A Model of Dynamic Trust Relationship from the Perspective of Risk

Yuan-yuan WANG [1], Qiang LI[*2],Wen-sheng NIU[3]

¹General EducationCenter, Xi'an Peihua University, Shaanxi Xi'an, 710125, P. R. China;

²School of Computer Science and Technology, Xi'an ShiyouUniversity, Shaanxi Xi'an, 710065, P. R. China;

³AVIC Xi'an Aeronautics Computing Technique Research Institute, Shaanxi Xi'an, 710068, P. R. China

Abstract — **Tackling the risk issues correctly is the key to ensure the scientific approach to trust decision-making. Aiming at the insufficient understanding and research of the nature relationship between trust and risk in the present research on dynamic trust relationships, this paper proposes a new theoretical model and a decision-making model of trust relationship from the perspective of risk, it analyzes in detail and gives the nature relationships between trust and risk, trust decision-making and risk decision-making. Trust is deemed to be another expression of risk. Trust decision-making is risk decision-making. The scientific approach to security decision-making is enhanced and the security decision-making becomes more rational, more comprehensive and more objective by the analysis of security decision-making process of trust, risk and credible decision-making.**

Keywords - Trust; Risk;Trust decision-making; Risk decision-making; Model of trust relationship

I. INTRODUCTION

Research of trust relationship is a research subject developed in recent twenty years. As the effective supplement and extension of traditional security mechanism, trust has become a more flexible and more effective security mechanism to adapt to the dynamic environment. It made the tasks of request service and provision service between entities more elaborated. Throughout the study of trust, numerous native and foreign scholars have proposed various trust relationship models in the open environment[1-14], which has promoted the research and the development of related theory of trust relationship. However, it is difficult for us to grasp and understand the nature of trust relationship because of the complexity of the concept of trust. Too many problems remain unsolved.

In the research of trust relationship, studies on the risk issues have been the focus of many scholars. Most scholars admit the close relationship between trust and risk. But until now, there is no final conclusion of nature relationship between trust and risk in the quantification research. Most existing trust models did not take the risk characteristics of trust into account. Some models[15-21] have a good try in this aspect, but there is still a big difference from the research of nature relationship between trust and risk. It remains a lot of problems.

(1) Analysis of the nature relationship between risk and trust is not clear. Analysis of risk is superficial.

(2) It lacks quantitative expression or quantitative analysis of relationships between multiple factors which impact trust and risk.

(3) It has limitation for the research of a particular mechanism or field, and so on.

Trust is always existed with risk. There is no absolute trust. Because of the existence of risk, all trust is relative. In an uncertain environment, risk and trust are two key factors influencing credible decision-making [22]. Pure trust is not able to obtain correct trust decision-making without under the control of risks. For the Trustees of same trust degree, they will make different decision-makings because the risk faced by subjects is different. This paper produced in such a context. It gives out the theoretical model and the decision-making model of trust relationship from the perspective of risk.

II.TRUST AND RISK

Risk is considered as the nature characteristic of things in many fields. However, up to now, the meaning of the word "risk" remains ambiguous. Different definitions have been proposed by scholars in different fields. This paper introduces following definition according to the requirements on risk issues in information science.

Definition 1: Risk. In certain condition and certain period, the grasp of possibility of negative effects on the decision-making target and predictability of harmful consequence of decision-making under the influence of various uncertain factors.

Many scholars[23-27] have proposed their different views on the concept of trust in the research of trust relationship. So far, same as the risk, there is no uniform definition of trust. But we can find that there is a common point that it emphasis the predictability of the acts of entities. At the same time, only grasping trust relationship from the perspective of risk can reach the nature characteristic of trust relationship and get a clearer concept of trust. We give out the definition of trust from the perspective of risk.

Definition2: Trust.In a particular context, Trustors think that they have ability to accommodate the possible risk brought by the Trustees and they are willing to accept and believe that Trustees' acts can achieve their desired objectives.

The characteristic of concomitant of trust and risk is manifested in that choosing trust means that you are ready to take the risk aroused by trust acts. Meanwhile, when you do trust decision-making, you must take risk factors into

account and do the decision-making under the control of risk. This is the perceived relationship between trust and risk. What is the nature relationship between trust and risk on earth? To date, there is no final conclusion. Following is several statements with final consensus.

(1) Proceeding from the production condition of trust, it is considered that trust can be referred only after the understanding of risk. There is no trust without risk. Risk and trust are two aspects of one problem occurred one by one[28].

(2) Trust is a risk-taking behavior. There is a causal relationship between trust and risk, but it is not clear that which is the causation and which is the result[29].

(3) There is a reciprocal relationship between trust and risk. Risk provides opportunity for trust, trust creates risk-bearing in return[30].

All the views above have their correctness and scientificity, but taken together, the relationship between trust and risk is still confused and without a final conclusion. This paper argues that:

(1) Trust is another expression of risk, and vice versa. Trust and risk are the expressions of a same thing from different views. Trust is from the perspective of affirmation to obtain the trust degree of thing. Risk is from the perspective of negation to take the potential losses into account. Both are the possibility judgments on results from individuals. They are belonging to the same concept according to the nature. In this sense, the combination of both can make a more objective and comprehensive evaluation for the trust status of the same thing.

(2) Trust decision-making is risk decision-making, and vice versa. Trust subject Trustor must take a number of factors into account before deciding whether to make interaction with potential partner Trustee or not. The trust degree on Trustee and the risk evaluation of this interaction are two most important factors. In general, trust decision-making must on the basis of taking risk into account. Similarly, risk decision-making is on the basis on trust. But they are from different views. In a reasonable case, judgment from the same individual for the same thing must be same no matter from the perspective of trust or risk. Only then results are valuable.

III. THE MODEL OF DYNAMIC TRUST RELATIONSHIP FROM THE PERSPECTIVE OF RISK

AThe Theoretical Model of Dynamic Trust Relationship from the Perspective of Risk

Trust is another expression of risk. Trust decision-making is a kind of risk decision-making. Both of them are a kind of subjective human behavior and be settled on the evaluation of subjective possibility. The only difference is about psychological guidance. Trust refers to the result of expectation. Risk refers to the negative result beyond the result of expectation. Since both of the trust and risk are subjective human behaviors, then surely they will be

affected by the preferences of human psychology and thoughts similarly. By comparing three types of different risk preferences, three types of trust preferences are given: trust favor, trust aversion, trust neutrality. We will give trust preference and risk preference a joint name individual preference. The corresponding relationship of trust preference and risk preference is as shown in Fig. 1.

Fig. 1.Types of Trustor and the corresponding relationship between trust preference and risk preference

Fig. 1 shows that credulity decision-maker (trust subject Trustor, the same below) whose trust preference is favor prefers to believe in each other and lacks of enough evaluation of risk, thus he corresponds to the risky decision-maker whose risk preference is favor. Similarly, the doubting decision-maker whose trust preference is aversion always suspects others and do the work indecisively, thus he corresponds to the cautious decision-maker whose risk preference is aversion. Rational decision-maker are sensible to no matter trust preference or risk preference, he belongs to neutrality decision-maker. All decisions cannot avoid being effected by the subjectivity of human beings, including the formulation of decision-making mechanism between entities. What we need to do is to try our best to consider comprehensively, respect experts, collect wisdom and to reduce the subjective effects as much as possible.

No matter inspected from the perspective of cognition or behavior, trust is accompanied by risk. Risk is another expression of trust. Trust exists just when the risk is perceived. Trust cannot live without risk. In order to grasp the trust status comprehensively, we must the treat the trust and build the theoretical model of trust relationship from the perspective of risk. As shown in Fig. 2.

In the theoretical model as shown in Fig.2, subjective trust is combined with perceived risk. Trust relationship was seen from the perspective of risk. Trust preference of Trustor determines its trust tendency. Risk preference determines its risk tendency. As mentioned above, trust tendency and risk tendency are corresponding to each other under the influence of preference. Subjective trust is the forecast evaluation of the possibility from Trustor for the Trustee's behavior which will achieve his prospective goals. Perceived risk mainly makes subjective evaluation for the possibility of negative results.
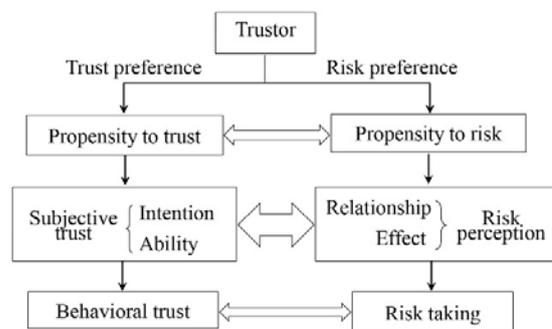

Fig. 2Theoretical model of trust relationship from the perspective of risk

There are two problems included in the subjective trust evaluation from Trustor to Trustee, one is that Trustor has good intention and believes Trustee's behavior could reach his prospective goal. Another one is that Trustor believes that Trustee is able to try his best to reach his prospective goal. Seen from these two aspects of trust, Trustor chooses to believe Trustee and has a good expectation on Trustee. This choice itself contains too much uncertain, namely risk. When Trustor makes risk evaluation for the request from Trustee, there are two issues are contained in the perceived risk as well. One is that Trustor thinks Trusteecannot make a commitment to their relationship, and Trustee's behavior probably could not reach his perceived goal. Another is that Trustee is willing to make an attempt, but Trustee is not able to reach the perceived goal of Trustor because of the constraints of environment and ability. The sources of these two concepts are different. The former comes from conscious intention of individuals, and the latter comes from the external factors such as environment and ability. The willing in the subjective trust involves the further development of relationship between both sides and corresponding to the relationship risk of risk cognition. The ability in the subjective trust involves whether the individual could reach the prospective goal after the endeavor and corresponding to the effect risk of risk cognition. Behavior trust is the external behavior of the Trustor's subjective trust. Trustor chooses to believe in Trustee, his behavior trust certainly will cause risk taking. Therefore, corresponding relationship exists between behavior trust and risk taking.

In conclusion, understanding the trust from the perspective of risk will contribute to a better understanding and analysis of trust relationship.

B. The Decision-making Model of Dynamic Trust Relationship from The Perspective of Risk and Instance Analysis

The decision-making model of trust relationship which takes risk into account consists of three parts: trust evaluation system, risk evaluation system and decision-making system, as shown in Fig.3.
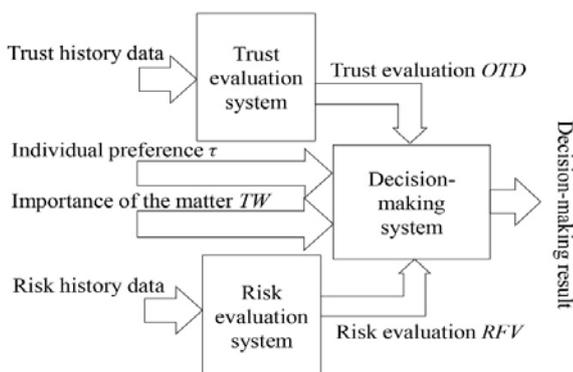

Fig. 3The decision-making model of dynamic trust relationship from the perspective of risk

In order to illustrate the principle of the model in Fig.3, we take interaction between entity i (Trustor) and entity j (Trustee) as an example to illustrate the operation process of this model.

There are extensive documents study on the overall trust evaluation and risk evaluation from Trustor to Trustee. In this paper, different models of trust evaluation and risk evaluation which can be referred from the relative documents (the relative documents as shown above) by readers have been proposed. This paper focuses on the discussion of the operation mechanism of decision-making system.

Entity i (Trustor) does decision-makings through the decision-making system according to certain security policy and based on the overall trust degree of entity j (Trustee), overall risk measurement value, individual preferences and the importance of transactions. Security policy influences the relationship between trust and risk, the acceptable trust degree of Trustor and the acceptable risk degree. Simultaneously, it is affected by its preference and the importance of transactions. Here the definition of trust decision is given firstly.

Definition 3.Trust Decision-making (TD) In the evaluation of trust relationship, TD is a judgment process that Trustor determines whether and how to response to the Trustee's request according to certain security poly and based on the comprehensive evaluation of Trustee's trust degree and risk measurement value.

Trust decision-making emphasizes that trust and risk should be taken into account at least in the decision-making process, and to determine the final action in accordance with the definition of security policy.

From the Fig.(1), it can be found that trust preference and risk preference are corresponding to each other. Therefore, trust preference and risk preference will be as one, namely individual preference. Thus, trust decision-making is a quaternion. Namely:

$$TD = (OTD, RFV, \tau, TW) \quad (1)$$

OTD is the total trust degree, RFV is the total risk measurement value, $\tau$is individual preference, TW is the importance of transaction.

Trust decision-making is divided into two stages:

One is ascertaining the trust relationship status and the acceptable sets of trust relationship status according to the classification standard of trust grade and risk grade. Trustor ensures the current trust relationship status according to his total trust degree OTD to Trustee and the risk measurement value RFV.

Another is judging whether to accept Trustee's request according to Trustor's preference τ, the importance of transaction TW and the certain security poly.

The first stage is to define the classification standard of trust grade and risk grade respectively. Trust degree is classified into seven discrete statuses which corresponding

to different trust intervals respectively. Similarly, the risk degree is classified into seven discrete statuses as well which is corresponding to different risk intervals respectively, as shown in Table 1. From the classification standard of comprehensive trust grade and risk grade, we can get the trust relationship status from the perspective of risk, as shown in Table 2.

It can be seen from the Table 2 that trust relationship status reaches to an optimal status gradually in the evolution process from the worst status TS_{49} of "completely distrust-absolutely high risk" in the top left corner to the right, the bottom, and the bottom right corner. The best status is the TS_1 of "completely trust- absolutely low risk" in the bottom right corner. Assume that, the acceptable set of trust relationship status is $TS_{accept} = \{TS_i \mid i = 1\sim4, 8\sim11, 15\sim18, 22\sim25\}$ (the dark grey area in Table 2). Correspondingly, it can be known that $OTD = 0.70$, $RFV = 0.30$ from the trust evaluation system and risk evaluation system. The trust relationship status of entity$i$ and entity j in this interaction is "relatively trust-low risk", namely TS_{10}, it meets $TS_{10} \in TS_{accept}$, it is acceptable.

TABLE I. THE CLASSIFICATION STANDARD OF TRUST GRADE AND RISK GRADE

Trust grade	The range of trust degree	Risk grade	The range of risk evaluation
Completely distrust	[0.00, 0.10]	Absolutely high risk	[0.90, 1.00]
Quite distrust	(0.10, 0.30]	High risk	[0.70, 0.90)
Not too trust	(0.30, 0.50)	Relatively high risk	(0.50, 0.70)
General trust	0.50	General risk	0.50
Relatively trust	(0.50, 0.70]	Relatively low risk	[0.30, 0.50)
Quite trust	(0.70, 0.90]	Low risk	[0.10, 0.30]
Completely trust	(0.90, 1.00]	Absolutely low risk	[0.00, 0.10]

TABLE II. STATUS OF TRUST RELATIONSHIP FROM THE PERSPECTIVE OF RISK

	Absolutely high risk	High risk	Relatively high risk	General risk	Relatively low risk	Low risk	Absolutely low risk
Completely distrust	TS_{49}	TS_{42}	TS_{35}	TS_{28}	TS_{21}	TS_{14}	TS_7
Quite distrust	TS_{48}	TS_{41}	TS_{34}	TS_{27}	TS_{20}	TS_{13}	TS_6
Not too trust	TS_{47}	TS_{40}	TS_{33}	TS_{26}	TS_{19}	TS_{12}	TS_5
General trust	TS_{46}	TS_{39}	TS_{32}	TS_{25}	TS_{18}	TS_{11}	TS_4
Relatively trust	TS_{45}	TS_{38}	TS_{31}	TS_{24}	TS_{17}	TS_{10}	TS_3
Quite trust	TS_{44}	TS_{37}	TS_{30}	TS_{23}	TS_{16}	TS_9	TS_2
Completely trust	TS_{43}	TS_{36}	TS_{29}	TS_{22}	TS_{15}	TS_8	TS_1

In order to introduce Trustor's rational judgment to the trust decision-making, Trustor's individual preferenceτ and the importance of transactions *TW* are introduced to the second stage of trust decision-making. For instance, the trust relationship status of entity i and entity j in an interaction evaluation is "not too trust- absolutely low risk", namely status TS_5, it does not meet $TS_5 \in TS_{accept}$, whether the security strategy should reject this interaction? Trustor's rational judgment plays a role now. The individual preference of decision-maker and the importance of transactions are the significant factors should be taken into account in the process of decision-making. If these factors be quantified and be taken into the calculation to do the research, it is no doubt that the effect of subjective deviation will be avoid. But, these factors can hardly be quantified. Secondly, even if these factors can be quantified, whether the quantification result can match the reality? Thirdly, is it better than qualitative analysis to make quantification for the effect from these factors to decision? And so on. Decision-making is a consequence of combined action of subjective consciousness and objective condition. Because limitation exists in pure quantification analysis or

pure qualitative analysis, the quantification can be made on easy-quantified indicator as much as possible, and the qualitative analysis can be made on hard-quantified indicators only when quantification analysis and qualitative analysis are combined to make the decision more rational and correct.

Firstly, we make qualitative grading on Trustor's preference τ and the importance of transactions *TW*. The effect on decision-making result can be reflected by changing the set of acceptable trust relationship status TSaccept. For example,

$$\tau = \{\text{Trust favor, Trust neutral, Trust aversion}\} \quad (2)$$

Of course, risk preference can be used for definition only if the uniqueness of definition kept in overall security poly, and it does nothing on the following judgment.

TW = {Absolutely important, Very important, Relatively important,General important,Not very important, Very unimportant, Completely unimportant}   (3)

After confirming the standard of classification, Trustor does the revision of TS_{accept} under the premise of basic set

of acceptable trust relationship status TS_{accept} = {TS_i | i = 1~4, 8~11, 15~18, 22~25} in accordance with its individual preference τ and the importance of upcoming being-handled transaction *TW*. For example, Trustor belongs to the type of trust favor (of course, it belongs to the type of risk favor as well), upcoming being-handled transaction belongs to the type of Relatively important, the security poly for TS_{accept} can be redefined as TS_{accept} = {TS_i| i= 1~5, 8~12, 15~19, 22~26, 29~33}, it corresponding to all the grey area in Table 2. Therefore, the trust relationship status of entity *i* and entity *j* in an interactive evaluation mentioned above is "not too trust- absolutely low risk", namely in the status $\text{TS}5$, the interaction of entity *i* and entity *j* can be accepted.

In the trust management, the same transaction can be completed by a different Trustee, or different Trustees could make a request to Trustor for interaction, then Trustor need to sort the trust status of multiple Trustees by priority. Security strategy needs the priority of trust relationship being assigned. The priority of trust relationship under different statuses can be determined by trust decision-making quaternion. The key of the problem is the comparison of trust relationships under the same status.

In order to compare the priority of trust relationships under the same trust relationship status, the concept of trust-risk balancing factor is introduced. Before introducing the concept of trust-risk balancing factor, explain two relationships first: one is that high trust necessarily implies low risk; low trust implies the high risk. There does not necessarily have a clear quantitative relationship, but the qualitative inverse relationship between two exist. Another is that it is defined in this paper that higher the risk measurement value is, higher the risk is. Thus there is an inverse relationship between risk measurement value and trust degree. After understanding these two relationships, the definition of trust-risk balancing factor is given.

Definition 4: Trust-Risk balancing factor Assume that in a same trust relationship status, trust interval is [T_L, T_U], risk measurement value interval is [R_L, R_U], trust-risk balancing factor ρ is:

$$\rho = W_T * \frac{T-T_L}{T_U-T_L} + W_R * \left(1 - \frac{R-R_L}{R_U-R_L}\right) (4)$$

W_T is the trust relationship weight, W_R is the risk relationship weight, $W_T, W_R \in [0,1]$, $W_T+W_R=1$; *T* is current trust degree, *R* is current risk measurement value, $T_L \leq T \leq T_U$, $R_L \leq R \leq R_U$.

W_T and W_R are the tendency degree of Trustor to trust relationship and risk relationship. If Trustor belongs to credulity decision-maker (risky decision-maker), then $W_T > W_R$. If Trustor belongs to doubting decision-maker, then $W_T < W_R$. If Trustor belongs to rational decision-maker, then $W_T = W_R$. The values of W_T and W_R are determined by security poly.

Under the same trust relationship status, the priority of different trust relationship is determined by comparing trust-risk balancing factor. Assume that $W_T = W_R =0.5$, enter the formula (4):

$$\rho = 0.5 \times \left[\frac{T-T_L}{T_U-T_L} + \left(1 - \frac{R-R_L}{R_U-R_L}\right)\right] (5)$$

Current trust relationship evaluation from Trustor to Trustee1 is *OTD*=0.52, *RFV*=0.47, it belongs to the type of "relatively trust- relatively low risk", namely status TS_{17}. The evaluation of Trustee2 is *OTD*=0.69, *RFV*=0.32, it belongs to the type of "relatively trust- relatively low risk" as well, namely status TS_{17}. From the Table 1, it can be known that, the corresponding trust degree interval of grade "relatively trust" is (0.50, 0.70], the corresponding trust degree interval of grade "relatively low risk" is [0.30, 0.50). Calculate the ρ in accordance with formula (5), then ρ_1=0.125, ρ_2=0.925. It illustrates that the trust relationship between Trustor and Trustee2 is better than the trust relationship between Trustor and Trustee1. It is denoted as:Trustor − Trustee2 ≻ Trustor − Trustee1.

Following is a further analysis. In the same trust relationship status (trust status "relatively trust- relatively low risk"), the different values of trust degree and risk measurement value cause the high and low difference of trust relationship and risk relationship. For example, *OTD*=0.52, correspondingly *OTD*=0.69, it belongs to low trust. Compared with *RFV*=0.32, *RFV*=0.47 belongs to high risk. According to this classification, the trust relationship evaluation from Trustor to Trustee1 is "low trust-high risk". The trust relationship evaluation from Trustor to Trustee2 is "high trust-low risk". From the view of qualitative analysis, the trust relationship "high trust-low risk" certainly should be prior to the trust relationship "low trust-high risk". Furthermore, if the trust relationship evaluation from Trustor to Trustee3 is *OTD*=0.52, *RFV*=0.32, then it belongs to "low trust-low risk". The trust relationship evaluation from Trustor to Trustee4 is *OTD*=0.69, *RFV*=0.47, then it belongs to "high trust-high risk". Calculate the value of ρ respectively, correspondingly, ρ_3=0.5, ρ_4=0.85. It indicates that Trustor − Trustee2 ≻ Trustor − Trustee4 ≻ Trustor − Trustee3 ≻ Trustor − Trustee1. Namely, "high trust-low risk" is prior to "high trust-high risk", "high trust-high risk" is prior to "low trust-high risk", "low trust-low risk" is prior to "low trust-high risk". It can be found that, the compared result by calculating trust-risk balancing factor is corresponding to real expectation. Different weights W_T and W_R produce different result (as shown in Table 3), but the difference of priority relationship only reflected on the priority of "high trust-high risk" and "low trust-low risk". It is impossible to change the priority of the trust relationship "high trust-low risk" and "low trust-high risk". In the practical usage, it is determined by security poly.

TableIII. Balancing factor of trust-risk ρ corresponding to different $W_T$and W_R

Relative trust status	OTD (T)	RFV (R)	$W_T = W_R$ =0.5	$W_T = 0.8$, W_R =0.2	$W_T = 0.2$, W_R =0.8
			ρ	ρ	ρ
High trust-low risk	0.69	0.32	0.925	0.94	0.91
High	0.69	0.47	0.85	0.79	0.31

trust-high risk					
Low trust-low risk	0.52	0.32	0.50	0.26	0.74
Low trust-high trust	0.52	0.47	0.125	0.11	0.14

IV. EFFECTIVENESS ANALYSIS OF THE MADEL EFFECTIVENESS ANALYSIS OF THE MODEL

The trust models which considered many risk factors existed many shortcomings because of the essential connotation of risk and trust relationship is not understand thoroughly. This paper proposes the trust relationship model under the perspective of risk, put the risk and trust on equal footing into consideration, enhance the scientific of trust decision.

According to the above analysis and case study, trust relationship model under risk perspective has the following characteristics:

(1)Model adopted a trust, risk and credible decision-integrated structure, reflects the effect of subjective and objective factors in the trust decision, it is more reasonable and effective compared to rely on simply trust or risk decision-making.

(2)The model introduces the risk to evaluate of the trust relationship, formed the trust relationship status viewed from the Angle of risk, make the formation of trust relationship is more comprehensive and objective.

(3)The model has a good dynamic adaptability capacity, it suitable for dynamic requirements of the safety decision-making in open network environment. It suitable for personal preference and the importance of a transaction and further illustrates dynamic adaptability of the model in different environment.

(4)The model achieved the quantify relationship of trust, risk and credible decisions, while changing the view that the most existing model considered the risk is just a decision attribute of trust, equate risk with trust, combined the quantitative and qualitative analysis, make the decision making process more effective, more in line with the nature characteristic of the trust, risk and decision making.

V. CONCLUSIONS

Trust mechanism provides a new train of thought to solve the problem of information security, make up for the traditional security mechanism cannot adapt to the limitations of dynamic environment on the safety requirements. However, trust and risk together, to accurately grasp the essence of the trust relationship, it must be understand trust relationship under the risk perspective. In this article, through in-depth study of the essence of trust and risk, put forward clearly trust and risk, as well as the relationship between trust and risk decision, equate risk with trust, given the trust relationship theory model and decision model under the risk perspective. Through analysis

of the security decision-making process which integrated trust, risk and trust decision, enhanced the scientific of security decisions, make the security decisions more rational, comprehensive and objective.

REFERENCES

[1] Almenarez F, Marin A, Diaz D, Sanchez J,"Developing a model for trust management in pervasive devices,"In: Bob Werner, ed. Proc. of the 3rd IEEE Int'l Workshop on Pervasive Computing and Communication Security (PerSec 2006). Washington: IEEE Computer Society Press, 2006, pp. 267-272.

[2] Almenarez F, Marin A, Campo C, Garcia RC. "PTM: A pervasive trust management model for dynamic open environments,"In: Proc. of the 1st Workshop on Pervasive Security, Privacy and Trust. Boston, 2004.

[3] Jameel H, Hung LX, Kalim U, Asjjad A, Lee SY, Lee YK. "A trust model for ubiquitous systems based on vectors of trust values," In: Proc. of the 7th IEEE Int'l Symp. on Multimedia. Washington: IEEE Computer Society Press, 2005, pp. 674-679.

[4] Theodorakopoulos G, Baras JS. "On trust models and trust evaluation metrics for ad-hoc networks," IEEE Journal on Selected Areas in Communications, vol.24, pp.318-328, Feb, 2006.

[5] Sun Y, Yu W, Han Z, Liu KJR. "Information theoretic framework of trust modeling and evaluation for an-hoc networks," IEEE Journal on Selected Areas in Communications, vol.249, pp.305-319, Feb, 2006.

[6] Sun Y, Yu W, Han Z, Liu KJR. "Trust modelling and evaluation in ad-hoc networks," In: Proc. of the Global Telecommunications Conf., Globecom 2005. Washington: IEEE Computer Society Press, 2005, pp. 1−10.

[7] He R, Niu JW, Zhang GW. "CBTM: A trust model with uncertainty quantification and reasoning for pervasive computing,"LNCS 3758. Berlin: Springer-Verlag, 2005, pp.541-552.

[8] Melaye D, Demazeau Y. "Bayesian dynamic trust model," LNCS 3690. Berlin: Springer-Verlag, 2005, pp. 480-489.

[9] Duma C, Shahmehri N. "Dynamic trust metrics for peer-to-peer system," In: Proc. of the 16th Int'l Workshop on Database and Expert Systems Applications (DEXA 2005). Washington: IEEE Computer Society Press, 2005, pp. 776−781.

[10] Shao K, Luo F, Mei NX, Liu ZT. "Normal Distribution Based Dynamical Recommendation Trust Model,"Journal of Software, vol. 23, pp. 3130-3148, Dec, 2012. (in Chinese with English abstract)

[11] Song SS, Hwang K, Macwan M. "Fuzzy trust integration for security enforcement in grid computing,"In: Proc. of the Int'l Symp. on Network and Parallel Computing (NPC 2004). LNCS 3222, Berlin: Springer-Verlag, 2005, pp. 9-21.

[12] Tang W, Chen Z. "Research of Subjective Trust Management Model Based on the Fuzzy Set Theory,"Journal of Software,vol.14, pp.1401-1408, Aug, 2003. (in Chinese with English abstract)

[13] Yu FJ, Zhang HG, Yan F. "A Fuzzy Relation Trust Model in P2P System,"Proceeding of the 2006 International Conference on Computational Intelligence and Security (CIS'2006) Part 2 IEEE Press, 2006, pp. 1497-1502.

[14] Li XY, Gui XL. "Research on Dynamic Trust Model for Large Scale Distributed Environment,"Journal of Software, vol.18, pp. 1510-1521, June, 2007. (in Chinese with English abstract)

[15] D. W. Manchala. "Trust metrics, models and protocols for electronic commerce transactions," InThe18thInternationalConferenceonDistributedComputingSystems,1 998, pp. 3-12.

[16] A. Jøsang, Daniel Bradley, Svein J. Knapskog. "Belief–Based Risk Analysis," in Proc. 2nd Australasian Information Security Workshop, ACSW Frontiers 2004, Dunedin, 2004, pp. 63-68.

[17] Daniel Cvrcek, Ken Moody. "Combining Trust and Risk to Reduce the Cost of Attacks," in Proc. Trust Management, 3rd International Conference, iTrust2005, Paris, 2005, pp. 372-383.

[18] Povey, D. "Developing Electronic Trust Policies Using a Risk Management Model," Vol. 1740 of the series Lecture Notes in Computer Science, Springer, 1999, pp. 1-16.

[19] Nathan Dimmock, Jean Bacon, Dvaid Ingram, Ken Moody. "Risk Models for Trust-Based Access Control (TBAC)," Vol. 3477 of the series Lecture Notes in Computer Science, Springer, 2005, pp. 364-371.

[20] Piotr Cofta, "Computing Recommendations to Trust," in Proc. Trust Management, 2nd International Conference, iTurst2004, Oxford, 2004, pp. 340-346.

[21] V. Cahill, B Shand, E Gray, N Dimmock. "Using Trust for Secure Collaboration in Uncertain Environments," IEEE Pervasive Computing, vol. 2, pp. 52-61, 2003.

[22] A. Jøsang, S. L. Presti. "Analysing the Relationship between Risk and Trust," in Proc. Trust Management, 2nd International Conference, iTrust2004, Oxford, 2004, pp. 135-145.

[23] A. Jøsang. "The right type of trust for distributed systems," in Proc. of the 1996 workshop on New security paradigms, Lake Arrowhead, 1996, pp. 131.

[24] Almenarez F, Marin A, Campo C, Garcia C. "PTM: A pervasive trust management model for dynamic open environments," in Proceedings of the 1st Workshop on Pervasive Security, Privacy and Trust, IEEE Computer Society, Boston, 2004, pp. 1-8.

[25] Grandison T, Sloman M. "A survey of trust in internet applications," IEEE Communications Surveys & Tutorials, Vol. 3, pp. 2-16, 2000.

[26] Blaze M, Feigenbaum J, Lacy J. "Decentralized trust management," IEEE Symposium on Security & Privacy, Vol. 30, pp. 164-173, 1996.

[27] Grandison T W. "Trust management for internet applications," UK: Imperial College, 2003.

[28] James S. Coleman, "Foundations of social theory," Belknap Press of Harvard University Press, 1998, pp. 133.

[29] Mayer, R.C., Davis, J.H. Schoorman, F. D. "An integrative model of organizational trust," Academy of Management Review, vol. 20, pp. 709-734, 1995,

[30] Rousseau, Denise M., Sitkin S. B., Burt, R. Camerer, C."Not so different after all: A cross discipline view of trust," Academy of Management Reviewvol.20, pp. 393-404, Mar, 1998.