Quantifying the Loss in Resource Benefit for Risk based Decision in Digital Business Ecosystem

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Abstract— **In a financial digital business ecosystem, the trusting agent by analyzing beforehand the possible risk in interacting with a probable trusted agent can make a better decision of its future course of interaction with it. Another factor that would help the trusting agent in deciding whether to interact or not with a probable trusted agent, is to determine the probability of it not achieving the full benefit of its invested resources. In this paper, we propose a methodology by which the trusting agent can determine the loss of its resource benefit in interacting with a probable trusted agent before proceeding.**

I. Introduction

The significance for the trusting agent to analyze the possible risk in interacting with a probable trusted agent to achieve its desired outcomes is substantial. The trusting agent, by analyzing the possible risk beforehand, could determine whether it will achieve its desired outcomes from the interaction or not and also gain an idea or direction in which its interaction might head. Risk is important in the study of behavior in e-commerce as 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 [1]. Risk plays a central role in deciding whether to proceed with a transaction or not. It can broadly be defined as an attribute of decision making that reflects the variance of its possible outcomes. Thus, it commands a central role in any discussion that is related to a transaction.

Digital Business Ecosystems is a new concept that is emerging worldwide as an innovative approach to support the adoption and development of information and communication technologies. Digital ecosystems transcend the traditional, rigorously defined collaborative environments from centralised, distributed or hybrid models into an open, flexible, domain clustered and demand-driven interactive environment [2-4]. A digital ecosystem is a new-networked architecture and collaborative environment that addresses the weakness of client-server, peer-to-peer, grid and web services. It is a self-organizing digital infrastructure aimed at creating a digital environment for networked organizations that supports the cooperation, knowledge sharing, development of open and adaptive technologies and the evolutionary business models. A demand driven business ecosystem interaction implies that the trusting agent wants to achieve certain desired outcomes in its future interaction and, based on that, it selects a trusted agent to interact with, who can fulfill its demand. It is possible there might be more than one agent who can fulfill the trusting agent's demand. The trusting agent can ease the decision making process of which agent to interact with, or it can firm its decision whether to interact with a trusted agent or not by analyzing the possible risk beforehand in interacting with them according to its demand. The possible risk in an interaction is a combination of the probability of failure in achieving the outcome and the possible consequences of failure.

Another factor which would assist the trusting agent in deciding which agent to interact with is to determine the degree to which it will not achieve the full benefit of its resources that it is going to invest while interacting with each agent. The trusting agent can determine this by first ascertaining the probability of the net worth of its resources that it is going to invest in interacting with the trusted agent and FailureLevel of that trusted agent. In this paper, we propose a methodology by which the trusting agent can determine the degree of it not achieving the full benefit of its resources invested in the interaction. We will propose and explain the methodology in the next sections.

II. Determining the FailureLevel in an interaction

As mentioned earlier, the trusting agent has to determine the probability of failure and the possible consequences of failure to its resources in order to analyze the possible level of Risk before initiating its interaction with a trusted agent. To quantify and represent semantically the probability of failure of an interaction, we defined the term 'FailureLevel' and the Failure scale in Hussain et al. [5]. FailureLevel quantifies and semantically expresses the possible level of failure in the interaction on the failure scale. The Failure scale as shown in Figure 1 represents the different levels of failure, possible in an interaction. The trusting agent determines the FailureLevel in interacting with the probable trusted agent beforehand by ascertaining its in-capability to complete the interaction, according to the expectations of its future interaction with it. In other words, the FailureLevel of an interaction is the extent to which the trusting agent thinks that it might not achieve its desired outcomes in interacting with a probable trusted agent.

The trusting agent communicates its desired outcomes and the resources it invests to achieve them, to the trusted agent before interacting with it, in the expected behavior or the mutually agreed behavior. The expectations or the desired outcomes that the trusting agent wants in its interaction with a

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Semantics of Failure Level	Probability of Failure	FailureLevels	Star Rating
Unknown	-	- 1	Not Displayed
Total Failure	91 - 100 % Probability of Failure	0	Not Displayed
Extremely High	71 – 90 % Probability of Failure	1	From ½★ to ★
Largely High	51 – 70 % Probability of Failure	2	From ★½★ to ★★
High	26 – 50 % Probability of Failure	3	From ★★½★ to ★★★
Significantly Low	11- 25 % Probability of Failure	4	From ★★★½★ to ★★★★
Extremely Low	0 – 10 % Probability of Failure	5	From ★★★★½★ to ★★★★★

Figure 1: The Failure scale

probable trusted agent can be classified at a higher level as the 'context' of the interaction. In other words, context represents the high level nature of the trusting agent's interaction with the probable trusted agent [6]. It can be decomposed into several detailed aspects known as the criteria. 'Criteria' is defined as the demand or the set of factors which show specifically what the trusting agent wants in its interaction with the trusted agent in the particular context. Criteria form the expectations or the desired outcomes of the trusting agent. By considering its expectations, the trusting agent will accurately determine the probability of failure in interacting with a probable trusted agent according to the criteria of its future interaction.

The possible interaction of the trusting agent with the probable trusted agent is in the future state of time. Hence, for risk analysis, the trusting agent has to determine the FailureLevel in interacting with the probable trusted agent in that future state of time. In order to achieve that, we propose that the trusting agent analyze the FailureLevel in interacting with a probable trusted agent in two stages. They are:

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

'Pre-Interaction start time phase' refers to the period of time before the trusting agent starts its interaction with the probable trusted agent, whereas 'Post-Interaction start time phase' is that period of time after the trusting agent commences and interacts with the probable trusted agent. For risk analysis, the trusting agent has to determine the FailureLevel in interacting with a probable trusted agent in this period of time, that is in the post-interaction start time phase. However, as this phase is in the future state of time, the trusting agent can only determine the FailureLevel by using some prediction methods. So to achieve this, we propose that the trusting agent should first ascertain the FailureLevel of the probable trusted agent according to the specific context and criteria as that of its future interaction in the pre-interaction start time phase. Based on those levels, the trusting agent can determine its FailureLevel in the post-interaction start time phase. The determined FailureLevel of the probable trusted agent in that time phase depicts the probability of failure in interacting with it, during the time of the trusting agent's interaction with it.

As mentioned in the literature, risk is dynamic - varying from time to time. As such, the trusting agent should take this dynamic nature of risk into consideration while undertaking risk analysis in interacting with a probable trusted agent. To incorporate that, we propose the trusting agent should divide the total time that it considers to determine the FailureLevel of the probable trusted agent, termed as the 'time space', into different non-overlapping parts, termed as 'time slots', and determine the FailureLevel of the trusted agent in each of those time slots. By doing so, the trusting agent ascertains the correct FailureLevel of the probable trusted agent in a time slot, according to its incapability to complete the criterions of its future interaction in that particular time slot, thus considering its dynamic nature while doing risk analysis. The time slots will be spread out either in the pre-interaction or in the post-interaction start time phase. The trusting agent has to determine the FailureLevel of the probable trusted agent in each time slot according to the time phase in which they fall. The methodology for determining the FailureLevel of the probable trusted agent in both the pre- and post-interaction start time phase is defined in Hussain et al [5]. In this paper, due to space limitation we will give only a brief overview of the methodology.

In the methodology, we propose that the trusting agent in each of the pre-interaction phase time slots should determine a crisp FailureLevel of the probable trusted agent on the Failure scale either by considering its previous interaction history with it or by soliciting for recommendations and then assimilating them according to the criteria of its future interaction. After determining the FailureLevel of the probable trusted agent in each of the pre-interaction start time slots, the trusting agent can utilize those to predict or ascertain its FailureLevel in the post-interaction start time phase. We propose that the trusting agent, while determining the FailureLevel of a probable trusted agent in a post-interaction start time slot, should determine the magnitude of occurrence of each level of failure within the domain of (0, 5) on the Failure scale rather than determining a crisp FailureLevel for that time slot as it does in the Pre-Interaction start time phase, because:

1. The FailureLevel of a probable trusted agent in a post-interaction time slot t+1 is predicted by considering its FailureLevels from its time space till time t. This might not give an accurate conclusion as compared to the one obtained in the pre-interaction time slots where the trusting agent determines the trusted agent's FailureLevel by either considering its past interaction history or by assimilating the recommendations. In order address this we propose that the trusting agent in each post-interaction time slot should determine the magnitude of occurrence of each level of failure on the failure scale, rather than determining a crisp FailureLevel, in interacting with the trusted agent.
2. Each level on the Failure scale represents different magnitude of failure, and subsequently its impact while determining the possible Risk in an interaction depends on its magnitude. Hence, in a post-interaction time slot, for the trusting agent to make an informed risk analysis in interacting with a probable trusted agent, we propose that it should determine the probability of occurrence of each FailureLevel on the Failure scale in that time slot, and then consider each of

them while determining the possible risk in that time slot. By considering the probability of occurrence of each FailureLevel, the trusting agent takes into account the different level of magnitude of failure that may possibly occur in a time slot while interacting with a probable trusted agent, and can utilize those to better determine the possible risk in interacting with it, as compared to what it could have determined by considering just a single degree of failure or FailureLevel.

Further, by representing the FailureLevel in interacting with the probable trusted agent in each time slot of the post-interaction start time phase by busbars of the different possible levels of failure, the trusting agent would get a better indication of how the probable trusted agent might behave in the interaction. As the FailureLevel of a probable trusted agent in the pre-interaction start time phase is determined strictly according to the criteria of its future interaction, the future FailureLevel determined by utilizing these levels too is strictly according those criteria.

For better understanding, let us consider an example of trusting agent 'A' wanting to interact with a trusted agent 'B' in context 'C'. The criteria that it wants in the interaction are C1 and C2. The trusting agent 'A' has no past interactions with the trusted agent, and in order to analyze the possible risk before initiating the interaction, it solicits for recommendations to determine the possible FailureLevel. Let us suppose that the trusting agent divides the time space into six equal time slots with four in the pre-interaction time phase (t-4 till t-1) and two in the post-interaction start time phase (t1 and t2). From the recommendations achieved, the trusting agent classifies them according to time, trustworthiness and assimilates them according to the criteria of its future interaction by using the methodology defined in Hussain et al. [5] to determine a crisp FailureLevel of the trusted agent in each of the pre-interaction start time slots. Based on the determined FailureLevel of the trusted agent in the pre-interaction time slots the trusting agent ascertains the probability of occurrence of the FailureLevel of the trusted agent in the post-interaction time phase. The determined FailureLevel of the trusted agent 'B' in the post-interaction phase is strictly according to the criteria of its future interaction with it. Let us suppose the FailureLevel determined for the trusted agent in the post-interaction time slots (t1 and t2) are as shown in figure 2 and 3 respectively.

Once the FailureLevel in interacting with a probable trusted agent has been determined, the trusting agent should then determine the resources that it going to invest in each of the time slot. In the next sections, we propose a methodology by which the trusting agent can ascertain the net worth of resources that it has at stake in each time slot.

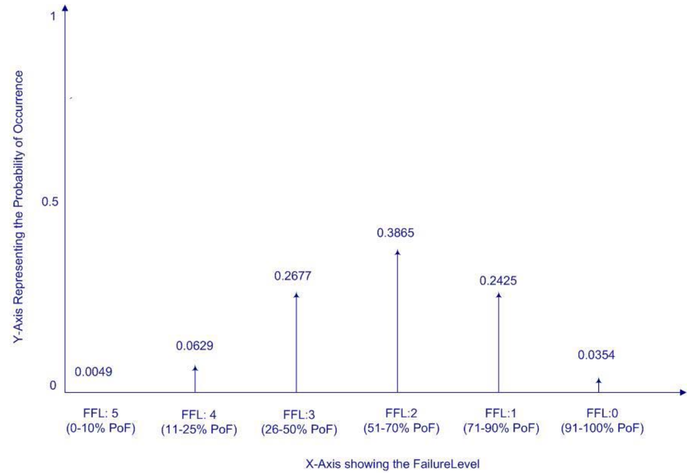

Figure 2: Magnitude of occurrence of each level of failure in time slot t1

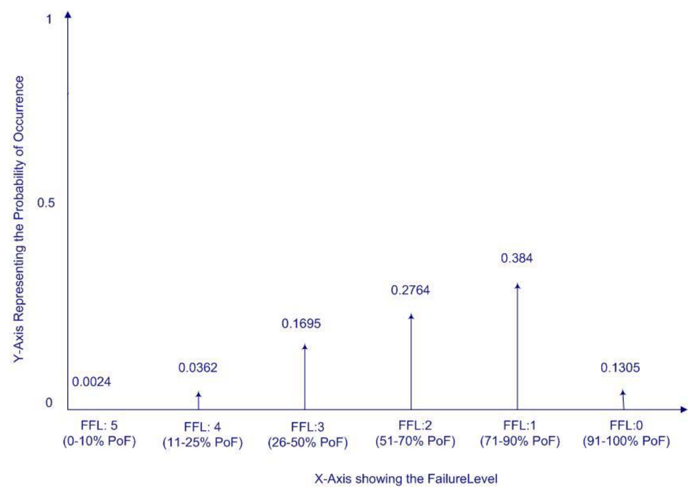

Figure 3: Magnitude of occurrence of each level of failure in time slot t2

III. DETERMINING THE AMOUNT INVESTED CURVE

As discussed earlier, in a digital business ecosystem a trusting agent interacts with a trusted agent according to the demand of its interaction. Hence, the resources invested by the trusting agent in the interaction might vary according to its demand. It can vary from being anything like the mutual exchange of goods between the agents or the receipt of certain products by the trusting agent from the trusted agent in exchange of the monetary value. In this paper, we assume that the trusting agent interacts with the probable trusted agent to achieve its demand in exchange of the monetary financial value. Subsequently, in our context, the term 'resources' refers to the financial resources invested by the trusting agent in its interaction with the trusted agent to achieve its demand. So in this paper we are interested in determining the degree to which the trusting agent will not achieve the full benefit of its resources that it is going to invest in an interaction. To achieve that the trusting agent has to first ascertain the probability of the net worth of its resources that it is going to invest in each time slot of its interaction.

The number of time slots in the post-interaction phase depends on the trusting agent's classification of the time space of the interaction. If there is more than one time slot in the post-interaction phase, then the net worth of the trusting agent's resources at stake in the interaction increases progressively as the time slots increase according to the total worth invested in each of them. To explain with an example, let us consider our previous discussion of the trusting agent 'A' wanting to interact with a trusted agent 'B'. In its interaction there are two time slots in the post-interaction time phase. In the first time slot, the trusting agent invests $15,000 in the interaction, hence, the maximum threshold of its resources at stake and the total worth of the interaction at the end of the first time slot is $15,000. In the second time slot, it invests $5,000 in the interaction and subsequently the net worth of its resources at stake is $20,000 at the end of the second time slot. But a point to be noted here is that at the beginning of the second time slot, the net worth of the interaction is already $15,000 which is the total amount invested in the first time slot. While determining the probability of an amount invested from its resources in the second time slot of its interaction, the trusting agent should consider the fact that the range of its net resources at stake in that time slot is from $15,000 to $20,000, and not from $0 to $5,000, as this is the range of amount invested in that particular time slot.

Additionally, the trusting agent should also consider the nature of investment of its resources in a time slot while determining the probability of a net amount invested from its resources throughout the time slot. It is possible the trusting agent may invest the maximum threshold of its resources at once in a time slot, or may invest it progressively, in stepwise way. For example, let us consider that the trusting agent divides its time space in such a way so that the duration of each time slot is 7 days. During the first time slot of the post-interaction phase, it is possible that the trusting agent 'A' may invest the total worth of the time slot i.e. $15,000 in the beginning or it may invest its resources progressively, that is in the order of $2,000; $3,000; $10,000 on days 1, 3 and 6 of the time slots respectively to gradually make the total worth of the time slot $15,000. In both cases, the probability of the net amount invested from its resources throughout the time slot is different. In the first case when the trusting agent invests $15,000 at the beginning of the time slot, the net amount of its resource that it has at stake, throughout the time slot is $15,000. On the other hand, if the resources were invested in a stepwise way, as explained earlier then the total worth of its resources at stake reaches $15,000 on day 6 of the time slot. This means that the trusting agent has $15,000 worth of resources at stake for only 2 days out of the 7 day period of the time slot. Hence, the trusting agent, according to the investment nature of its resources should first ascertain the probability of the net worth of its resources at stake throughout the time slot.

To achieve that, we propose the calculation of an *Amount Invested Curve (AIC)*. This curve gives the probability of a net amount invested and at stake, throughout the duration of the time slot. Another important property of this probabilistic model of the amount invested curve is that it describes the probability of the worth of the interaction to be at least a certain amount throughout the duration of the time slot. To calculate the amount invested curve (AIC) we utilize the Fundamental Probability Formulae to determine the probability of an amount being invested throughout the time slot [7].

To obtain the amount invested curve for our example, let us consider that the trusting agent invests $20,000 in the interaction. Out of that, $15,000 is invested in the first time slot and $5,000 in the second time slot to make the total worth of the interaction $20,000. Further let us consider that the trusting agent invests its resources progressively in both the time slots t1 and t2. It invests $2,000; $3,000; $6,000 and $4,000 on days 1, 3, 4 and 6 respectively of the first time slot and $2,000; $2,000 and $1,000 on days 2, 3 and 6 respectively of the second time slot to make the total worth of the interaction $20,000. Determining and representing in Figures 4 and 5 respectively the amount invested curve for the time slots t1 and t2 by using the probability function formulae.

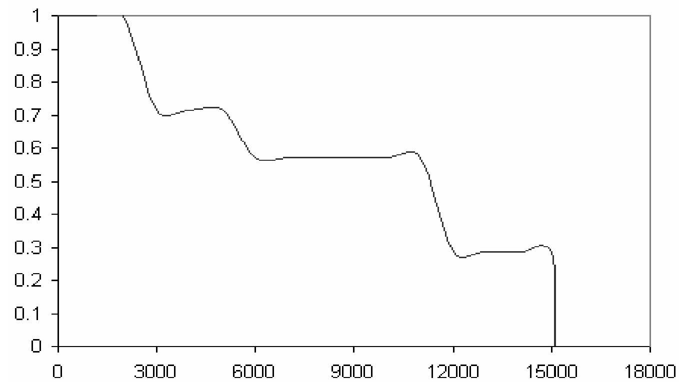

Figure 4: Amount invested curve for time slot t1

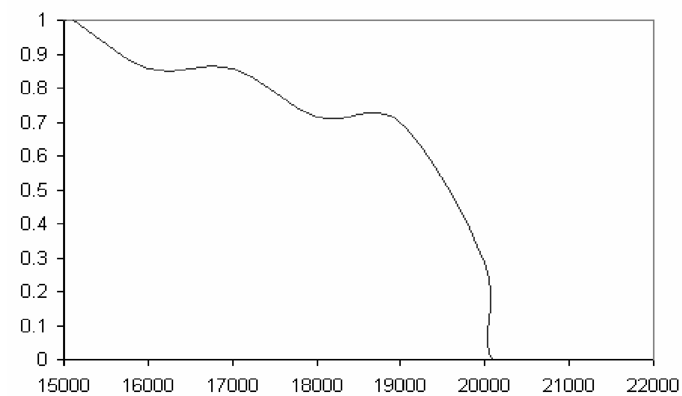

Figure 5: Amount invested curve for time slot t2

The essence of the amount invested curve is that it gives the probability of a net amount at stake throughout the duration of the time slot, as it was initially decided in the mutually agreed behavior. In other terms the amount invested curve of each time slot, shows the probability of the trusting agent investing a net amount from its resources throughout the time slot to achieve its desired outcomes of that time slot, while interacting with a probable trusted agent.

However, as discussed earlier, it is possible that a trusting agent might not achieve its full desired outcomes according to its expectations in interacting with a probable trusted agent due to its FailureLevel. Alternately, it can be stated that the trusting agent might not get the full benefit of its resources that it invests in a time slot while interacting with a probable trusted agent to achieve its desired outcomes, due to its FailureLevel. The degree to which the trusting agent might not get the full benefit of its resources invested in a time slot depends on the magnitude of the FailureLevel of the trusted agent in that time slot. The higher the magnitude of failure of the probable trusted agent in a time slot, the higher the probability of the trusting agent not getting the full benefit of its resources in that time slot and vice versa. The trusting agent, by considering the degree to which it will not achieve the full benefit of its resources in interacting with a probable trusted agent, can make a better informed decision of which trusted agent to interact with whilst determining the possible risk in interacting with that probable trusted agent. In the next section, we will propose a methodology by which the trusting agent can determine the degree of not achieving the full benefit of its resources in interacting with a probable trusted agent.

IV. Determining the Factual Amount Invested Curve

As discussed earlier, the trusted agent with whom the trusting agent wants to interact with and invests its resources to achieve its desired outcomes, may be subjected to a FailureLevel, resulting in the trusting agent not getting the full benefit its resources due to the under-achievement of its desired outcomes. Taking this into consideration, we propose the calculation of the *Factual Amount Invested Curve (FAIC)*. The factual amount invested curve shows the required probability of a net amount to be invested by the trusting agent, throughout the duration of the time slot to achieve its desired outcomes by taking into consideration the FailureLevel of the trusted agent. Hence, the factual amount invested curve (FAIC), which shows the increased probability of a net amount that the trusting agent needs to invests in a time slot, is an extension of the amount invested curve (AIC). The AIC of a time slot, shows the actual probability of the trusting agent investing a net amount from its resources throughout that time slot according to the expected or mutually agreed behavior, whereas the FAIC of a time slot shows the required probability of the trusting agent to invest a net amount from its resources throughout that time slot by considering the FailureLevel of the trusted agent.

To obtain the FAIC of a time slot, the AIC of that time slot should be convolved with the FailureLevel of the trusted agent of that time slot. We utilize the cumulants method for the convolution of these two functions. In this method, the convolution of the independent random variables can be expressed as a sum of their individual cumulants, which can then be used to model the output curve, which is the FAIC by using either Gram-Charlier series expansion or Beta distribution. In our problem, an advantage of using this method over the conventional point by point method for convolution is that, in the cumulants method the convolution of the independent random variables can be determined as a sum of their individual cumulants, whereas in the conventional method it is necessary to divide the AIC into different parts and then convolve it with the density function of the FailureLevel of the trusted agent in that time slot. The output of the convolution, which is the FAIC, is an inflated curve as compared to the AIC. This curve is inflated as it shows the increased probability of a net amount that the trusting agent needs to invest in that time slot.

Considering the previous example, the trusting agent 'A' can determine the FAIC while interacting with a probable trusted agent 'B' in time slots t1 and t2, by convolving the FailureLevel of the trusted agent in those time slots, represented in Figures 2 and 3 with the AIC of those time slots represented in Figures 4 and 5. The resultant inflated FAIC of time slots t1 and t2, are given in figure 6 and 7 respectively. These curves show the required probability of a net amount to be invested throughout the time slot by the trusting agent, considering the FailureLevel of the trusted agent, as compared to what it was initially investing i.e. the AIC. Once the trusting agent determines the FAIC of each time slot, it can then determine the probability of not achieving the full benefit of its resources in that time slot.

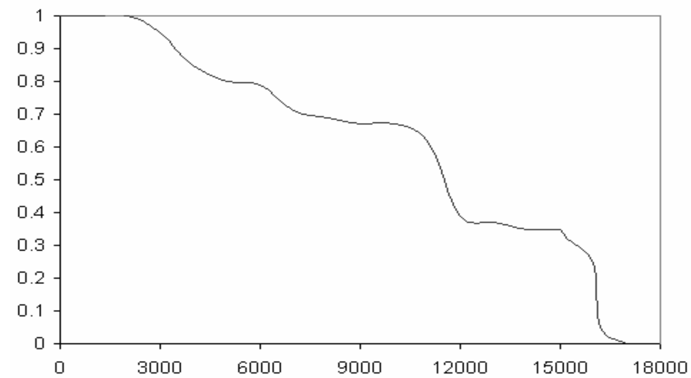

Figure 6: Factual Amount invested curve for time slot t1

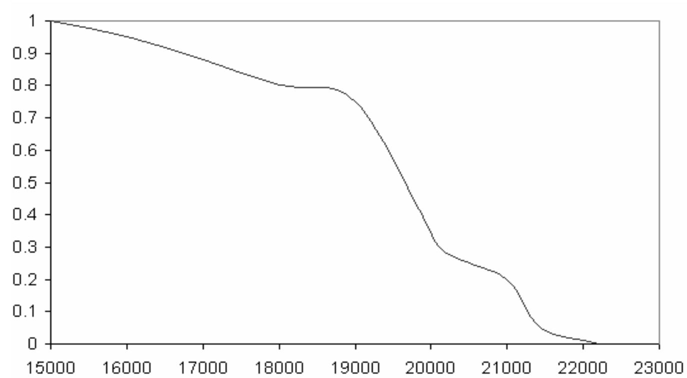

Figure 7: Factual Amount invested curve for time slot t2

V. Determining The Probability of Loss in Resource Benefit

The probability of the trusting agent not achieving the full benefit of its resources in a time slot or the probability of the *Loss of Resource Benefit (LORB)* in a time slot, can be determined by ascertaining the level to which the trusted agent will not complete its desired outcomes of that time slot, in the financial resources it initially promised. This is equivalent to the probability of the trusting agent not attaining its expected behavior at the end of the time slot as promised earlier, in the amount initially decided during the expected or the mutually agreed behavior.

The LORB index of a time slot gives the probability of the trusting agent not achieving the full benefit of its resources invested in that time slot, due to the trusted agent not completing its desired outcomes of that time slot in the amount initially promised according to the expected behavior or the mutually agreed behavior. Hence, LORB of a time slot is simply the ordinate on the FAIC, at the end of net resources invested in a time slot, i.e. at the end of AIC. By definition of FAIC, this ordinate is the probability of that amount needed to be at stake, and this amount will not invested by the trusted agent as it is more than what was initially agreed upon. Hence

$$LORB = FAIC\ (w)$$

Where, w is the abscissa at the end of AIC, and

FAIC (w) = Factual amount invested curve after investing the total resources of this time slot.

To explain better, the AIC of a time slot shows the probability of the net amount invested by the trusting agent in that time slot, to achieve its desired outcomes as decided earlier in the expected behavior. In other terms, at the end of the AIC the trusting agent expects to achieve its desired outcomes of that time slot, in the resources it invested according to the expected or mutually agreed behavior. FAIC of a time slot shows the required probability of the net amount to be invested by the trusting agent to achieve its same desired outcomes, by considering the FailureLevel of the trusted agent of that time slot. As opposed to what was promised initially, it is possible that at the end of AIC, the trusting agent still has some desired outcomes to achieve, due to the FailureLevel of the trusted agent. Subsequently, the ordinate on the FAIC immediately at the end of AIC, shows the probability of the trusting agent not achieving the full benefit or expected returns of its resources that it has invested in that time slot.

Extending the previous example, the trusting agent 'A' can utilize the methodology to determine the probability of it not achieving the full benefit of its resources (LORB) in interacting with the trusted agent 'B' in the time slots t1 and t2 of its interaction. In time slot t1, the trusting agent invests its resources progressively in the order of \$2000, \$3000, \$6000, and \$4000 to achieve its desired outcomes of that time slot. But as shown in Figure 8 at the end of the net resources invested, that is, at the end of AIC, the LORB index in that time slot is 0.35, which means that there is a probability of 35 % that the trusting agent will not achieve the full benefit of its resources that it invested in this time slot. Similarly the LORB index of time slot t2 is determined and represented in Figure 9.

The trusting agent can utilize the probability of it not achieving the full benefit of its resources in each time slot of the post-interaction phase, to make an informed decision of which probable trusted agent to interact with, apart from considering the possible risk in interacting with each of them.

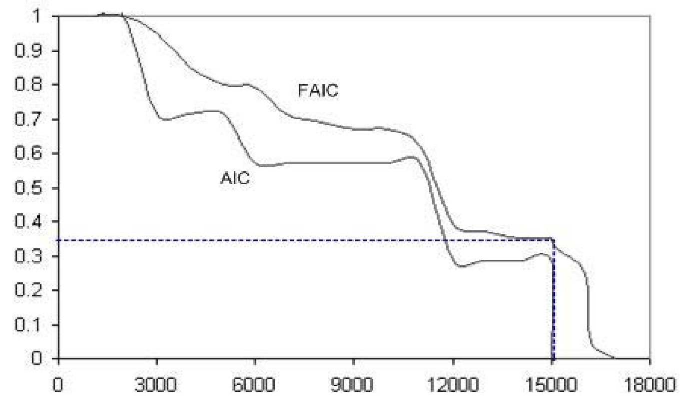

Figure 8: LORB for time slot t1

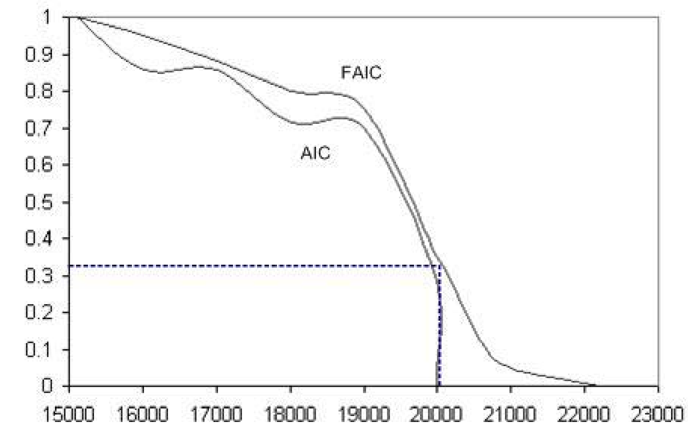

Figure 9: LORB for time slot t2

VI. CONCLUSION

In this paper, we proposed a methodology by which the trusting agent can determine beforehand the probability of it not achieving the full benefit of its resources in interacting with a probable trusted agent. The trusting agent ascertains this by considering the net resources invested by it as decided initially according to the expected behavior, and the FailureLevel of the trusted agent in achieving its desired outcomes. The trusting agent can utilize this probability while make an informed decision of which probable trusted agent to interact with, apart from considering the possible risk in interacting with each of them.

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