

A Survey on Trust Evaluation in E-commerce

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ABSTRACT

E-commerce is becoming a popular and growing industry in which buyers and sellers are trading with each other on the Internet. A large number of E-commerce companies have created very profitable businesses since E-commerce Web sites (such as JD.com, eBay.com) or pioneering E-commerce traders (such as Taobao.com, Amazon.com) showed up more than 10 years ago. One of the most important factors that impact the success of E-commerce is ensuring security and trust. Undoubtedly, in lack of trust as a key element of online business communications, E-commerce will face a lot of challenges. Trust evaluation plays an important role in E-commerce for evaluating trust relationship between enterprises and customers, which assists on providing qualified services and enhancing user privacy and security. However, current literature still lacks a comprehensive study on trust evaluation in E-commerce. In this paper, we propose review criteria of trust evaluation in E-commerce and survey the current literature by analyzing its advantages and shortcomings according to the proposed criteria. At last, we discuss unsolved issues and current challenges and propose future research trends in the area of trust evaluation in E-commerce.

CCS Concepts

• General and reference~Surveys and overviews • General and reference~Evaluation.

Keywords

Trust evaluation; E-commerce; trust management; reputation; credibility.

1. INTRODUCTION

With the rapid development of the Internet, E-commerce is the key to future economic growth. It helps breaking the boundaries of time and space, changes trade forms and accelerates the commodity circulation of whole society, thus reduces effectively the cost of production, improves market competitiveness, and also provides more choices for sellers and buyers.

According to the types of E-commerce participants, E-commerce is classified into different categories, such as Business-to-Customer (B2C), Business-to-Business (B2B), Peer-to-Peer (P2P), Customer-to-Customer (C2C), and Government-to-Customer (G2C). The E-commerce provides us a platform for resource sharing and online transactions. The Internet, unlike real life that we can communicate face-to-face with each other and get direct information about others, is full of uncertainty. So it is difficult to ensure that each of transaction parties is honest and trustworthy. Although encryption, digital signature, authentication and network intrusion detection technologies could protect the security in network transactions, there still exist shortcomings in the process of the trust evaluation between transaction parties. So how to quantify credibility has become a problem.

In E-commerce environments, the trustworthiness of a seller is totally important to potential buyers, especially when the buyers barely know the seller. Most existing trust evaluation models just calculate a single value to reflect the general trustworthiness of a seller, but they do not take any transaction context information into account. Accordingly, malicious sellers in transactions might easily cheat a buyer. For example, a malicious seller could accumulate a high credibility by selling qualified and cheap products and then deceive buyers by attracting them to buy expensive products with low quality. How to evaluate the trustworthiness of involved transaction parties in E-commerce becomes crucial for business success.

In this paper, we study the basic knowledge about E-commerce trust. We propose uniform and holistic criteria to evaluate the performance of trust evaluation. Then we conduct a literature review on trust evaluation towards trustworthy E-commerce in order to point out a number of open issues and challenges and suggest future research trends.

The rest of the paper is organized as follows. The basic concepts and criteria of trust evaluation in E-commerce are introduced in section 2. Section 3 reviews the recent literature based on E-commerce categories. Section 4 summarizes the current problems of trust evaluation in E-commerce and proposes future research direction. Section 5 draws conclusions.

2. CONCEPTS AND CRITERIA OF TRUST EVALUATION IN E-COMMERCE

E-commerce refers to the buying and selling of goods and services via electronic channels, primarily the Internet. Online retail is decidedly convenient due to its 24-hour availability, global reach and generally efficient customer service. In what follows, we

introduce some basic concepts related to trust evaluation and criteria of trust evaluation in E-commerce.

2.1 Basic Concepts

Trust: Trust is a multidisciplinary, multidimensional and multilevel concept. There are various definitions in the literature. Common notions are expectation, confidence, and belief regarding the integrity, reliability and ability of an entity [19].

In general, trust is subjective because each entity has different acceptably trust levels. It is also dynamic because many factors affect the trust. It can be further developed and evolved due to good experience. However, bad experience can cause trust to decay [19]. From the point of view of digital system, the trustworthiness of the trustee is assessed based on lots of trust attributes and the trustor's criteria, e.g., integrity, reliability, ability, etc. The five factors affecting trust can be divided into [19]:

- a) Trustee's objective criteria, such as a trustee's dependability and security. Particularly, the reputation of the trustee is assessed publicly based on its earlier behaviors.
- b) Trustee's subjective criteria, such as trustee's honesty.
- c) Trustor's subjective criteria, such as trustor's attitudes towards trust.
- d) Trustor's objective criteria, such as trustor's policies and expectation for a trust decision.
- e) Context that the trust relationship exists in, such as the aim of trust, the risk of trust and the context of trust (e.g., time, place, activity, their operational mode, devices being used, etc.). Context contains any information that can be used to describe the situation of involved entities.

E-commerce trust evaluation should concern part or all of above trust factors in different situation for different purposes.

Trust: Trust refers to the degree of the trustworthiness of an entity that someone trusts in. Based on the Oxford English Dictionary, trust is trustor's assessment of an individual regarding trustor's criteria and a number of trust attributes after some direct or indirect interactions with the individual.

Trust evaluation: Trust evaluation is a method to evaluate the trustworthiness of the target. It's significant in E-commerce because when trade is happening, the participants barely know each other. Trust evaluation aids customer purchase decision in E-commerce. The methods of trust evaluation applied by different trustors could be different. But the goal is the same: maximize the accuracy of evaluating the trustworthiness of the trustee.

Trust management: Blaze et al. [20] firstly defined trust management. With the application of trust management in research for network security, Grandison [21] proposed a more general definition "Trust management is the activity of collecting, encoding, analyzing and presenting evidence relating to competence, honesty, security or dependability with the aim of making assessments and decisions with regard to trust relationships." It has been studied that trust management was used in the context of access control, public key architecture, and peer-to-peer reputation systems. Meanwhile, trust management also benefits the industries that require collaboration and sharing, and financial services such as autonomous E-commerce.

Recommender system: It is one of the most important computer-based intelligent methods to find out the most appropriate goods

or services from large amounts of products. It has been proved to be an important tool that can overcome the problem of information overload by sifting through the large set of data and recommending information relevant to the user. Typically, in an E-commerce environment, the trading data between consumers and sellers and items are analyzed by the recommender system to find relationships among them, and the items bought by similar users are provided as recommendations. Applying this technology, it is reported that some E-commerce systems, such as Taobao.com, JD.com, and Netflix.com, have increased E-commerce sales by providing E-commerce system browsers for buyers, building customer loyalty and increasing cross-selling.

2.2 Criteria of Trust Evaluation in E-commerce

Herein, we propose a number of criteria for assessing the performance of trust evaluation in E-commerce. The purpose is to figure out potential problems of current research in order to find out open research issues and direct future researches.

To provide trustworthy E-commerce under any circumstances, researches on trust evaluation in E-commerce should achieve the following goals:

- a) **Trustworthiness (T):** The trust evaluation should be robust to overcome various potential attacks. The evaluation should prevent E-commerce from various attacks, for example, the speculation and defamation of credit and credit fraud.
- b) **Adaptability (Ad):** In E-commerce, the trust relationships among participants could be dynamically changed due to good transaction experiences or bad ones. Since trust is context-aware, it is essential for trust evaluation to be adaptive to context changes.
- c) **Usability (Us):** Users in E-commerce should drive Design. Trust evaluation should consider trustor's subjective opinion and be usable with regard to user-device interaction. E-commerce mainly provides intelligent services by interacting with human beings. Users should drive the design of trust solutions if they are related to the E-commerce participants. This concern is caused by the subjective characteristic of trust.
- d) **Privacy (Pr):** User privacy, including personal information and user data, should be flexibly preserved according to the policies and expectations of E-commerce users when user data are collected for trust evaluation. Trust evaluation in E-commerce should allow the participants to preserve their privacy to the maximum extent.
- e) **Accuracy (Ac):** The accuracy of trust/reputation evaluation should be ensured without any doubt.
- f) **Efficiency (E):** Trust evaluation should be efficient in order to dynamically manage trust relationships in E-commerce.
- g) **Uniformity (Un):** It is preferred to offer a uniform model to consider participants subjective voting with trusted credibility for trust evaluation.
- h) **Comprehension (C):** The trust evaluation should concern various trust influencing factors in a comprehensive way. This is essential for achieving accurate trust evaluation.
- i) **Generality (G):** Trust evaluation for various E-commerce services and systems can be commonly or widely used in different application scenarios, which is a preferred objective for trust evaluation.

3. LITERATURE REVIEW

In E-commerce environments, a comprehensive and holistic trust evaluation requires that all above criteria can be well satisfied. We review some major articles in recent ten years and pay more attention on the recent five years. We use certain keywords to gather the reviewed articles: trust or trust evaluation or trust assessment or trust generation or reputation generation, reputation assessment or reputation evaluation or trust management or reputation system and E-commerce, by searching in all authoritative databases, such as IEEE Explorer, ACM library, Springer library, and Science Direct. We classify our review based on E-commerce categories: B2B E-commerce application scenarios, B2C E-commerce application scenarios, C2C E-commerce application scenarios, P2P E-commerce application scenarios and others. Other E-commerce application scenarios are those scenarios that do not correspond with the specific E-commerce application scenarios, but are in E-commerce environments. We use the proposed criteria to analyze and measure existing work, in order to find current problems, then possible to propose new research directions.

3.1 B2B E-commerce Application Scenarios

At the present time, although E-commerce has developed for many years, it still exists many problems. The most serious problem is that people lack of trust and faith in the transaction. Because of fraud behavior, lack of honesty and potential attacks, there exist dangerous traps between enterprises. It is necessary to improve B2B E-commerce markets quality of service by the study of trust evaluation. Assessment of the trustworthiness of the business can factually decrease fraud behavior and make B2B E-commerce transactions successful easily.

Lu and Ma [12] explored the trust evaluation system of the enterprise in B2B E-commerce business and a trust evaluation model was established based on the Markov process. The trust evaluation model includes time, the reputation of buying agents and the heavy-weight of transactions as the restraining variables. They control five influencing factors to build a stable credit evaluation model. They are individuation, quality of transaction, transactions no related to interaction, informational and security. Individuation means whether the selling enterprise provides personalized services or not. The quality of the transactions means the quality of service and the quality of product. Transaction no related to interaction means the communication in favor of the buying enterprise or the communication among the buyers. Informational means supply as much as possible information about the products. Security means the protection of business information. Time is a restraining variable, adjusting the influence of the prior transactions on the present greatly. The shorter the time between transactions is, the greater the effect. It is obvious that larger amounts of trading have a greater influence on the trust evaluation. The better the reputation of buyer, the more accurately the reputation of the selling enterprise is assessed, satisfying the criterion Uniformity. So this model satisfies the criterion Comprehension. Through simulations, it's concluded that the Markov process-based model for the B2B E-commerce trust evaluation has the ability of anti-jamming and better stability, thus satisfies the criterion Trustworthiness partially. The result of the experiments indicates that the trust of seller is evaluated accurately with the model proposed by Lu and Ma [12] and the risk of transaction is reduced. So the model satisfies the criterion Accuracy. This trust evaluation model can be used in B2B E-commerce application scenarios in general, satisfying the criterion

Generality partially. But it didn't consider privacy, adaptability, usability and uniformity.

3.2 B2C E-commerce Application Scenarios

The B2C E-commerce means the transaction between enterprise and individual consumers. The website provides a free trading platform for such kind E-commerce. Only in accordance with the requirements, any enterprises and individual consumers can perform trades with each other in this platform. The B2C E-commerce is one of the most important business modes for the Internet economy and its rapid development has already appeared in these years. China B2C merchandise in online shopping includes popular goods and modern IT products, such as clothes, cosmetics, jewelries, books, mobile phones, computers, digital products, etc. Shopping online is full of individuation and diversification and its consumption development will play an important role in the direction of social spending habits model. However, there still exist many problems in the B2C E-commerce enterprise development, e.g., transaction safety, payment safety, delivery service and customer trust. The last issue is the key to promote and ensure the fast development of B2C E-commerce.

Most of recent researches of E-commerce trust are qualitative, which made the results of research lack of persuasion. To change the actuality, Lu et al. [2] put forward an evaluating system of B2C E-commerce trust. To assess the evaluating system proposed by Lu et al. [2], an experiential survey approach of collecting data was used. Research subjects mainly included undergraduates and graduates, MBA students. 220 subjects participated in the experiment, 192 questionnaires were useful, which included 86 female students and 106 male students. After data was collected, reliability analysis and model testing were done with SPSS and Lisrel separately, which are two main tools when analyzing research data of E-commerce trust. This study implied that reputation, trust propensity, security control and policy & law have an influence on whether an individual trusts an E-commerce business. In turn, this will influence their purchasing intentions. But only some of methods of data analysis were used in the example, factor analyzing, regression analyzing and so on were not included. This work result can be used for deciding what factors should be concerned in B2C E-commerce trust evaluation. This study focused on investigating trust impact factors, thus supports the criterion Comprehension. The evaluating system of B2C E-commerce trust can be used in B2C E-commerce application scenarios, which satisfies the item Generality partially.

For the enterprises of E-commerce, customer trust is a survival and significant development issue, so evaluating customer trust factually will be the key research. But current customer trust evaluation focused mostly on theoretical studies, not based on quantitative research and empirical analysis. Zhao and Xu [15] found out the key factors that influence customer trust based on the analysis on survey data that came from China Internet Information Center, for supporting the criterion Comprehension. They made comprehensive and quantitative evaluation on customer trust for B2C E-commerce enterprise based on factor analysis method. This work provided some advices on the E-commerce standards, including industry standards, laws and regulations, improvement of the E-commerce store admittance threshold and management in an increasingly competitive environment in order to improve the healthy development of the enterprises. This study mainly focused on customer trust evaluation for B2C E-commerce based on factor analysis, but ignored other aspects of trust evaluation, such as trustworthiness,

adaptability, usability, privacy, efficiency, generality, and uniformity.

3.3 C2C E-commerce Application Scenarios

As an important transactional mode in E-commerce, C2C shows a strong development trend in China. Some big C2C shopping websites, such as Taobao, TOM EBay and Paipai have 67.1% market share of online shopping. Even so, E-commerce credit is still the biggest obstacle to the overall development of E-commerce in China and C2C E-commerce websites suffer to a great extent from widespread credit problems. Because participants of C2C are generally individuals and small enterprises with little popularity, both parties of the transaction lack channels of understanding and have no access to the identity and credit status of trading partners, this implies that cyber fraud is more likely to occur. Currently, major C2C E-commerce websites adopt the credit evaluation system to increase user trust of online transactions. However, the existing trust evaluation system is so weak that it can't prevent the lack of honesty and poor reputation of credibility.

Li [1] proposed an improved evaluation model, considering the effect of different users in different situations. The evaluation made by a user with multiple transaction experiences is more convincing than that made by a user without any transaction experiences. The evaluation made by the user with large transactions is more influential than that made by the user with small transactions. If a buyer has ever traded with multiple sellers, then the evaluation made by the buyer is more convincing than that made by the user who has only ever traded with one seller. So this work satisfied the criteria Uniformity and Accuracy. Accordingly, this can effectively inhibit the speculation and defamation of credit and credit fraud. Thus, the criterion Trustworthiness can be somehow enhanced.

Besides, the improved evaluation model proposed by Li [1] considered the initial credit value of both the buyer and the seller. Because when both of them are allowed to log into a C2C website for the first time, major C2C shopping websites set up the initial credit value of both the buyer and the seller as zero, which makes the buyer fail to make a judgment of the difference of the seller's credit rating. Accordingly, Li [1] held that the initial credit value of the seller is related to the third-party services the seller adopts. The initial credit value of the seller is the sum of the scores that the seller gets in conducting various third-party service authentications. When the buyer and seller have never traded with each other, the seller's initial credit value is determined by the third-party services that it conducts which concerns the criterion Accuracy. The more all-rounded the third party services are, the higher his initial credit value is. When the buyer conducts an online transaction with the seller, the seller's credit value is formed from the evaluation made by the buyer after the transaction is over. At this time, the proportion of the initial credit value is smaller and smaller. During the transaction process, the buyer makes his evaluation in terms of the service, quality, distribution and payment of the product that finally constitutes the score of the evaluation. The previous evaluation on the seller has certain impact on the seller's credibility. And the more experienced the buyer is, the higher his evaluation credibility is, and the more recent the evaluation is, the better it can reflect the latest credibility of the seller. In addition, it can prevent the speculation and defamation of credit and credit fraud to a certain degree, satisfying the criterion Trustworthiness partially. The product of multiplication of user's credibility, user's evaluation score and time weight constitute the real credit score of the seller

made by the user. And the total credit rating of the seller is the sum of the credit scores evaluated by various buyers. It also considers the impact of time factor, a user's historical evaluation may have expired showing that its role in evaluating the user's current credibility should be reduced, all of which supports the criterion Accuracy. However, the impact of the latest evaluation on credibility should be bigger, and the latest evaluation should better reflect the user's credibility than any previous evaluation.

In particular, this model [1] considers not only direct credibility factors, but also indirect credibility factors, satisfying the criterion Comprehension. The more the transactions between Buyer and other transaction users, the higher the credibility of the evaluation made by Buyer. There is a parameter to control the weight of direct credibility, which has an inverse relationship with the number of the users and other users trading with it. When the value keeps increasing, it means that the role of the user's indirect credibility in judging the other user's credibility is bigger and bigger when the buyer trades with more and more users. However, the weight of indirect credibility will not exceed a certain value, which shows that the role of indirect credibility is increasing, but it is impossible for it to completely replace the user's credibility.

This model divides user evaluation into four factors: product, service, distribution and payment, with each factor corresponding to one evaluation. One evaluation question is respectively designed for each factor of product, service, distribution and payment. For example, on the aspect of service, the question can be designed as "What about the seller's service attitude?", and the answers to the question are respectively "good", "ordinary" and "bad", respectively corresponding to "+1, 0, -1". In this way, a user can make a relatively objective evaluation of the seller's performance in these aspects during the transaction process. So the criteria Accuracy and Comprehension are satisfied. The improved credit evaluation model can be applied in C2C scenarios in general, satisfying the criterion Generality partially.

After analyzing the factors influencing the transactions in C2C E-commerce, Zhang and Guo [10] firstly built a hierarchical trust evaluation index system by summarizing the influence factors in C2C E-commerce application scenarios. The hierarchical trust factors include technology factors, website factors and customer factors. Every first hierarchical trust factor consists of three second hierarchical factors. Technologies are composed of online transaction security mechanism, online shopping payment pattern and online transaction system availability. Website factors consists of website decoration, quality of products supplied by sellers and seller's service after sales. Customer factors include customer consumption psychology, online transaction experience and other customers' recommendation. So the criterion Comprehension is satisfied. The authors established a Trust evaluation model for C2C E-commerce based on fuzzy sets theory. This evaluation model was experimented with examples, and it was confirmed that the model could be applied to evaluate the trust in C2C E-commerce accurately, which considers the criterion Accuracy. In addition, the model proposed by Zhang and Guo [10] can be not only applied in C2C E-commerce, but also used in other autonomous trust management systems, satisfying the criterion Generality.

Wu et al. [4] proposed six new factors for online auctions in C2C E-commerce. The first factor is the extent of the feedback that a participant obtains from other participants about their satisfaction with the transaction. The second factor is the positive feedback ratio that indicates the number of satisfied transactions to all the transactions that a participant makes with other participants. The

third factor is the credibility of the feedback that the participant gains. The fourth factor is the transaction price of a transaction. The fifth factor is the decay of transaction time. The last one is the savings of the participants. When six factors influencing the trust of the entity were taken into account, it was more accurate to compute the trustworthiness of the entity. It also took participants' behavior changes over time into account. So the criteria Comprehension and Accuracy are satisfied. This trust evaluation system can deal with dynamic participant behaviors because a malicious user could make a number of transactions normally but deceive sometimes. So it is difficult for other participants to recognize a malicious participant because the ratio indicating his positive feedback is very attractive. To handle this problem, a good reputation system should be established to monitor the trust value changes of the participants, especially the trust value that decreases considerably. Thus, this model proposed moving time windows to handle this situation. Two time windows were used to compute a participant's average trust value and recent trust value. The trust evaluation system can get the values changes by obtaining two trust values over time and subtracting the later one from the earlier one. If the trust value drops dramatically, it means that the participant's reputation is not trustworthy. Then, the evaluation system will take notes about the participant or even withdraw this participant's privileges for selling or buying. Accordingly, the criterion Adaptability is satisfied and the criterion Trustworthiness is somehow supported. The experiment results reveal that the malicious and collusive participants can be distinguished from honest participants by the proposed trust evaluation system. The empirical analysis also demonstrates that the proposed system can spot malicious participants. So the criterion Trustworthiness is satisfied partially. From this research, it was concluded that a holistic trust evaluation model, including some of the factors that Wu et al. [4] have advised, can make participants more satisfied with the auction websites services, and detect malicious behavior and participants easily. This trust evaluation system can be generally applied in C2C E-commerce application scenarios, satisfying the criterion Generality partially.

3.4 P2P E-commerce Application Scenarios

As an important technology in E-commerce, P2P E-commerce now has been increasingly drawing more and more attention. However, in P2P networks and P2P E-commerce environments, a peer can join and leave the group anytime. In absence of a central management in most P2P environments, the dynamic statuses of each peer and the networks introduce additional challenges to trust evaluation. It is logical to doubt its trustworthiness before trading with an unknown peer. Accordingly, to enable the trust evaluation before interacting with a number of unknown peers makes the transaction more secure. When a P2P network is applied for E-commerce applications particularly, the trust evaluation becomes an important issue.

Wang et al. [3] proposed a novel model to evaluate the target peer's transaction trust, which takes the transaction amount property into account. This method is based on transaction experiences of other peers but differentiates different kinds of transaction amounts and determines different influence factors according to the amount of the new transaction. Besides, the new method also holds the temporal dimension weighing more on the fresh transactions weigh more than the old transactions. So the criterion Comprehension is satisfied. This makes trust evaluation more accurate, thus supports the criterion Accuracy. This model can be used to serve as the risk indication of new transactions. Using this model, before interacting with a number of potential service providers, the end peer can investigate their transaction

histories, evaluate transaction risk, and then determine to select the most suitable service provider. From this point of view, the model supports the criterion Trustworthiness partially.

The novel model for evaluating a target peer's transaction trust proposed by Wang et al. [3] also adds the credibility of responding peers into trust evaluation. The credibility value (e.g., the value between 0 and 1) of a responding peer is determined by its recommendation history. It can result from the deviations of its recommendations in multiple rounds. In other words, constant low deviations lead to a high credibility level while constant high deviations lead to a low credibility level. When evaluating the new trust value, credibility values or recommendation trust of responding peers should be considered. The credibility level of responding peers is significant and beneficial to decrease possible noise. So the criterion Uniformity is satisfied. Thus, the evaluation model proposed by Wang et al. [3] is comprehensive and objective.

This model can be used in both decentralized E-commerce environments without a central management server (e.g., P2P) and centralized E-commerce environments with a central management server (e.g., Taobao.com). The difference is that if there is no central server, it needs plenty of communications between peers to collect all information for a target peer. If the central server is in disposition, these problems will not exist any more. The server will be responsible for collecting all information and evaluating the current trust value and risk value of a new transaction. Accordingly, the model satisfies the criterion Generality.

Inconsistency of peer evaluation criteria will result in unfair assessment of the service provider, a trust model in P2P E-commerce systems was proposed by Yu et al. [6] based on the recommendation, which takes evaluation criteria differences into account to solve the problem, but it didn't take other factors into consideration. So we think the trust model satisfies the criterion Comprehension partially. Peers need to decide their own evaluation criteria, and provide to other peers as interaction references. Each peer in the system has a unique credibility of recommendation. The trust model introduced two trust parameters for updating the credibility of recommendation, which are updating range and updating strength. An algorithm was applied to update the credibility of recommendation by the trust model. A peer selects recommendation peers whose evaluation criteria are similar. The Analytic Hierarchy Process (AHP) method determined the evaluation criteria of the peers. The AHP is a structured technique to help people cope with complex decisions. Rather than prescribing a correct decision, the AHP can help people to determine one. An AHP hierarchy is a structured means of describing the problem at hand. It includes an overall goal, a set of options or alternatives for reaching the goal, and a set of criteria or factors that relate the alternatives to the goal. Analysis and simulation demonstrate that the trust model can evaluate the peers' trust value with a smaller overhead, and identify malicious behaviors in P2P E-commerce systems, which can improve the quality of service in P2P E-commerce systems effectively. So we believe that the criteria Trustworthiness and Generality are satisfied partially and the criterion Accuracy is satisfied.

Wang and Varadharajan [13] proposed a novel peer trust evaluation model. Using this method, the trustworthiness of a certain peer can be calculated by investigating its transaction history with other peers if the end peer has no previous transactions with it. Because the novel peer trust evaluation model investigates the transaction history between peers in E-commerce, so we believe it can be efficient to dynamically manage trust

relationships between peers in E-commerce, thus satisfying the criterion Efficiency. At the same time, a time-based evaluation is added in this model that the fresh transactions weight more than the old transactions, satisfying the criterion Adaptability. After the investigation, the probability of a given threshold of trust value for a peer can be evaluated. With these results, a set of “good” peers can be chosen that satisfy the requirement of the end peer, satisfying the criterion Usability. This satisfies the criterion Accuracy. After that, the end peer can interact with them for their services. This peer trust evaluation model can be used in P2P E-commerce application scenarios, satisfying the criterion Generality partially.

Li et al. [16] proposed a novel transaction trust evaluation model taking the transaction period, transaction amount and the trust value of source peer into consideration, which reflects transaction amounts and recommender’s trust value when calculating the trust value of the peer. The authors thought that the higher the source peer’s trust value is, the more trustworthy his feedback. The larger the amount of the transaction is, the more important the feedback. This satisfies the criterion Uniformity. Besides, the model introduces the transaction period factor while updating peer’s trust value, which means that the feedback occurred in different periods have different influence on the trust value of a peer. The very old transactions should be neglected and the fresh transactions weigh more since they are more significant. This satisfies the criterion Comprehension, which results in accurate trust evaluation. This model is also effective against malicious behaviors. So it satisfies the criteria Accuracy and Trustworthiness. Moreover, experiments showed that this model performs better than other existing trust models. The new model can effectively describe the trust status of peers and thus indicate the risk of new transactions, satisfying the criterion Trustworthiness partially. This trust evaluation model can be applied in P2P E-commerce application scenarios, but further investigation is needed to show its applicability for other E-commerce categories. So we believe that the criterion Generality is satisfied partially.

3.5 Other E-commerce Application Scenarios

In this section, we review the papers that do not correspond with any specific E-commerce application scenarios, but the models are used in E-commerce environments.

It has been proved that Collaborative Filtering (CF) is one of the most successful recommendation methods among many recommendation technologies, which has been widely applied in many E-commerce scenarios. The success of CF recommendation depends mainly on locating similar neighbors to get recommendation items. However, many researchers have found that the process of finding similar neighbors often fail, because of some inherent weaknesses of CF based recommendation. To deal with this problem, Zhong et al. [5] proposed a trust feedback recommendation algorithm based on the basic notations about trust cognitive process and directed trust graph (DTG), which is constructed according to trust links between users. The trust feedback recommendation algorithm has the ability to spread trust relationship, satisfying the criterion Efficiency. In this method, there is no need to calculate similarity between users, but take advantage of the trust relation between them to conduct prediction calculation. Zhong et al. incorporates the process of the analysis of human trust perception into the recommendation algorithm. They showed the advantages of the different algorithms through experiments on Epinions datasets, and the experimental results indicated good effectiveness of the trust based recommendation approach Zhong et al. proposed. One limitation of this method is

that it was tested and verified only based on one dataset. So we believe that the criterion Accuracy is satisfied partially. Effectiveness of the trust feedback recommendation algorithm should be further proved based on trust datasets that their characteristics are different from the Epinions datasets. In addition, Zhong et al. put forward three important research problems that need to be examined: (1) Study the influence on recommendation accuracy when the method of setting trust value between two participants changes; (2) Study the relation between the accuracy of the trust feedback recommendation algorithm and weighted control factor function; (3) Study the effectiveness of the method applying other datasets and compare the practicability of the approach with other analogous means.

Morid and Shajari [7] proposed a trust-scoring model named Enhanced E-commerce Trust Model (E2CTM). To evaluate the trust in a trustee (Trust_Val) in E2CTM, the model used the rating given by that trustor to the trustee (LocalTrust) and the average rate of the other trustors in that trustee (Reputation), satisfying the criterion Efficiency. The proposed model supported critical issues for centralized e-commerce systems. First, a trustor having little experience with a trustee can use another trustor’s experience with that trustee (Reputation) by allowing Reputation to affect Trust_Val more than LocalTrust. However, a trustee with good reputation who begins to perform fraudulent transactions should be prevented from doing so. This was accomplished by allowing a trustee’s recent Reputation to rapidly affect that trustee’s overall reputation. Also, a trustee with a bad reputation who is a good partner for a certain trustor was allowed to continue to trade with that trustor. This was achieved by giving LocalTrust more weight than Reputation. So we believe this model satisfies the criterion Accuracy. To test the success of E2CTM to address the above concerns, an online auction electronic shopping system was simulated and the performance of E2CTM was tested by comparing to the conventional trust model used by most electronic shopping systems (ESS). To do so, buyer behavior was simulated for auction participation. An enhanced decision model based on a Manchala model was used. In this model, participants were assumed to have different purchasing behaviors and risk taking attitudes according to parameters such as their familiarity with E-commerce purchasing and age. The simulation results for the overall performance showed the advantages of E2CTM over the conventional trust models. These advantages were more significant when there were a low percentage of fraudulent transactions in the system. Moreover, the simulation results for two other situations (fraudulent behavior of a seller with a good reputation and good behavior of a bad seller with certain buyers) confirmed E2CTM superiority, satisfying the criterion Trustworthiness partially. A limitation to implementing E2CTM on a large market such as eBay is that it requires more memory space since it calculates the individual experiences of a buyer with different sellers in addition to seller reputation. However, this cost is negligible for a big marketplace, especially because the overall number of sellers a certain buyer trades with is not large. This trust model can be implemented in a wide range of applications from a small business environment such as micropayment systems to a large marketplace such as an electronic shopping system, thus satisfying the criterion Generality.

Zhang et al. [8] proposed a trust vector including three values for Contextual Transaction Trust (CTT). When computing the CTT values, three identified important context factors, consisting of Transaction Time, Produce Category, and Transaction Amount, are considered. This model supports the criterion Comprehension. Meanwhile, the evaluation of each CTT value is based on both

past transactions and forthcoming transactions. In particular, with different parameters specified by a buyer regarding context dimensions, different sets of CTT values can be computed. Accordingly, all these trust values can display the reputation profile of a seller that indicates the dynamic trustworthiness of a seller in different price ranges, time periods, products, product categories and any necessary combination of them. Zhang et al. named this new model as ReputationPro. However, in ReputationPro, the computation of reputation profile requires new data structures for appropriately indexing the pre-computation of aggregation over large-scale ratings and transaction data in three context dimensions, as well as novel algorithms for promptly answering buyers' CTT queries. Besides, storing pre-computed aggregation results consumes a large volume of space, particularly for a system with millions of sellers. Accordingly, reducing storage space for aggregation results is also an important issue. To deal with these challenging problems, Zhang et al. first proposed a new index scheme CMK-tree by extending the two-dimensional K-D-B-tree that indexes spatial data to support efficient computation of CTT values. Then, they further extended the CMK-tree and proposed a CMK-tree RS approach to reduce the storage space allocated to each seller. The two approaches are not only applicable to three context dimensions that are either linear or hierarchical but also consider the characteristics of the transaction-time model—that is, transaction data is inserted in chronological order. Additionally, the proposed data structures can index each specific product traded in a time period to evaluate the trustworthiness of a seller in selling a product. Finally, the experimental results show that the CMK-tree is superior in efficiency of computing CTT values to all three existing approaches in the literature. Particularly, when answering a buyer's CTT queries for each brand-based product category, the CMK-tree has almost linear query performance. Additionally, with significantly reduced storage space, the CMK-tree RS approach can further improve the efficiency in computing CTT values. Therefore, the proposed ReputationPro model is scalable to large-scale E-commerce Web sites in terms of efficiency and storage space consumption, satisfying the criterion Generality.

Liu et al. [9] proposed optimization Hidden Markov Model based on Particle Swarm Optimization (PSOHMM) to develop a new reputation model. The proposed algorithm takes full advantage of global searching capability of PSO and avoids BW (Baum-Welch) algorithm trap into the local optimum. Aiming at the interval and normalized constraints in HMM, the authors employed remapping and renormalized methods in an iterative process. Based on the efficiency of PSOHMM algorithm, they proposed the reputation evaluation framework based on Hidden Markov Model. The simulation experiments demonstrated that PSOHMM is superior to the BW algorithm to search for optimal model parameters and is more stable than it. So we believe the criterion Accuracy is satisfied. Compared with Average and Beta reputation evaluation algorithm, PSOHMM has a fast response to the sellers' behavior changes in E-commerce, which satisfies the criterion Adaptability. But, the collusion attack of buyers is not considered in the reputation model, thus it does not satisfy the criterion Trustworthiness. It is required to develop a more robust PSOHMM reputation model to resist the attacks from malicious buyers. The PSOHMM model not only fits into E-commerce environments, but also can be applied in other applications. For instance, it can be used to research the reputation of suppliers in supply chain management and the reputation of products in Product Lifecycle Management. So we believe the criterion Generality is satisfied.

Divsalar and Azgomi [11] firstly investigated all three general dimensions of trust in E-commerce, including institutional trust, technology trust and trading party trust. This satisfies the criterion Comprehension. They established a trust evaluation model in E-commerce based on analyzing conception and component of trust in E-commerce. Two features exist in the trust evaluation model. Firstly, trust is evaluated dynamically. With a change in any of trust variables, the new value is evaluated for trust, thus it satisfies the criterion Adaptability. Secondly, it is optional. This means that it is capable of making partial study of trust on contexts presented in general dimensions of trust. The advantage of partial study of trust is that the trust parameters are mostly personal and each agent has its own belief, which can serve as basis of trust evaluation. The manner is such that some trusted parties (TMA, trust manager agent) have been envisaged distributed in the network. TMAs have duties to evaluate, maintain and spread trust for agents. The presented computational model has the ability of calculating all contexts of the trust. Then, a case study is presented to show efficiency and rationality of the proposed computational formula of trust. So we believe that the criterion Accuracy is satisfied. But Divsalar and Azgomi did the case study with only three consumers who purchase from a common E-vendor. In future, it is needed to do a case study with different suppliers and different shopping with more experiments and sufficient data to demonstrate the advantages of the proposed model.

Cai et al. [14] used a common industry terminology and methods in core business processes to build a closed-loop green E-commerce model and a practicable trust value quantitative measurement tool. The proposed model has the following characteristics: (1) The trust processes of products/service network in entire chain forms complete closed-loop operations; (2) The processes in trust chain are different from those in supply chain; (3) A member's trust value represents its trust manner that was performed in a group. The trust evaluation performance indicators of green commerce include four aspects: reliability (RL), effectiveness (EF), cost (CO), asset management (AM). The Reliability (RL) expresses the operational stability and anti-interference ability of the entire trust chain, mainly Mean Time Between Failures (MTBF), Mean Time To Repair (MTTR), and order fulfillment indicators. This satisfies the criterion Trustworthiness partially. The Effectiveness (EF) comes from the trust requirements of the user, national industrial standards, mandatory requirements, laws and regulations, and relationship agreements or cooperation requirements, as well as related product service requirements of some authorities. This satisfies the criterion Usability. The Cost (CO) donates the cost-effectiveness of trust chain operation, including management costs, sale cost, reverse cost, etc. The Asset Management (AM) describes the asset management of trust chain, including Cycle Time, Return, and so on. Therefore, the proposed model may be helpful to many E-commerce corporations who want to improve their trust management or build an integrated trust evaluation system with remanufacturing. So we believe that the criterion Accuracy is satisfied. In the future, a fully distributed network assessment is considered where evaluated nodes are free from location constraints, and decision makers can complete the assessment independently in a stipulated period, so trust measurement can hire outside experts to review for increasing the objectivity and fairness of trust assessment.

Fang et al. [17] proposed a five-sense feedback oriented reputation mechanism for Virtual Marketplaces (VMs) by combining novel elements of 3D technology and virtual reality.

Specifically, a five-sense oriented feedback provision approach is used to provide buyers' feedback of products they have bought in the form of five human senses simulated by virtual reality. This satisfies the criterion Comprehension. A user study is done to compare the mechanism with traditional reputation mechanisms in VM environments. The questionnaire survey with a stratified sampling method mainly focuses on user's trust in the mechanism (institutional trust) and user's trust in other users (interpersonal trust) respectively based on the four perspectives of trust typology – benevolence, competence, integrity and predictability. The findings illustrate that: (a) users prefer shopping in VMs with the proposed reputation mechanism over that with traditional reputation mechanisms; (b) compared with traditional reputation mechanisms, the proposed reputation mechanism can not only effectively ensure user's trust in the mechanism, but also greatly promote user's trust in other users. This satisfies the criteria Accuracy and Usability. However, for the scenarios where buyers only provide subjective ratings, the authors applied the approach of Subjectivity Alignment for Reputation Computation (SARC), where ratings provided by one buyer can then be aligned (converted) for another buyer according to the two buyers' subjectivity. Evaluation results indicate that the SARC can more accurately model sellers' reputation than the state-of-the-art approaches. Besides, it can also be applied in traditional E-commerce environments to cope with the subjectivity difference problem, satisfying the criterion Generality partially.

Han and Jiang [18] proposed a Fuzzy Theory Based Trust Evaluation Model (FBTEM) for E-commerce to solve the uncertainty and subjectivity of E-commerce entities during the processing of trust evaluation. This model improves the algorithm of trust by considering the calculation of the entity initial trust, the credibility of the entity and the danger level of malicious behaviors. This satisfies the criterion Comprehension. The experiment shows that it can restrain malicious behaviors effectively and is more objective, satisfying the criterion Trustworthiness partially and the criterion Accuracy. But the various parameters and influencing factors also need specific analysis and the way to calculate trust need further improvement. So these problems will be improved in the future study.

In Table 1, we give a comparison of the reviewed literature. Y represents that a trust evaluation model can satisfy the property. N represents the model cannot satisfy the property. P represents that the trust evaluation model can satisfy the property partially. Blank represents the property was not mentioned or considered in the article.

Table 1: Comparison of versatility for trust evaluation in E-commerce

Work	T	Ad	Us	Pr	Ac	E	Un	C	G
[1]	P				Y		Y	Y	P
[2]								Y	P
[3]	P				Y		Y	Y	Y
[4]	P	Y			Y			Y	P
[5]					P	Y			
[6]	P				Y			P	P
[7]	P				Y	Y			Y
[8]								Y	Y
[9]	N	Y			Y				Y

[10]					Y			Y	Y
[11]		Y			Y			Y	
[12]	P				Y		Y	Y	P
[13]		Y	Y		Y	Y			P
[14]	P		Y		Y				
[15]								Y	
[16]	P				Y		Y	Y	P
[17]			Y		Y			Y	P
[18]	P				Y			Y	

4. OPEN RESEARCH ISSUES AND FUTURE RESEARCH TRENDS

4.1 Open Issues and Challenges

According to the above analysis, we find a number of open issues in trust evaluation in E-commerce.

First, we can conclude that only half of the reviewed articles [1, 3, 4, 6, 7, 12, 14, 16, 18] discussed the robustness of trust evaluation to overcome potential attacks. They only mentioned that they could resist some potential attacks and detect some malicious behaviors, but none of them can resist all existing attacks and all kinds of malicious behaviors.

Second, privacy was seldom considered in reviewed papers. User privacy consisting of personal information and user data should be flexibly protected when user data are collected for trust evaluation according to the policy and expectation of E-commerce users. Trust evaluation in E-commerce should allow the participants to preserve their privacy to the maximum extent. But all reviewed papers did not mention it.

Third, usability was ignored except [13, 14, 17]. Most reviewed papers did not mention the property of usability. Trust evaluation should consider trustor's subjective opinion and must be usable with regard to user-device interaction. E-commerce mainly provides intelligent services by interacting with human beings. Users should drive the design of trust solutions if they are related to the E-commerce participants due to the subjective characteristic of trust.

Fourth, adaptability is seldom discussed except [4, 9, 11, 13]. E-commerce has the feature of mobility and complexity. But most trust evaluation models in the literature are fixed and can't support context-awareness. Since E-commerce has different mission contexts and requirements in terms of trust level and performance, the proposed trust models should evaluate trust adaptive to these changes.

Fifth, no solution is holistic by satisfying all criteria. As illustrated in Table 1, many models were proposed for trust evaluation, but none of them can satisfy all criteria.

4.2 Future Research Trends

All above open issues motivate future research. We further suggest a number of promising research directions about trust evaluation in E-commerce based on the literature review as follows.

A. Potential attacks and malicious behaviors should be identified. The trust evaluation should be robust to overcome various potential attacks when the participants are trading with each other in E-commerce. Also the trust evaluation should have

the ability to identify the type of attack or malicious behavior, because it is useful to optimize the model.

B. Privacy preservation should be enhanced. User privacy should be well preserved in E-commerce. Nowadays, users pay more attention to their personal privacy especially when they communicate in E-commerce, because the other side of the communication is probably a stranger in many E-commerce application scenarios. Therefore, designing effective personalized and privacy protection schemes for trust evaluation in E-commerce becomes particularly important.

C. Usability of trust evaluation should be improved in E-commerce. E-commerce mainly provides intelligent services by interacting with human beings. When buyers want to buy products on the website based on trust evaluation, the usability of the trust evaluation or management system has a major impact on user decision making on seller selection and purchase.

D. Context-awareness should be concerned in trust evaluation with adaptability. Trust evaluation should be context-aware since trust relationship is dynamic and E-commerce has the feature of mobility and complexity, which cause frequency changes of trust. So, trust evaluation mechanisms in E-commerce should sense the mission contexts and requirements in order to act accordingly. Depending on the required levels of security, performance and/or reliability, a different kind of evaluation formula or a different level of trust can be adopted to fit into a specific mission context and situation.

E. A holistic trust evaluation model is expected. A trust evaluation model should perfectly achieve all criteria or most of them. It should be trustworthy to detect and identify potential attacks. It can preserve user privacy when user data are collected for the purpose of trust evaluation according to the policy and expectation of E-commerce users. It should be a uniform model to consider participants subjective voting with trusted credibility for trust evaluation, and should be economic to support all E-commerce application scenarios. Can we design such a model, which is still an open issue for future investigation?

5. CONCLUSIONS

In this paper, we introduced the basic knowledge of trust in E-commerce and proposed criteria to analyze the performance of trust evaluation models. We review the state of the art of trust evaluation to show how it has been applied to build security and trust in E-commerce. Analysis on the performance of the existing work was conducted based on the proposed uniform criteria in order to find open issues, point out research challenges and suggest future research trends.

Trust evaluation in E-commerce will remain challenging because none of existing work can satisfy all criteria and there are still a number of open issues. This motivates future research on a holistic privacy preserving trust evaluation with robustness, adaptability and usability. This could be the biggest challenge in this research field.

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