

# Human Intervention on Trust Decisions for Inter-Enterprise Collaborations

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**Abstract**—Trust is an important factor in the success of inter-enterprise collaborations. Trust decisions are made based on whether the incentives to participate in a collaboration outweigh the risks involved. Supporting these decisions is a central activity in inter-enterprise trust management. In this paper, we review factors affecting human trust decision making in online environments and apply them to the domain of inter-enterprise collaborations. To validate their applicability, we evaluate how the Pilarcos collaboration management toolset, and particularly its trust management system, can be mapped to them.

**Index Terms**—inter-enterprise collaborations, trust decisions, trust development, Pilarcos trust management system

## I. INTRODUCTION

Inter-enterprise collaborations are the drivers of the European economy, as the majority of the economy is constituted of small and medium-sized enterprises [1], [2]. Due to limited resources such as money, manpower, hardware and software, they need to collaborate with other enterprises in order to expand their business and attain a competitive edge in fields dominated by large enterprises [3], [4].

Inter-enterprise collaborations are defined as networks of autonomous enterprises providing a composed service to the end-users. The success of the inter-enterprise collaborations relies on their efficient establishment in dynamically evolving open service ecosystems, which support opportunistic selection of collaboration partners beyond the enterprises' slowly evolving strategic networks. The open nature of these ecosystems, combined with the autonomy of the enterprises involved, makes trust management a challenge.

Trust decision making is a core activity in the trust management process in the domain of inter-enterprise collaborations. Trust decisions are made during the establishment and the continuation of the inter-enterprise collaborations. They measure the subjective willingness of the enterprise to participate in the collaboration, given the risks and incentives involved [4]. The goal of automated support for these trust decisions is to help protect enterprise assets, which are endangered by uncertain and risky situations. Therefore, trust decisions play a crucial role in the establishment and operation of inter-enterprise collaborations.

The establishment of inter-enterprise collaborations should be efficient in terms of cost and time. For this purpose, routine decisions are automated. Human intervention is still needed, however, whenever the available supporting information is

insufficient or the risks and stakes are too high for the decision to be trusted to the automated system. Due to this, it becomes necessary to study human preferences for trust decision making in risky and uncertain situations.

The overall objective of the research is to resolve how to support human interventions for semi-automated trust decision making in the domain of inter-enterprise collaborations. To support this goal, the main research question of this paper is how human preferences regarding trust decision making in the research literature, focusing on the business-to-consumer (B2C) setting, can be applied to the field of inter-enterprise collaboration. We address this research question by (i) studying human preferences in context of the process of trust decision making with previously unknown or little known enterprises, and (ii) validating the applicability of the identified factors by comparing them against the Pilarcos collaboration management framework, particularly its trust management system.

Studying human preferences to trust decision making in the domain of inter-enterprise collaborations serves three purposes. First, it helps in understanding the phenomenon of human trust decision making in the domain of inter-enterprise collaborations. Second, understanding human preferences will contribute to the development of future automated or semi-automated trust management systems that can satisfy human needs, which in turn leads to better usability and helps users entrust their routine decision making to these tools. Lastly, it provides a basis for evaluating existing trust management systems for further improvements. Some of these purposes tie into future work, which we will return to later in this paper.

The rest of the paper is organized as follows. Section II discusses human preferences on trust decision making applicable in the domain of inter-enterprise collaborations. Section III presents the Pilarcos middleware tools and trust management system, and maps the concepts from the previous section to Pilarcos in order to evaluate their applicability. Section IV presents the conclusions and future work.

## II. HUMAN PREFERENCES FOR TRUST DECISION MAKING

This section presents the human preferences for trust decision making in terms of: (A) approaches to human trust development and (B) qualitative and quantitative criteria affecting trust decision making. The approaches to trust development

are correlated with different criteria for trust decision making. This is because movement between different stages and cycles of trust development requires trust decision making which is, in turn, dependent on different criteria.

So far, few studies address the problem of human intervention regarding trust decision making, particularly with previously unknown or little known enterprises in the domain of inter-enterprise collaborations. On the other hand, human trust decision making in risky situations has been researched in the domain of B2C e-commerce. Considering the findings in existing literature and the involvement of human users in the problem under consideration, we believe that findings from the literature in the domain of B2C can be mapped to the field of inter-enterprise collaborations with some adaptation.

#### *A. Approaches to Human Trust Development*

Two approaches to human trust development can be identified in the existing literature: the cyclic and the staged approach [5].

The **cyclic trust development approach** is based on the satisfaction of prior expectations about behavioral outcomes. The satisfaction gained builds the confidence of the trustor, whereas continuous dissatisfaction at any stage lowers the existing trust level.

Fung et al. [6] introduce a cyclic approach to trust development in the domain of B2C e-commerce. Their model of cyclic approach lists information quality, interface design and reputation as factors contributing to initial trust formation. On the other hand, Deelman et al. [7] have proposed an elaborated model, also representing the cyclic approach to trust development, based on the model of Fung et al. The model of Deelman et al. addresses trust development in the domain of inter-enterprise e-commerce through factors such as willingness to trust, estimation of the trustworthiness of the trustee enterprise, evaluation of past experiences, situation and risk inherent in the current situation.

Both Deelman et al. and Fung et al. mainly focus on the cyclic nature of trust development. Deelman et al. [7] have modified the list of factors affecting initial trust development from the factors given by Fung et al. [6] based on the domain of their research. However, the list of factors given by both the models is insufficient in context with the domain of inter-enterprise collaborations. There are other factors, such as contracts, shared beliefs, legal terms and conditions, playing a significant role in the trust development during initial stages. Furthermore, the models also do not clearly state the criteria behind distrust or dropping out of further transactions. Both models are of the view that negative evaluations generate distrust and, through that, dropping out of the trust relationship. They do not clearly state, however, whether only one negative evaluation or continued negative evaluations results in dropping out. We believe that this is, in fact, determined by the effect the negative evaluations have on the enterprise. For example, if only one transaction creates huge losses for the enterprise, drop out will occur immediately. On the other hand, if the effect is trivial, then continuity and persistence of

the negative evaluations becomes the basis for dropping out. In addition, the model given by Deelman et al. states that the factor list is followed in the given fixed sequential order, but we do not agree as the following of the order depends on the subjective preference of human users.

The **staged trust development approach** works on the assumption that the development of online trust takes place in different stages. Shapiro et al. [8] and Ba et al. [9] have proposed three-staged trust development models. The three stages given by the model of Shapiro et al. are deterrence-based, knowledge-based and identification-based. In turn, Ba et al. have given calculus-based, information-based and transference-based stages to trust development. Both these models have weak points, when considered against inter-enterprise collaboration. First, they do not show the effect of opportunistic behavior or deviations on the trust levels at any stage. Second, they assume a limited view of the collaboration, as they are of the viewpoint that knowledge/information-based trust becomes dominant during the second stage, after a series of direct interactions. We believe that it can also be used during the first stage, based on the information gained from the reputation networks in addition to calculus-based trust. Furthermore, the model of Shapiro et al. considers deterrence-based trust as the first stage, whereas we assume that calculus-based trust, which employs weighing of potential gains versus risks, to be the more influential in the case of trust development with the previously unknown, little known and even known enterprises.

In addition to the two models above, Kim et al. [10] and McKnight et al. [11] have both proposed two-staged models of trust development. The different stages in their models are the initial or exploratory, and commitment stage. The model proposed by Kim et al. does not clearly state the criteria behind a shift from initial trust to the robust trust of the commitment stage, or departure. For example, in the case of inter-enterprise collaborations, the occurrence of significant deviations from the accepted terms and conditions have been identified as criteria behind departure from the collaboration [3], [12]. The model also does not provide a precise list of factors affecting trust formation during the initial and committed stage. In contrast, the model proposed by McKnight et al. does not address the notion of departure from the trust relationship at any stage. This is unrealistic, as the priorities of the enterprises can change at any time.

#### *B. Criteria for Trust Decision Making*

The criteria for trust decision making are defined as different qualitative and quantitative characteristics or standards required for decision making in an uncertain and risky situation [13], [14], [5]. In the domain of inter-enterprise collaborations, different criteria for trust decision making are specific to the trustor, trustee, context and/or collaboration being considered.

**Trustor criteria**, such as propensity to trust, emotions and culture, have direct impact on the trust decision making. **Propensity to trust** is the human behavioral trait referring

to the trustor's general expectations or attitude about trusting humanity. It reflects their willingness to extend trust to any trustee, purely based on their inherent willingness to trust others and independent of any information about a trustee's characteristics [14]. **Emotions** are defined as the cognitive approach to trust decision making which are also independent of the trustee or the situation [15], [16]. They dominate trust decision making by facilitating the formulation of perceptions about the available information and the situation at hand. **Culture** is defined as a personality trait of the trustor, influencing their attitude in perceiving the available information for trust decision making [15].

**Trustee criteria** refer to reputation information on the trustee, affecting the process of trust decision making. Reputation information is defined as the knowledge about the past and present behavior of the trustee, aiding the assessment of their trustworthiness [3], [13], [17]. It also provides a basis for trying to predict the future behavior of the trustee. Trustworthiness is defined in terms of three high-level classes: ability, benevolence and integrity [14]. With previously unknown enterprises, third-party reputation networks are the main source of reputation information during the initial stages of trust development. On the other hand, information gained from past direct experiences of the trustor with the target enterprises act as the main source of reputation information during the committed stage.

**Contextual criteria** represent information that changes depending on the current situation. It comprises three aspects: system trust, a user interface to aid decision making, and external environmental factors. McKnight et al. [18] introduce structural assurances and situational normality as components of **system trust**, and Pavlou [19] has later added facilitating factors to the list. **Structural assurances** refer to the impersonal structures which help in generating trustworthiness when dealing with uncertain situations [18], [5], such as guarantees, safety nets, legal contracts and regulations. **Situational normality** refers to the trustor's belief or assumption that the situation at hand is safe and positive for gaining the desired benefits [18], [5]. **Facilitating factors** [19] are defined as non-governing factors referring to the perception about the trustee's integrity or adherence to the general and unanimously established rules and commitments regarding the collaboration, such as shared standards, goals and beliefs between the collaborators. The **user interface** of the trust management system is responsible for presenting the information required for trust decision making regarding inter-enterprise collaboration in a clear and efficient manner. **External environmental factors** refer to the contextual factors constituting social, economic and technological issues affected by the current conditions, such as a recession.

**Collaboration-specific criteria** refers to the collaboration objectives and perspectives affecting trust decision making [17]. The **objectives** are defined as the pre-set goals of the inter-enterprise collaboration and its participating enterprises. On the other hand, the **perspectives** which are based on the objectives represents the viewpoint of the trustor towards

trust formation [17]. We identify seven different types of perspectives: organizational, economical, social, technological, behavioral, psychological and the service perspective [17], [3], [12]. The organizational perspective refers to characteristics of the enterprise, such as setup and size, whereas the competencies and abilities of the enterprise fall under the technological perspective [17], [3]. The economical perspective reflects the financial condition of the enterprise, in addition to the possibilities of monetary risks and incentives involved in the inter-enterprise collaboration [17], [3]. The social perspective represents the association of the enterprise with its external environment in general, such as the activities and contributions of the enterprises in the social context or through the consideration of contracts, monitoring and security mechanisms [17], [12]. The behavioral perspective points to the past or present behavior of the enterprise in context to inter-enterprise collaborations [3], [17], [12], whereas the psychological perspective represents the intentions of the enterprises willing to collaborate [12]. Finally, the service perspective considers the details of the service offers made by the enterprises for collaborating with other enterprises [3], [12].

### III. TRUST MANAGEMENT IN PILARCOS

This section compares the concepts we have discovered in existing literature against the existing Pilarcos trust management system, with the goal of validating their applicability to inter-enterprise collaborations. Our ongoing research on resolving the problem of human intervention in the domain of inter-enterprise collaborations is ultimately tested through implementation of the concepts in the Pilarcos middleware. Firstly, Pilarcos and its trust management system are briefly presented in Section III.A before going into details in Section III.B. The main findings from the evaluation are discussed in Section III.C.

#### A. Pilarcos Middleware and Trust Management System

The Pilarcos middleware facilitates the establishment and operation of inter-enterprise collaboration in open and distributed environments. It provides support for automated collaboration management and ecosystem evolution processes by providing solutions to interoperability and trust management problems [3], [20]. Pilarcos defines inter-enterprise collaborations as a "*loosely-coupled, dynamic constellation of business services*" [3]. The collaborations are formed based on Business Network Models (BNM). A BNM defines the structure of the virtual enterprise in terms of the roles and interactions between them, in addition to the policies based on the legal and regulatory systems of the business domain under consideration [21]. A BNM repository in the Pilarcos middleware contains templates for the different kinds of collaborations available. Considering the scope of the paper, our focus is on the Pilarcos trust management system specifically.

In Pilarcos, trust is defined as "*the extent to which one party is willing to participate in a given action with a given partner in a given situation, considering the risks and incentives involved*" [4]. The system performs automated local

and context-aware trust decisions. The Pilarcos middleware requires trust decisions at two kinds of points: joining and continuing the collaboration, when additional resources must be committed. The trust decisions are made by producing risk estimations and comparing them to risk tolerance [3], [4]. The risk estimates are based on reputation information, whereas risk tolerance is based on the strategic importance of the collaboration to the business of the enterprise [3], [4].

The Pilarcos trust management system makes automated trust decisions according to pre-defined local policies. In addition, mutually decided shared policies are negotiated at each collaboration establishment by all the collaborating enterprises, and are encoded in contracts; these policies influence the local policy setup as well. The automated trust decisions are performed in the routine cases leading to clear acceptance or rejection. On the other hand, human users are prompted for trust decision making during cases that fall under the gray area between routine accept or reject. In these cases, a trust decision expert tool handles the required human intervention [22].

### B. Comparison of Human Preferences Against Pilarcos

The correlation between the human preferences found in the existing literature and the process of trust decision making followed by the Pilarcos trust management system helps in validating their applicability of the findings in the domain of inter-enterprise collaboration. Table I presents the summarization of the evaluation of Pilarcos and its trust management system against the human preferences specified in Section II.

1) *Approach to Trust Development*: The working of the Pilarcos trust management system contains the elements of both the cyclic and the staged approach to trust formation [3], [4]. As previously mentioned, the Pilarcos trust management system triggers trust decisions both during the establishment and operation of the collaboration. For an unknown or little known collaborator, the first trust decision point is equivalent to the initial stage of trust formation marked by either no or low trust. On the other hand, the following trust decision points are equivalent to the committed stage, where decisions are made based on the experience gained by direct interaction with the collaborating enterprises. This continuation point comes whenever more resources need to be committed or significant reputation changes occur during the collaboration.

The Pilarcos middleware tracks the operation of the inter-enterprise collaboration using monitors local to each enterprise. Whenever a service detects significant deviations in terms of misbehavior and failure to comply with contractual commitments, it notifies the other participating enterprises, and joint recovery actions can be taken. If needed, the parties responsible are replaced by new partners in the inter-enterprise collaboration. The first-hand experiences gained during the collaboration constitute local reputation information. The local reputation information is fed to a reputation system during the termination phase for the short-term collaborations [4]. In the case of long-term collaborations, the local information is fed at the pre-decided checkpoints during the operational phase. This local information together with external reputation

Comparison Criteria		Pilarcos	
Approach to Trust Development		Combined (Cyclic + Staged)	
Human Trust Decision Criteria	Trustor Criteria	Propensity to Trust	Policies and contracts
		Emotions	Trust decision expert tool
		Culture	Business Network Model defining structure of the collaboration
	Trustee Criteria	Reputation	Experiences gained from earlier collaborations, first hand information from monitors and shared through reputation networks. The experiences are represented as the effects of actions on assets: monetary, reputation, satisfaction and control.
	Contextual Criteria	System Trust	Contract, possibility of contract negotiation, existence of interoperability measures, and monitoring
		User Interface	User interface of expert tool
		External Environmental Factors	Context repository
	Collaboration specific Criteria	Perspectives	Services, Economical, Technological, Behavioral.
		Objectives	Shared and Enterprise specific objective

TABLE I  
EVALUATION OF HUMAN PREFERENCES AGAINST PILARCOS.

information is used in risk evaluations for future establishment and operation of inter-enterprise collaborations.

The repeated use of the information representing different criteria for trust decision making during the collaboration makes the Pilarcos trust management system cyclic in nature. On the other hand, the two kinds of decision points representing the two different stages of trust formation makes the Pilarcos trust management system staged in nature at the same time. Therefore, we conclude that Pilarcos trust follows a combined approach to trust development.

2) *Criteria for Trust Decision Making*: The criteria supported by the Pilarcos middleware and its trust management system are discussed below. As presented in Section II, they are divided into four groups: trustor, trustee, contextual and collaboration-specific criteria. The **trustor criteria** include propensity to trust, emotions and culture.

**Propensity to trust**: The local policies and the contracts established mutually by all the collaborating enterprises during the negotiation phase represent propensity to trust in Pilarcos. The contract is not just data; it is defined as an active and distributed agent containing meta-information constituting all the rules and regulations responsible for dynamically governing the established inter-enterprise collaborations [23].

**Emotions**: Emotions come into play in the Pilarcos trust management system through the trust decision expert tool that handles human interventions in trust decisions. The user interface of the trust decision expert tool affects the emotions of the human users during trust decision making. Therefore, emotions play an important role in the establishment and operation of the inter-enterprise collaborations through human

intervention.

**Culture:** For Pilarcos, the choice of BNM for the collaboration represents its culture, for the purposes of trust decision making. As noted before, the BNM contains information about the processes, roles, interaction between roles and governing acceptable behavioral policies. The information contained in the BNM also dominates the process of automated search and selection of potential partners for the collaboration.

The **trustee criteria** consists of reputation information.

**Reputation information:** Pilarcos uses reputation information for calculating risk estimations [3], [4]. The main sources of reputation information are experiences gained from earlier collaborations and those shared through third-party reputation networks. Local monitors are responsible for gathering first-hand experiences during the collaboration. In addition, external reputation information shared through reputation networks is used particularly when local experiences are not readily available. Both the local and external reputation information is transformed to a uniform format of the number of experiences, each representing major negative, minor negative, no change, minor positive or major positive effects to four different assets: monetary, reputation, satisfaction and control [3].

The **contextual criteria** include system trust, user interface and external environmental factors.

**System trust:** The existence of legally binding contracts regulating the collaborations act as a structural assurance. The perception of situational normality is supported in multiple ways: The Pilarcos middleware provides the possibility of contract negotiation iteratively until all the collaborating enterprises are satisfied with the contents of the contract [20]. Furthermore, the existence of automated interoperability assurance between the collaborating enterprises also affects trust decision making positively [3]. The interoperability checking is performed during the selection of potential partners for the collaboration. In addition, monitoring of the collaboration to detect deviations and misbehavior also acts as a factor for observing situational normality [21]. The shared objective of the collaboration, in addition to shared technical and semantic communication standards, act as facilitating factors.

**User interface:** The Pilarcos trust decision expert tool handles human intervention for trust decisions [22]. The user interface of the expert tool provides the user with required information about risk, reputation, collaboration progress and context. It is designed based on the usability principles provided by Nielsen for designing user interfaces [24] and supported by a number of different cognitive strategies of user interface: cognitive fit theory, cognitive learning theory, unified theory of acceptance and use of technology and technology acceptance model [25], [26].

**External environmental factors:** The Pilarcos trust management system explicitly models context as one of the parameters influencing automated trust decision making. Context information comes from three sources: internal state of the system of the enterprise, state of business of the enterprise, and state of the business network the enterprise is involved in [3]. All these sources of information are affected by external

environmental factors. A recession might affect the internal financial condition of the enterprise, for example, which would in turn affect the decision of the enterprise to enter into the collaboration. Therefore, contextual information provided by Pilarcos is related to the external environmental factors affecting the process of trust decision making.

**Collaboration-specific criteria** include objectives and perspectives.

**Objectives:** There are two types of objectives to consider: the shared objective of the inter-enterprise collaboration and the individual objectives of the enterprises involved. The collaboration objective is shared between the collaborating enterprises, whereas the individual goals of the enterprises can differ. Both types of objectives are present in Pilarcos. Collaboration objectives, such as monetary gains, reputation and customer satisfaction, are considered during the population process, where the selected service offers can be required to satisfy a set of criteria on e.g. their pricing [21]. On the other hand, the objectives of the enterprises come to play during the negotiation phase and contract establishment through risk tolerance policies, which can e.g. require that the probability of minor or major reputation gain is sufficiently high [4].

**Perspectives:** Pilarcos considers the service, economical, technological and behavioral perspectives of trust formation. The comparison of the service offer details against the requirements of the roles of the business process while selecting the potential partners for inter-enterprise collaboration provide a service perspective [20], [21]. Weighing potential benefits against possible losses and risks in trust decisions reflects the economical perspective. Interoperability checking of technical and connectivity issues ensuring reception and delivery of the messages among participating enterprises relates to the technical perspective. Use of reputation information, i.e. information about the past behavior of the enterprises, ties to the behavioral perspective on trust formation.

### C. Discussion

The comparison of the criteria affecting human trust decision making against the Pilarcos system demonstrates that the concepts drawn from the domain of B2C e-commerce are applicable in the domain of inter-enterprise collaborations as well, after some necessary adjustments. While the objectives and perspectives of the collaboration have a strong influence on trust decisions in inter-enterprise collaborations, for example, they have had very little emphasis in the B2C literature, as it focuses on reasonably simple interactions between the consumer and the enterprise.

Once these adjustments have been made, the resulting criteria can be used to describe trust management in Pilarcos, i.e. the criteria used in Pilarcos map into the human decision making concepts. Further, the identified concepts all have a match in Pilarcos; in other words, Pilarcos supports the different criteria found in this work, which provides a good basis for satisfying the needs and expectations of human users.

#### IV. CONCLUSION AND FUTURE WORK

Trust is the prominent factor aiding the existence, feasibility and success of the inter-enterprise collaborations. The existence of trust mitigates the feeling of uncertainty and fear inherent in relying on other autonomous partners, and relaxes the need for constrictive risk mitigation methods to support the collaboration. Trust decisions measure this willingness to accept the risks involved. While routine trust decisions can be automated for efficiency, human intervention must be supported in non-routine situations. For this purpose, we have analyzed the existing literature on human trust decision making in the online environment, and applied the concepts to inter-enterprise collaborations.

Understanding the human process of trust decision making, in terms of different elements and criteria of trust decision making and the trust development process, helps resolve the overarching research question of how to support human intervention in trust decisions for inter-enterprise collaborations. In this paper, we have found that existing research on human trust decisions in the B2C domain can be applied to the domain of inter-enterprise collaborations, with some adjustments. The applicability of the identified decision criteria has been evaluated against the existing Pilarcos middleware and trust management system, demonstrating that the inter-enterprise collaboration management middleware can be described through these concepts, and that it also addresses all the identified criteria.

As a next step, we plan to populate the decision criteria and trust development model presented in this paper with different existing trust management systems within the domain of inter-enterprise collaborations in order to provide a comparative analysis of the trust management processes in related work. The study also provides input for our continued work on developing user-friendly interfaces for inter-enterprise collaboration management, which forms a second branch of our work on supporting human intervention in trust decisions for inter-enterprise collaborations; we have completed the user interface for simple trust decisions, and plan to continue the work through implementing a more flexible expert tool that allows the reconfiguration of collaborations and simulating the effects of policy changes as well.

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