the time spot and the post-interaction start time phase is limited to the current time slot at which the risk assessing agent is at present, then it determines the FailureLevel (FFL) of the risk assessed agent in the post-interaction start time phase by either considering its past-interaction history with it (if any) in the expectations and in the time slot of the interaction, or by soliciting recommendations from other agents, or by a combination of both.
- In the case of the risk assessing agent not being able to determine the FailureLevel of the risk assessed agent for each assessment criteria of its expectations in the current time slot, by using either its own past-interaction history or the recommendations from other agents, then it utilizes the approach mentioned in the next point to determine the FailureLevel (FFL) of the risk assessed agent in the post-interaction start time slot.
- If the time spot and the post-interaction start time phase extend to a point in time in the future, then the risk assessing agent utilizes the FailureLevel (PFL) that it determined for the risk assessed agent from the beginning of the time space till the preceding time slot, to determine its FailureLevel (FFL) in each time slot of the post-interaction time phase.

4 Determining the FailureLevel in the Pre-interaction phase

In this section, we will propose the methodology by which the risk assessing agent can ascertain the FailureLevel of the risk assessed agent according to the expectations of its future interaction with it, in the pre-interaction start phase time slots. As discussed earlier, the pre-interaction start time phase refers to that period of time in which the risk assessing agent considers the previous impression of the risk assessed agent, before determining its FailureLevel in the post-interaction start time phase of its interaction. Subsequently, this period of time ranges from the beginning of the time space to the time spot of the interaction. There are two methods by which the risk assessing agent can determine the FailureLevel of a risk assessed agent in the pre-interaction start time phase. They are:

a) Direct past Interaction-based Probability of Failure: by considering its past interaction history with the risk assessed agent in the expectations of its future interaction with it; and
b) Reputation-based Probability of Failure: by soliciting recommendations from other agents and then assimilating them to determine the inability of the risk assessed agent to complete the interaction according to the expectations of its future interaction with it.

In the next sub-sections we will explain in detail each method with which the risk assessing agent can determine the FailureLevel in interacting with the risk assessed agent in the each time slot of the pre-interaction start time phase.

4.1 Determining Direct Past Interaction-Based Probability of Failure in an Interaction

The direct past interaction-based probability of failure method refers to the risk assessing agent determining the probability of failure or FailureLevel in interacting with the risk assessed agent in a time slot, based on its past interaction history with it in that particular time slot. Further, the past interaction of the risk assessing agent with the risk assessed agent should be strictly according to the expectations and the same significance attached to each assessment criterion, as in its future interaction with it. This is necessary in order to take into consideration the property of dynamic nature of risk which varies according to the variation of the context and assessment criteria. Hence, if the risk assessing agent does have a past interaction history with the risk assessed agent in a pre-interaction start time slot, in the same context but in partial fulfillment of the assessment criteria of its expectations, then we propose that it cannot consider its past interaction history in order to determine the FailureLevel of the risk assessed agent in the total assessment criteria of its expectations in that time slot, due to the assessment criteria slightly varying from its past interaction as compared to the expectations of its future interaction. In such case, we propose that the risk assessing agent should determine the FailureLevel of the risk assessed agent in that time slot by using a combination of its direct past interaction history in the same assessment criteria from its past interaction as its expectations and the reputation of the risk assessed agent in the varying assessment criteria, to determine the FailureLevel of the risk assessed agent in that time slot. Three scenarios arise when the risk assessing agent determines the FailureLevel of the risk assessed agent in a pre-interaction start time slot by considering its past interaction history with it in that time slot. They are:

Scenario 3: The assessment criteria of the risk assessing agent's previous interaction and their significance are the same as those of its expectations of its future interaction.

If the context, assessment criteria and their significance of the risk assessing agent's previous interaction with the risk assessed agent in a time slot of the pre-interaction start time phase are exactly to the same as the expectations of its future interaction with it, then we propose that the risk assessing agent can utilize its risk relationship that it has formed with the risk assessed agent in that time slot, and consider the FailureLevel (AFL) that it had determined for the risk assessed agent in that interaction, as its FailureLevel (PFL) for that particular time slot. A detailed explanation of how the risk assessing agent ascertains the FailureLevel (AFL) of the risk assessed agent, after interacting with it is given in Hussain et al. [18].

In order to give more importance to the fresh status of the risk assessed agent which are in the time slots near or recent to the time spot of its interaction, the risk assessing agent should adjust the determined FailureLevel of the risk assessed agent in a pre-interaction start time slot 't-z' ($PFL_{Pt\text{-}z}$), according to the weight that it considers to give to that time slot depending on where it falls in the time space of its interaction. Hence the FailureLevel (PFL) of the risk assessed agent 'P' in a pre-interaction start time slot 't-z' based on the risk assessing agent's past interaction history with it in that time slot is represented by:

$$PFL_{Pt\text{-}z} = ROUND\ (w * AFL_{Pt\text{-}z}) \quad (2)$$

where, 'P' represents the risk assessed agent,

't' represents the time spot of the interaction,

'z' represents the number of time slots prior to the time spot of the risk assessing agent's interaction with the risk assessed agent,

'w' is the weight applied to the FailureLevel (AFL) of the risk assessed agent depending upon the time slot 't-z'.

The resultant value from equation 2 is rounded off to determine the crisp FailureLevel value for the risk assessed agent 'P' on the Failure Scale in the time slot 't-z' ($PFL_{Pt\text{-}z}$).

Scenario 4: The criteria of the risk assessing agent's previous interaction vary partially from the expectations of its future interaction, or the assessment criteria of the risk assessing agent's previous interaction are the same as those of its expectations, but the significance of these assessment criteria vary from those of the expectations of its future interaction.

Case 1: If the context of the previous interaction of the risk assessing agent with the risk assessed agent in a time slot of the pre-interaction start time phase is the same, but the assessment criteria differ partially as compared to the expectations of its future interaction, then we propose that the risk assessing agent from its previous interaction should consider only those partial criteria which are similar to the assessment criteria in the expectations of its future interaction and utilize them to determine the trustworthiness of the risk assessed agent in those, while considering the rest of the assessment criteria of its expectations by the reputation-based method, and then combine them to determine the FailureLevel (PFL) of the risk assessed agent in that time slot.

Case 2: If the assessment criteria of the risk assessing agent's previous interaction with the risk assessed agent in a time slot of the pre-interaction start time phase are identical to the expectations of its future interaction with it, but the significance of the criteria in its previous interaction vary from those of the assessment criteria of the expectations of its future interaction, then we propose that the risk assessing agent in such a case consider the criteria from its previous interaction and utilize them to determine the trustworthiness of the risk assessed agent in these.

In both the cases, the risk assessing agent cannot utilize the FailureLevel (AFL) that it had determined for the risk assessed agent in its previous interaction in a time slot of the pre-interaction start time phase as the FailureLevel (PFL) of the risk assessed agent in the pre-interaction start time slot of its current interaction, as was done in the previous scenario. This is because in the first case, the FailureLevel (AFL) of the risk assessed agent determined in the past interaction is not exactly according to the expectations of its future interaction; and in the second case, the FailureLevel (AFL) of the risk assessed agent determined in the past interaction is not according to the significance of the expectations of its future interaction. Therefore in such cases, we propose that the risk assessing agent take into consideration the relative 'assessment criteria' from its past interaction which are in the expectations of its future interaction, along with their corresponding 'Commitment Level' value that it

had determined in its past interaction, and utilize them to determine the risk assessed agent's trustworthiness in those assessment criteria according to the weight to be given to its status in that time slot. 'Commitment Level' is a value which the risk assessing agent ascertains for each assessment criterion of its interaction with the risk assessed agent, when it determines its Actual FailureLevel (AFL) in the interaction. The Commitment Level value shows whether or not a particular assessment criterion was fulfilled by the risk assessed agent according to the expectations of the interaction, and is represented by a value of either 1 or 0. Further explanation of the way to determine the commitment level value for each assessment criterion of the interaction is given in the sub-section 4.2.1. Hence, the risk assessing agent by considering an assessment criterion along with its commitment level from its past interaction, which are in the expectations of its future interaction, should determine the trustworthiness of the risk assessed agent in those assessment criteria in a pre-interaction start time slot, according to the weight to be given to the status of the risk assessed agent in that time slot.

The risk assessing agent can determine the trustworthiness of the risk assessed agent 'P' in an assessment criterion (C_n) by considering its past interaction history with it a time slot 't-z' of the pre-interaction start time phase by:

$$T_{PCn\ t\text{-}z} = (w * \text{Commitment Level}_{Cn}) \tag{3}$$

where, 'P' represents the risk assessed agent,

'Cn' represents the assessment criterion, in which the trustworthiness of the risk assessed agent 'P' is being determined,

'Commitment Level $_{Cn}$' represents the level of commitment of the risk assessed agent in assessment criterion 'Cn',

'w' is the weight applied to the commitment level of the risk assessed agent to consider its status in the time slot 't-z'.

If there is more than one assessment criteria in the risk assessing agent's past interaction history with the risk assessed agent which matches the expectations of its future interaction with it, then the risk assessing agent by using equation 3 should determine the trustworthiness of the risk assessed agent for each of those assessment criteria. To consider the other assessment criteria of its expectations in which the risk assessing agent does not have any past interaction history with the risk assessed agent, we propose that it solicit recommendations from other agents and utilize them to determine the reputation of the risk assessed agent in those. It should then utilize the trustworthiness or reputation value of the risk assessed agent determined in each assessment criterion of its expectations to ascertain its FailureLevel for each of them. It should then combine the determined FailureLevel of each assessment criteria according to its significance in order to ascertain the FailureLevel (PFL) of the risk assessed agent in that time slot. The methodology for the risk assessing agent to ascertain the FailureLevel of the risk assessed agent in a time slot by utilizing its trustworthiness (determined by using its past interaction history) and/or its reputation (determined from the recommendations from other agents) in the assessment criteria of its expectations is mentioned in sub-section 4.2.4.

Scenario 5: The assessment criteria of the risk assessing agent's previous interaction are completely different from the expectations of its future interaction.

If the context of the risk assessing agent's previous interaction with the risk assessed agent in a time slot of the pre-interaction start time phase is the same, but the assessment criteria are completely different as compared to the expectations of the future interaction, then the risk assessing agent cannot utilize its past interaction history in determining the FailureLevel (PFL) of the risk assessed agent of that time slot. In such cases, we propose that the risk assessing agent determine the FailureLevel of the risk assessed agent by utilizing the reputation-based probability of failure method.

4.2 Determining Reputation-Based Probability of Failure in an Interaction

The reputation-based probability of failure method is utilized by the risk assessing agent in order to determine the probability of failure or FailureLevel in interacting with the risk assessed agent in a time slot of the pre-interaction start time phase, if it does not have any past interactions with it in that time slot, either in all or in the partial expectations of its future interaction with it. In such cases, we propose that the risk assessing agent rely on other agents by soliciting recommendations from those who have interacted in that time slot with the risk assessed agent in the assessment criteria of interest, and then utilize their recommendations to determine the reputation and then the FailureLevel in interacting with the risk assessed agent for those assessment criteria. The risk assessing agent, in order to determine the reputation of the risk assessed agent in the expectations or in partial expectations, issues a reputation query to solicit recommendations from other agents by specifying the risk assessed agent, the particular assessment criterion or criteria and the time in which it wants the recommendations to be. The agents who have had a previous interaction history with the risk assessed agent in the same time and assessment criterion or criteria, reply with their recommendations. The agents who reply with the recommendations are termed the 'Recommending Agents'. We consider that whenever an agent interacts with another agent, a risk relationship forms between them. This relationship is dependent on the time, context and assessment criteria of their interaction. We propose that when a risk assessing agent issues a reputation query soliciting recommendations for the risk assessed agent from other agents in a particular time and criteria related to a context, and if an agent has a previous interaction history with the risk assessed agent for those criteria and period of time for which its recommendation is being sought, then it communicates the risk relationship to the risk assessing agent that it had formed while interacting with the risk assessed agent in that time slot. Based on the risk relationships received from different agents, the risk assessing agent assimilates them and determines the reputation and then the FailureLevel of the risk assessed agent for the assessment criteria of interest for the particular time slot.

It is possible that the recommendations which the risk assessing agent receives for a risk assessed agent in a pre-interaction start time slot, might contain other criteria apart from the ones which are of interest to it in its interaction. Furthermore, it is possible that the risk assessing agent might receive more than one recommendation from different recommending agents for an assessment criterion of interest in a

particular time slot. Subsequently, to utilize such recommendations, we propose that the risk assessing agent should classify all the recommendation that it receives from different recommending agents for its request according to the assessment criterion or criteria of its interest, and then utilize each of them in order to determine the reputation of the risk assessed agent in those assessment criterion or criteria. But it would be difficult for the risk assessing agent to comprehend and understand the risk relationship that it receives from each recommending agent and later assimilate them, if each agent when solicited gives its recommendation in its own format. So in order to alleviate this, we propose a standard format called the 'Risk Set' for the recommending agent to communicate its recommendation to the risk assessing agent. In the next sub-section we will propose the format for the risk set.

4.2.1 Defining the Format for Risk Set

Risk Set is defined as a standard format for the recommending agents to communicate their recommendations in an ordered way to the risk assessing agent. The risk assessing agent, by getting the recommendations from the recommending agents in an ordered way, can comprehend and classify them according to the criterion or criteria which are of interest to it in that time slot. The format of the Risk Set is:

{RA1, RA2, Context, AFL, (Assessment Criterion, Commitment level), Cost, Start time, End time}

where, *RA1* is the risk assessing agent in the interaction, which is also the recommending agent while giving recommendation.

RA2 is the risk assessed agent in the interaction.
Context represents the context of the interaction.

AFL represents the 'Actual FailureLevel' determined by the recommending agent after interacting with the risk assessed agent, by assessing the level of non-commitment in the risk assessed agent's actual behavior with respect to its expectations.

(Assessment Criterion, Commitment level) 'Assessment Criterion' represents the assessment criterion in the recommending agent's expectations of the interaction with the risk assessed agent. The combination of (Assessment Criterion, Commitment level) is represented for each assessment criterion in the expectations of the recommending agent's interaction with the risk assessed agent. This is the set of factors on which the recommending agent interacted with the risk assessed agent and later assigned it with the 'Actual FailureLevel' (AFL) in its interaction. These criteria are necessary to mention while giving recommendations so that a risk assessing agent who solicits recommendations knows the assessment criteria on which this particular risk assessed agent has been assigned the recommended FailureLevel (AFL). In this way, it can consider only those recommendations which are of interest to it according to the expectations of its future interaction. 'Commitment level' specifies whether or not the particular assessment criterion was fulfilled by the risk assessed agent according to the expectations of its interaction. A value of either 0 or 1 is assigned to it, based on the commitment of the risk assessed agent for that criterion. A value of 0 signifies that the assessment criterion was not fulfilled by the risk assessed agent

Table 1. The commitment level of each assessment criterion

Commitment Level	Semantics of the Value
0	The risk assessed agent did not commit to the assessment criterion as it was expected from it according to the expectations
1	The risk assessed agent committed to the assessment criterion exactly according to the expectations

according to the expectations, whereas a value of 1 signifies that the assessment criterion was fulfilled according to the expectations. Further explanation is given in Table 1.

Cost represents the total financial value of the recommending agent at stake in the interaction.

Start Time is the time at which the recommending agent started the interaction with the risk assessed agent.

End time is the time at which the interaction of the recommending agent ended with the risk assessed agent.

Once the risk assessing agent classifies all the recommendations that it receives from the recommending agents according to the criterion or criteria of interest to it in a particular time slot, it should then assimilate them in order to determine the reputation of the risk assessed agent according to those criterion or criteria in the particular pre-interaction start time slot. But before assimilating the recommendations from the recommending agents, the risk assessing agent should first classify them according to their credibility. We will discuss this in the next sub-section.

4.2.2 Credibility of the Recommendations

When the risk assessing agent issues a reputation query for a risk assessed agent, there is the possibility that some recommending agents will reply with recommendations which are incorrect. In order to omit and avoid such recommendations while determining the reputation and then the FailureLevel of the risk assessed agent in a pre-interaction start time slot, the risk assessing agent should first classify each recommendation of interest for a risk assessed agent according to its credibility, and then assimilate it accordingly. To achieve this, we adopt the methodology proposed by Chang et al. [3] of classifying the recommendations according to their credibility. In this methodology, the authors state that the risk assessing agent maintains the credibility value of all the recommending agents from which it took recommendations, which in turn denotes the correctness of the recommendations communicated by them to the risk assessing agent. We represent the credibility value of the recommending agents maintained by the risk assessing agent as the 'Recommending Agent's Credibility Value' (*RCV*). RCV of a recommending agent is context-based, and we consider that the risk assessing agent maintains the RCV for a recommending agent in each context for which it took its recommendation. This value is used to determine whether or not the particular recommending agent is credible while giving recommendations in the particular context.

An agent whose RCV is known to the risk assessing agent is termed as the 'Known' recommending agent, whereas an agent whose RCV is unknown to the risk assessing

agent is termed as an 'Unknown' recommending agent. The known agents are further classified into two types, 'Trustworthy' agents and 'Untrustworthy' agents. Trustworthy agents are those agents whose RCV is within the specified range which is considered to be trustworthy by the risk assessing agent, whereas untrustworthy agents are those agents whose RCV is beyond the specified range which is considered as trustworthy. We consider that the credibility values of the recommending agents ranges from (-5, 5), and an agent whose RCV is within the range of (-1, 1) is considered as a trustworthy recommending agent by the risk assessing agent. Within that range, a value of 0 specifies that the recommendation communicated by the recommending agent for the risk assessed agent is exactly similar to what the risk assessing agent finds after its interaction with that agent. A positive value to the range of 1 specifies that the risk assessing agent finds that the recommending agent recommends a lesser value for the risk assessed agent, as compared to what it determines for the risk assessed agent after its interaction. A negative value to the range of -1 specifies that the risk assessing agent finds that the recommending agent recommends a higher value for the risk assessed agent, as compared to what it determines for the risk assessed agent after the interaction. The RCV of a recommending agent in a context is determined by the risk assessing agent based on its previous recommendation history with it, in that context. Further explanation of the way to determine the RCV of a recommending agent is given in Hussain et al. [17].

We consider that the risk assessing agent in the reputation-based probability of failure method to determine the FailureLevel of the risk assessed agent, considers only those recommendations which are from trustworthy and unknown recommending agents and omit the ones from untrustworthy recommending agents, in order to ascertain the correct reputation of the risk assessed agent. In other words, the risk assessing agent assimilates only those recommendations from agents whose credibility in communicating them in that context is trustworthy or unknown, and omits considering recommendations from those agents whose credibility is untrustworthy. Therefore to summarize, the risk assessing agent, while utilizing the recommendations of other agents to determine the reputation of the risk assessed agent in the assessment criteria of its expectations, should take into consideration:

- The credibility of the recommendations: The recommendations which the risk assessing agent should consider should be from trustworthy or unknown recommending agents, and not from untrustworthy recommending agents.
- The time slot of the recommendations: The time slot in which the risk assessing agent wants to determine the reputation of the risk assessed agent should match with the time of the recommendations that it considers.
- Expectations of its interaction: The recommendations considered by the risk assessing agent should be either in the exact or partial assessment criteria of its interest according to the expectations of its future interaction.

In the next section, we will propose a methodology by which the risk assessing agent can assimilate the recommendations after classifying them according to its credibility, time and criteria to ascertain the reputation of the risk assessed agent in the assessment criterion or criteria of its interest in a time slot of the pre-interaction start time phase.

4.2.3 Assimilating Recommendations for Ascertaining Reputation-Based FailureLevel of a Risk Assessed Agent

As mentioned earlier, it is possible that in a time slot the risk assessing agent might receive recommendations which contain other assessment criteria apart from those which are of interest to it in its present interaction. Further, it is possible that the risk assessing agent may receive more than one recommendation for an assessment criterion of interest in a time slot. Hence, in order to take into consideration all such types of recommendations, the risk assessing agent should determine the reputation of the risk assessed agent in each assessment criterion of interest from its expectations, by assimilating all the recommendations that it receives for the risk assessed agent for that particular criterion from the recommending agents. The risk assessing agent in such a case should consider the 'Commitment Level' value for the particular assessment criterion of interest, from all the recommendations which communicate in that criterion, and then adjust it according to the credibility of the recommendations (if it is from a trustworthy recommending agent) and the weight to be given to it according to the status of the risk assessed agent in that time slot, to ascertain the reputation of the risk assessed agent in that particular assessment criterion.

The reputation of a risk assessed agent 'P' in an assessment criterion 'Cn' (Rep_{PCn}) in a pre-interaction time slot 't-z' can be determined by assimilating the trustworthy and unknown recommendations that it receives from the recommending agents by using the following formulae:

$$\text{Rep}_{\text{PCn t-z}} = (\alpha * (w * \frac{1}{K} (\sum_{i=1}^{K} RCV_i \oplus \text{Commitment Level}_{Cn}^{i}))) + (\beta * (w * \frac{1}{J} (\sum_{o=1}^{J} \text{Commitment Level}_{Cn}^{o}))) \quad (4)$$

where, 'RCV_i' is the credibility value of the trustworthy recommending agent 'i',

'Commitment level $_{Cn}$' is the level of commitment recommended by the recommending agent for assessment criterion 'Cn' for the risk assessed agent in the particular time slot 't-z',

'K' is the number of trustworthy recommendations that the risk assessing agent gets for the risk assessed agent in assessment criterion 'Cn' in time slot 't-z',

'J' is the number of unknown recommendations that the risk assessing agent gets for the risk assessed agent in assessment criterion 'Cn' in time slot 't-z',

'α and β' are the variables attached to the parts of the equation which will give more weight to the recommendation from the trustworthy known recommending agents as compared to those from the unknown recommending agents. In general $\alpha > \beta$ and $\alpha + \beta = 1$,

'*w*' is the weight applied to consider the status of the risk assessed agent in time slot 't-z'.

The reputation value of the risk assessed agent 'P' in an assessment criterion 'Cn' is determined in two parts as shown in equation 4. The first part of the equation calculates the reputation value of the risk assessed agent 'P' in the assessment criterion 'Cn' by taking the recommendations of the trustworthy recommending

agents. The second part of the equation calculates the reputation value of the same risk assessed agent 'P' in the same assessment criterion 'Cn' by taking the recommendations of the unknown recommending agents. The recommendations from the untrustworthy 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 α and β respectively. It depends upon the risk assessing agent how much weight it wants to assign to each type of recommendation. Furthermore, each recommendation for the risk assessed agent in a time slot is adjusted according to the weight to be given to the status of the risk assessed agent in that time slot. The RCV of the trustworthy recommending agent is also considered while assimilating its recommendation. As shown in equation 4, the RCV 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 the credibility and accuracy by which it communicates its recommendations. The rules for the adjustment operator '$\oplus$' are:

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

It is possible that in a time slot 't-z', the risk assessing agent may not receive any recommendation for the risk assessed agent 'P' in an assessment criterion 'Cn' of its interest from its expectations, for which it does not have any past interaction history. In this case, we propose that the risk assessing agent should assume a value of '0' as the reputation of the risk assessed agent for that assessment criterion 'Cn' ($Rep_{PCn\ t\text{-}z}$) in that time slot. It is because the risk assessing agent assimilates the recommendations and determines the reputation of the risk assessed agent in an assessment criterion to ascertain its capability to complete that criterion. Hence, if there is no recommendation for the risk assessed agent in a time slot for a criterion, then in order to conduct a sensible risk analysis, we assume that the risk assessing agent considers that the risk assessed agent is incapable of completing the assessment criterion in that time slot. Hence, it should assign to it a value of '0' as its reputation for that assessment criterion.

The risk assessing agent should utilize equation 4 to determine the reputation of the risk assessed agent either in all or in partial assessment criteria of its expectations, in a pre-interaction start time slot for which it does not have any past interaction history. In the next section, we will propose an approach by which the risk assessing agent ascertains the FailureLevel of the risk assessed agent for each assessment criteria of its expectations, based on its determined trustworthiness in it (according to its past interaction history) or based on its determined reputation in it (according to the recommendations from other agents).

4.2.4 Ascertaining the FailureLevel (PFL) of the Risk Assessed Agent in a Pre-interaction Start Time Slot

Once the risk assessing agent ascertains the trustworthiness of the risk assessed agent in the partial assessment criteria of its expectations by using its past interaction history

(discussed in scenario 4), and the reputation of the risk assessed agent by using recommendations from the other agents in the rest of the assessment criteria of its expectations (discussed in section 4.2.3), or the reputation of the risk assessed agent using the recommendations from other agents in all of the assessment criteria of its expectations, then it should combine them in order to determine the FailureLevel (PFL) of the risk assessed agent in the pre-interaction start time slot 't-z', according to the expectations of its future interaction. To achieve this, the risk assessing agent has to first ascertain the FailureLevel of the risk assessed agent for each assessment criterion of its expectations, from its determined trustworthiness or by its determined reputation.

The trustworthiness or the reputation of the risk assessed agent in against an assessment criterion shows its level of capability to meet the particular criterion. To determine the FailureLevel of the risk assessed agent for that criterion, the extent of its inability to complete the given assessment criterion has to be determined. To achieve this, we propose that the risk assessing agent should map the trustworthiness or the reputation of the risk assessed agent in each assessment criterion of its expectations in a pre-interaction start time slot 't-z', on the Failure Scale (FS). By doing so, the risk assessing agent knows the capability of the risk assessed agent to meet that assessment criterion on the Failure Scale, in the time slot 't-z'. It can then determine the probability of failure of the risk assessed agent in committing to that assessment criterion in that time slot according to its expectations, by ascertaining the difference between what it expects in that assessment criterion, and how far the risk assessed agent can fulfill it according to its trustworthiness or reputation for that criterion. The value achieved gives the probability of failure of that assessment criterion in that time slot. The FailureLevel of the assessment criterion in that time slot is then achieved by mapping the probability of failure of that assessment criterion to the Failure Scale.

As mentioned earlier, the levels on the Failure Scale between 0 and 5 represent varying degrees and magnitudes of failure. Hence, for ascertaining the FailureLevel of the risk assessed agent in an assessment criterion, its trustworthiness or reputation for that 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 assessment criterion has to be ascertained on the Failure Scale. The trustworthiness or the reputation of the risk assessed agent in an assessment criterion can be represented on the Failure Scale (FS) by:

$$T_{PCn\ t\text{-}z\ FS} = \text{ROUND}\ (T_{PCn\ t\text{-}z} * 5) \qquad \text{or,}$$

$$\text{Rep}_{PCn\ t\text{-}z\ FS} = \text{ROUND}\ (\text{Rep}_{PCn\ t\text{-}z} * 5) \tag{5}$$

where, '$T_{PCn\ t\text{-}z\ FS}$' represents the trustworthiness of the risk assessed agent in time slot 't-z' and in assessment criterion 'Cn' on the Failure Scale,

'$T_{PCn\ t\text{-}z}$' represents the trustworthiness of the risk assessed agent in assessment criterion 'Cn' and in time slot 't-z',

'$\text{Rep}_{PCn\ t\text{-}z\ FS}$' represents the reputation of the risk assessed agent in time slot 't-z' and in assessment criterion 'Cn' on the Failure Scale,

'$\text{Rep}_{PCn\ t\text{-}z}$' represents the reputation of the risk assessed agent in assessment criterion 'Cn' and in time slot 't-z'.

Once the risk assessing agent has determined the trustworthiness or the reputation of a risk assessed agent against an assessment criterion on the Failure Scale, it can

then ascertain the probability of failure to achieve that particular assessment criterion in that time slot according to its expectations, by determining the difference between what it expects from the risk assessed agent in the assessment criterion and how far the risk assessed agent can fulfil it according to its trustworthiness or reputation in that. The risk assessing agent expects the risk assessed agent to complete the assessment criterion according to its expectations. This expectation of the risk assessing agent can be quantified with a value of 5 on the Failure Scale, as it represents the lowest probability of failure of the assessment criterion and expresses the maximum commitment by the risk assessed agent to its expectations. The probability of failure to achieve an assessment criterion 'Cn' according to the expectations in interacting with the risk assessed agent 'P' in a time slot 't-z', according to its trustworthiness or reputation in this can be determined by:

$$\text{Probability of Failure}_{PCn\ t\text{-}z} = \left(\frac{5 - T_{PCn\ t\ -\ z\ FS}}{5}\right) * 100 \quad \text{or,}$$

$$\text{Probability of Failure}_{PCn\ t\text{-}z} = \left(\frac{5 - Rep_{PCn\ t\ -\ z\ FS}}{5}\right) * 100 \tag{6}$$

The determined probability of failure to achieve assessment criterion 'Cn' according to the expectations, in interacting with the risk assessed agent 'P' and in time slot 't-z' will be on a scale of 0-100 %. The risk assessing agent from this can determine the FailureLevel (PFL) of the risk assessed agent 'P' in assessment criterion 'Cn' and in time slot 't-z' on the Failure Scale ($PFL_{PCn\ t\text{-}z}$) by:

$$PFL_{PCn\ t\text{-}z} = \text{LEVEL (Probability of Failure}_{PCn\ t\text{-}z}) \tag{7}$$

By using the above steps, the risk assessing agent should determine the FailureLevel of the risk assessed agent for each assessment criterion of its expectations in a pre-interaction start time slot. Once it does that, it can then determine the risk assessed agent's crisp FailureLevel in that time slot according to its expectations, by weighing the individual FailureLevel of each assessment criterion according to its significance. As discussed earlier, all assessment criteria in an interaction will not be of equal importance or significance. The significance of each assessment criterion might depend on the degree to which it influences the successful outcome of the interaction according to the risk assessing agent. The levels of significance for each assessment criterion (S_{Cn}) are shown in Table 2.

The crisp FailureLevel of the risk assessed agent 'P' in a pre-interaction start time slot 't-z' ($PFL_{Pt\text{-}z}$) is determined by weighing its FailureLevel to complete each

Table 2. The significance level of each assessment criterion

Significance level of the assessment criterion (S_{Cn})	Significance Rating and Semantics of the level
1	Minor Significance
2	Moderately Significant
3	Largely Significant
4	Major Significance
5	Highly or Extremely Significant

assessment criterion of the expectations in that time slot, with the significance of the assessment criteria. Hence:

$$PFL_{Pt\text{-}z} = ROUND\left(\frac{1}{\sum_{n=1}^{y} S_{Cn}} \left(\sum_{n=1}^{y} S_{Cn} * PFL_{PCn\ t\text{-}z}\right)\right) \quad (8)$$

where: 'S_{Cn}' is the significance of the assessment criterion 'Cn';

'$PFL_{PCn\ t\text{-}z}$' represents the FailureLevel of the risk assessed agent 'P' in assessment criterion 'C_n' in time slot 't-z'; and

'y' is the number of assessment criteria in the expectations.

By using the proposed methodology, the risk assessing agent should ascertain the FailureLevel of the risk assessed agent in each time slot of the pre-interaction start time phase according to the expectations of its future interaction, either by its past-interaction history or by the recommendations for the total assessment criteria of its expectations, or as a combination of its past interaction history in the partial assessment criteria of its expectations and the recommendations from the recommending agents for the other assessment criteria. Once the risk assessing agent has determined the FailureLevel (PFL) of the risk assessed agent in each of the pre-interaction start time slots according to the expectations of its future interaction, it can then utilize these to predict and ascertain the FailureLevel (FFL) of the risk assessed agent in the time slots of the post-interaction start time phase. As the FailureLevel of the risk assessed agent in the pre-interaction start time slots is according to the expectations of its future interaction, its determined FailureLevel in the time slots of the post-interaction start time phase will also be strictly according to the expectations of the risk assessing agent's future interaction with it.

5 Determining the FailureLevel in the Post-interaction Phase

In this section, we will propose the methodology by which the risk assessing agent can ascertain the FailureLevel of the risk assessed agent in the actual period of interaction and according to the expectations of its future interaction with it. As discussed earlier, the risk assessing agent's actual period of interaction with the risk assessed agent is represented by the post-interaction start time phase, and this period of time ranges from the time spot of the interaction to the end of the time space. Two scenarios arise when the risk assessing agent determines the FailureLevel of the risk assessed agent in the post-interaction start time phase. They are:

Scenario 6: The post-interaction start time phase of the risk assessing agent's interaction with the risk assessed agent is limited to the current time slot in which it is at present.

If the time spot and the duration of the risk assessing agent's interaction with the risk assessed agent is limited to the current time slot (as shown in Figure 3), then the risk assessing agent can determine the FailureLevel (FFL) of the risk assessed agent in the post-interaction start time slot by:

Case 6.1: Using its past interaction history with the risk assessed agent, if it is in the same expectations and time slot of its future interaction.

If the risk assessing agent has a past interaction history with the risk assessed agent in the time slot of its future interaction with it and in the same assessment criteria and significance, as the expectations of its future interaction with it, then it can consider the risk relationship of its previous interaction with the risk assessed agent and utilize the FailureLevel (AFL) which it had ascertained for the risk assessed agent in that previous interaction, as its FailureLevel (FFL) in the post-interaction start time slot. This is based on the assumption that the FailureLevel of the risk assessed agent in a time slot remains constant. Hence, the FailureLevel (FFL) of the risk assessed agent 'P' in a post-interaction start time slot 't_z', based on the risk assessing agent's past interaction history with it in that time slot and in the expectations of its future interaction is represented by:

$$FFL_{Ptz} = AFL_{Ptz} \tag{9}$$

where, 'P' represents the risk assessed agent,

't_z' represents the time slot in which the risk assessing agent is determining the FailureLevel of the risk assessed agent,

Case 6.2: Using a combination of its past interaction history and the recommendations from other agents.

If the risk assessing agent has a past interaction history with the risk assessed agent in the same context and in the same time slot of its future interaction with it, but in the partial assessment criteria of its expectations, then it should utilize those partial assessment criteria and their corresponding 'Commitment Level' values to determine the trustworthiness of the risk assessed agent for those assessment criteria as discussed in scenario 4. It should then solicit recommendations from other agents for the remaining assessment criteria of its expectations by issuing a reputation query, and then assimilate them to ascertain the reputation of the risk assessed agent for those assessment criteria as discussed in section 4.2.3.

However, in each of the cases discussed previously (scenario 4 and section 4.2.3), the risk assessing agent adjusts the trustworthiness and/or the reputation of the risk assessed agent by the variable '*w*' according to the weight to be given to the status of the risk assessed agent, depending upon the time slot in the pre-interaction start time phase. In the present case, where the risk assessing agent determines the trustworthiness of the risk assessed agent by using its past interaction history and/or the reputation of the risk assessed agent by soliciting recommendations from other agents, in the current time slot; the value for the variable '*w*' should be 1. Hence, the risk assessing agent can determine the trustworthiness of the risk assessed agent 'P' in an assessment criterion 'Cn' by considering its past interaction history with it, in a post-interaction start time slot 't_z' by:

$$T_{PCn\,tz} = (\text{Commitment Level}_{Cn}) \tag{10}$$

where, 'P' represents the risk assessed agent,

'Cn' represents the assessment criterion, in which the trustworthiness of the risk assessed agent 'P' is being determined,

'Commitment Level $_{Cn}$' represents the level of commitment of the risk assessed agent in assessment criterion 'Cn',

Similarly, the risk assessing agent can determine the reputation of the risk assessed agent 'P' in an assessment criterion 'Cn' by utilizing the recommendations of other agents in a post-interaction start time slot 't_z' by:

$$\text{Rep}_{PCn\,tz} = (\alpha * (\frac{1}{K} (\sum_{i=1}^{K} RCV_i \oplus \text{Commitment Level}_{Cn}^{i}))) + (\beta * (\frac{1}{J} (\sum_{o=1}^{J} \text{Commitment Level}_{Cn}^{o}))) \quad (11)$$

where, 'RCV_i' is the credibility value of the trustworthy recommending agent 'i',

'Commitment level $_{Cn}$' is the level of commitment recommended by the recommending agent for assessment criterion 'Cn' for the risk assessed agent in the particular time slot 't_z',

'K' is the number of trustworthy recommendations that the risk assessing agent receives for the risk assessed agent in assessment criterion 'Cn' in time slot 't_z',

'J' is the number of unknown recommendations that the risk assessing agent receives for the risk assessed agent in assessment criterion 'Cn' in time slot 't_z',

'α and β' 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 $\alpha > \beta$ and $\alpha + \beta = 1$.

The risk assessing agent should utilize equations 10 and 11 to ascertain the trustworthiness or the reputation of the risk assessed agent for each assessment criterion of its expectations, by using its past interaction history with it or by the recommendations from other agents respectively. Based on the determined trustworthiness or the reputation of the risk assessed agent for each assessment criterion of its expectations, the risk assessing agent can then determine the FailureLevel (FFL) of the risk assessed agent in the post-interaction start time slot by using the methodology proposed in Section 4.2.4.

It may be the case that the risk assessing agent does not have any past interaction history with the risk assessed agent in the time slot of its interaction, nor does it get recommendations from other agents for all the assessment criterion of its expectations in the time slot of its interaction. In this case, we propose that the risk assessing agent cannot utilize the above proposed methodology to determine the FailureLevel (FFL) of the risk assessed agent in the post-interaction start time phase of its interaction, and should utilize the methodology proposed in scenario 7 to determine the FailureLevel (FFL) of the risk assessed agent in that time phase.

Scenario 7: The post-interaction start time phase of the risk assessing agent's interaction with the risk assessed agent begins and extends till to a point in time in the future.

As discussed in the earlier sections, if the time spot or the duration of the risk assessing agent's interaction with the risk assessed agent extends to a point in time in

the future (as shown in Figure 4), then the risk assessing agent has to determine the FailureLevel (FFL) of the risk assessed agent in those time slots by utilizing the prediction methods based on the previous impression that it has about the risk assessed agent. In other words, in order for the risk assessing agent to determine the FailureLevel (FFL) of a risk assessed agent in a post-interaction start time slot (if it is at a future point in time), it should know its FailureLevel according to the expectations of its future interaction from the beginning of the time space to the time slot preceding the one in which the FailureLevel (FFL) of the risk assessed agent has to be determined. The risk assessing agent should then utilize the determined FailureLevel of the risk assessed agent to that time slot, and predict its FailureLevel (FFL) in the time slots of the post-interaction start time phase. Hence, in our method we propose that the risk assessing agent, in order to determine the future FailureLevel of the risk assessed agent at time slot 't1' of the post-interaction phase in Figure 4, should consider all its FailureLevel values from the beginning of the time space to the time slot preceding it, i.e. to time slot 't-1'. Two cases arise when the risk assessing agent has to ascertain the FailureLevel (FFL) of the risk assessed agent in the future period of time of its interaction.

Case 7.1: The determined FailureLevel (PFL) of the risk assessed agent in the pre-interaction start time slots has features of either stochastic variation or trends in variation. In this case, we propose that the risk assessing agent, while determining the FailureLevel (FFL) of a risk assessed agent in a time slot of the post-interaction start time phase at a future period of time, should determine the magnitude of occurrence of each level of failure within the domain of (0, 5) on the Failure Scale in that time slot, rather than determining a crisp FailureLevel as it does in the Pre-Interaction start time slots. This is because determining the probability of failure of an interaction in the future period of time deals with uncertainty as it is being determined at a point in time in the future; and subsequently, when the FailureLevel series of the risk assessed agent has variability in it, the uncertainty of its behaviour over the future period of time should be captured, while ascertaining its FailureLevel during that time period. This uncertainty about the behaviour of the risk assessed agent is not totally captured when it is being represented by a crisp FailureLevel value. Hence, in order to take into consideration this uncertainty while ascertaining the FailureLevel of the risk assessed agent in a time slot at a future period of time, the risk assessing agent should ascertain the magnitude of the occurrence of each level of failure on the Failure Scale.

Our method for determining the FailureLevel (FFL) for a risk assessed agent at a future time slot 't1' (in Figure 4) by taking into consideration the uncertainness in its behaviour, is by taking its FailureLevel in each time slot from the beginning of the time space till time slot 't-1' and utilize the Gaussian Distribution to determine the probability of the future FailureLevel (FFL) in that time slot being any level on the Failure Scale (FS). As discussed earlier, the domain of the Failure Scale ranges from (-1, 5), with -1 denoting 'Unknown' level of failure. So the FailureLevel (FFL) of a risk assessed agent in the post-interaction start time slot should be determined in the domain of (0, 5) on the Failure Scale. Within this domain, there are six possible levels of failure. To determine the risk assessed agent's FailureLevel (FFL) at time slot 't1' within each of those levels, let us suppose that the risk assessing agent has determined the FailureLevel of the risk assessed agent in each time slot from the beginning of the

time space till time slot 't-1'. These FailureLevel values of the risk assessed agent are represented as:

$$\{FL_{t-K}, \ldots\ldots FL_{t-3}, FL_{t-2}, FL_{t-1}\}$$

where, k is the number of time slots preceding the one in which the FFL is being determined.

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

$$\mu_{FL} = \frac{1}{K} \sum_{i=1}^{K} FL_i \tag{12}$$

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

$$\sigma^2 = \frac{1}{K-1} \sum_{i=1}^{K} (FL_i - \mu_{FL})^2 \tag{13}$$

Since FFL ~ (μ, σ^2), then for any random variable FFL according to Gaussian distribution [15] the probability of FFL in a given range within the domain of (0, 5) on the Failure Scale can be determined according to equation 14.

$$P(a < FFL \leq b) = \frac{1}{\sqrt{2\prod\sigma}} \int_{\frac{a-\mu}{\sigma}}^{\frac{b-\mu}{\sigma}} e^{\frac{-t2}{2}} dt \tag{14}$$

By using equation 14, the risk assessing agent should ascertain the magnitude of the occurrence of each level of failure in the domain of (0, 5) on the Failure Scale, in a post-interaction start time slot. By doing so, the risk assessing agent would know the different levels of severity of failure and their level of occurrence in interacting with the risk assessed agent in a particular time slot of its interaction; and hence, the variability in the behaviour of the risk assessed agent over that particular future period of time of its interaction. The determined severities of failure are strictly according to the expectations of interaction between the risk assessing agent and the risk assessed agent. The risk assessing agent can also determine the FailureLevel (FFL) of the risk assessed agent in a time slot 't1' of the post-interaction start time phase, by utilizing the moments and cumulants of the obtained FailureLevel series of the risk assessed agent up to time slot 't-1'.

If there is more than one time slot in the post-interaction start time phase of the risk assessing agent's interaction with a risk assessed agent as shown in Figure 4, then the risk assessing agent has to determine the FailureLevel (FFL) of the risk assessed agent in each time slot of the post-interaction start time phase ('t1' till 't5' in Figure 4), to ascertain the performance risk in interacting with it. To ascertain the FailureLevel (FFL) of the risk assessed agent in the post-interaction start time slot 't2', the risk assessing agent, after determining the magnitude of occurrence of each level of failure in interacting with the risk assessed agent in the post-interaction start time slot 't1', should take the level with the highest probability of occurrence as the FailureLevel of the risk assessed agent in time slot 't1'. It should then consider the time slots from the

beginning of the time space till time slot 't1' as shown in Figure 4, and utilize equations 12 - 14 to determine the magnitude of occurrence of different severities of failure in interacting with the risk assessed agent in post-interaction start time slot 't2'. By using the proposed methodology the risk assessing agent should determine the probability of occurrence of each FailureLevel on the Failure Scale in interacting with a risk assessed agent in each time slot of the post-interaction start time phase, according to its expectations.

Case 7.2: The determined FailureLevel (PFL) of the risk assessed agent in the pre-interaction start time phase has seasonal characteristics, and is the same in all the time slots of that time phase. In this case, the FailureLevel series of the risk assessed agent depicts a seasonality trend and the FailureLevel (FFL) of the risk assessed agent in the time slots of the post-interaction start time phase will be the same as that determined in the pre-interaction start time slots.

Scenario 8: The post-interaction start time phase of the risk assessing agent's interaction with the risk assessed agent extends till a point of time in the future, but the time spot is in the current period of time.

If the post-interaction start time phase of the risk assessing agent's interaction with the risk assessed agent extends to a point of time in the future, but the time spot of the interaction is in a time slot which has an overlap of the pre- and post- interaction start time phases as shown in Figure 6, then the risk assessing agent can ascertain the FailureLevel (FFL) of the risk assessed agent in time slot 't1' by using the methodology proposed in scenario 6, if it has either past interaction history with the risk assessed agent in that time slot or it gets recommendations from other agents in all the assessment criteria of its expectations in that time slot. In case the risk assessing agent does not have any of these, then it can utilize the methodology proposed in scenario 7 to ascertain the FailureLevel (FFL) of the risk assessed agent in all the time slots of the post-interaction start time phase.

Once the risk assessing agent ascertains the FailureLevel (FFL) of the risk assessed agent by using the methodology proposed either in scenario 6 or in scenario 7 in each time slot of the post-interaction start time phase, then it should ascertain the 'FailureLevel Curve' of the interaction in order to quantify the level of failure in interacting with the risk assessed agent.

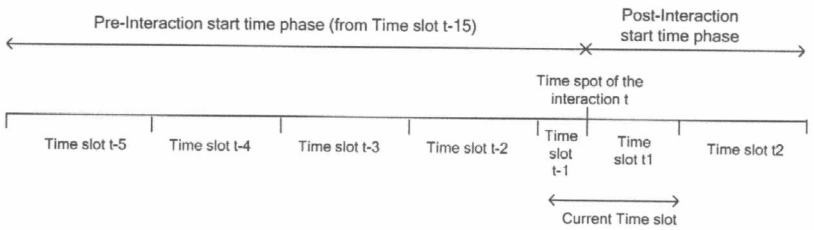

Fig. 6. The time spot and the post-interaction start time phase of the interaction

6 Determining the FailureLevel Curve of the Interaction

The 'FailureLevel Curve' (FLC) of the interaction quantifies and represents the performance risk in interacting with the risk assessed agent, based on its determined FailureLevel during the period of risk assessing agent's interaction with it. In other words, to the risk assessing agent the FailureLevel Curve represents the magnitude of the occurrence of different levels of severity of failure during the time period of its interaction with the risk assessed agent, according to its expectations. Hence, the FailureLevel Curve is such that the abscissa of the curve gives the level or severity of failure from the Failure Scale and the corresponding ordinate or impulse gives the probability of occurrence of that level. A point to be noted here is that the FailureLevel Curve of the interaction is determined by considering only the post-interaction start time phase of the time space. This is because the risk assessing agent wants to analyze the perceived risk in interacting with a risk assessed agent during the time in which it possibly interacts with it. This duration of time is represented by the post-interaction start time phase from its time space and subsequently the FailureLevel Curve of the interaction which represents the performance risk, should be ascertained by utilizing only the FailureLevel (FFL) of the risk assessed agent in each of the post-interaction start time slots. Two scenarios arise while ascertaining the FailureLevel Curve of the interaction. They are:

Scenario 9: The post-interaction start time phase of the risk assessing agent's interaction with the risk assessed agent is limited to the current time slot in which it is at present.

If the post-interaction start time phase of the interaction is limited to the current time slot as shown in Figure 3, and if the risk assessing agent ascertains the FailureLevel (FFL) of the risk assessed agent by utilizing either its past-interaction history or by soliciting recommendations from other agents, or a combination of both as discussed in scenario 6, then the determined FailureLevel (FFL) of the risk assessed agent in the post-interaction start time phase is a crisp value on the Failure Scale. In such cases, the FailureLevel Curve (FLC) of the interaction would represent just the determined FailureLevel (FFL) on the abscissa and its corresponding ordinate represents the probability of occurrence of that level, which in such cases is 1.

Scenario 10: The post-interaction start time phase of the risk assessing agent's interaction with the risk assessed agent extends till a point of time in the future.

If the time spot or the post-interaction start time phase extends to a future point in time as shown in Figure 4, and if there is a seasonal characteristics in the risk assessing agent's FailureLevel (PFL) in the pre-interaction start time phase as mentioned in case 7.2, then the FailureLevel (FFL) of the risk assessed agent in the post-interaction start time slots is the same as it is for the pre-interaction start time phase. In this case, the FailureLevel Curve (FLC) of the interaction would be determined as mentioned in scenario 9. On the contrary, if the FailureLevel (PFL) of the risk assessed agent variability in it (either stochastic variation or trends in variation) as mentioned in case 7.1, then the risk assessing agent ascertains the FailureLevel (FFL) of the risk assessed agent in each of the post-interaction start time

slots as the probability of occurrence of each level of failure on the Failure Scale. In this case, the FailureLevel Curve (FLC) of the interaction is plotted by constructing the probability histogram of the sum of the probability of occurrence of each FailureLevel over the time slots of the post-interaction start time phase divided by the number of time slots within that time phase.

For example, consider an interaction scenario between risk assessing agent 'A' and the logistics company (termed as risk assessed agent 'B') in the context 'Transporting Goods' and in the assessment criteria 'C1-C4', if the risk assessing agent's 'A' interaction with the risk assessed agent 'B' is limited to the current period of time as shown in Figure 3 and if agent 'A' ascertain the FailureLevel (FFL) of agent 'B' in the time phase of its interaction as 2 on the Failure Scale, by either utilizing its past interaction history or recommendations from other agents as discussed in scenario 6, then the FailureLevel Curve (FLC) of the interaction in this case is shown in Figure 7. The FailureLevel Curve represents just one level of failure, as the FailureLevel (FFL) of the risk assessed agent is being determined over a period of time which is limited to the current time slot, by either using direct past interaction history or/and by using recommendations from other agents.

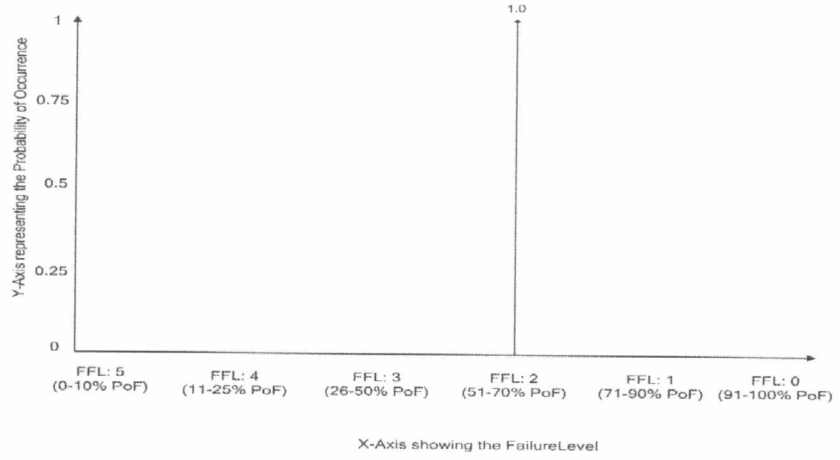

Fig. 7. The FailureLevel Curve when the interaction is limited to the current time slot and there is a single time slot in that time phase

If the risk assessing agent's 'A' interaction with agent 'B' extends to a point of time in the future as shown in Figure 4, then agent 'A' has to ascertain the FailureLevel (FFL) of the risk assessed agent 'B' in those time slots by using the methodology proposed in scenario 7. In this case, the FailureLevel Curve (FLC) of the interaction represents those levels of failure which occur in each of the post-interaction start time slots. The probability of the occurrence of each of these levels of failure is determined by the sum of the occurrence of a FailureLevel throughout the

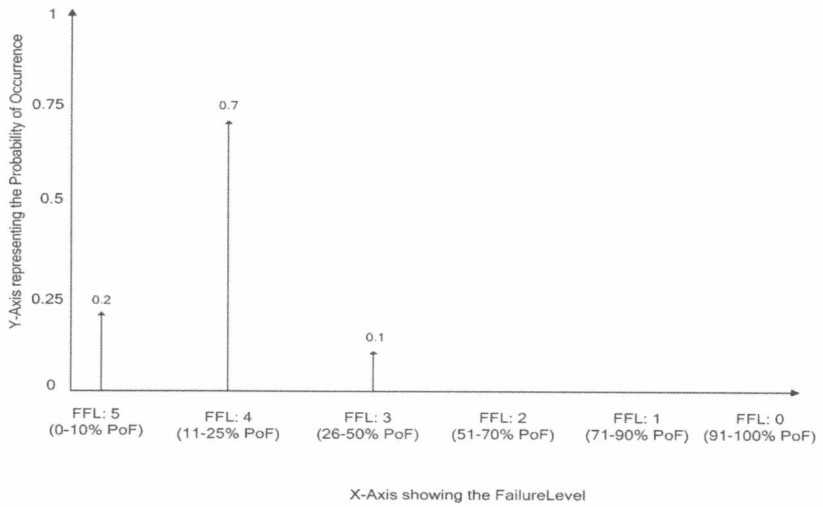

Fig. 8. The FailureLevel Curve of the interaction when the interaction extends to a point of time in the future and there are multiple time slots in that time phase

post-interaction start time slots, divided by the number of time slots within that time phase. An example of the FailureLevel Curve of the interaction determined in such scenario by considering the time slots of Figure 4 is shown in Figure 8.

The risk assessing agent 'A' by analyzing the magnitude of failure of a level and the probability of occurrence of that level in interacting with the risk assessing agent can determine the level of failure in achieving its desired outcomes in forming an interaction with that agent. This would help it to get an idea of the direction in which its interaction might head, and whether or not it will achieve its desired outcomes in interacting with the particular risk assessed agent. The risk assessing agent can consider the FailureLevel Curve (FLC) which represents the level of failure in interacting with a risk assessed agent, and utilize it to determine the other subcategory of perceived risk in interacting with it, i.e. the financial risk.

7 Conclusion

In an e-commerce interaction, it is possible that the risk assessing agent might have to decide and choose an agent to interact with from a set of risk assessed 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 risk assessing agent an indication of the probability of failure of the interaction (FailureLevel) and the possible consequences of failure to its resources. In this chapter we proposed a methodology by which the risk assessing agent can determine the FailureLevel beforehand in interacting with a risk assessed agent. The determined FailureLevel is strictly according to the demand of the risk assessing agent's future interaction with the risk assessed agent.

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