Aalto University
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Degree Programme of Computer Science and Engineering

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Supporting Users' Trust Decisions
on Inter-Enterprise Collaborations

Master's Thesis
Espoo, September 28, 2011

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ABSTRACT OF
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The thesis addresses the domain of inter-enterprise collaborations, which are particularly useful for small and medium-sized enterprises for attaining competitive edge in fields dominated by large enterprises.

Trust decision making regarding joining and continuing the collaboration is an important element of trust management. Inter-enterprise collaborations have trust management systems performing automated trust decision making. However, automated trust decision making is possible only in routine cases while human intervention is required for other cases. Human intervention for trust decision making is an open research question in the domain of inter-enterprise collaborations.

To resolve the problem of human intervention in context to inter-enterprise collaborations, literature on trust, trust decision making and development and human behavioral strategies is explored. Based on the literature review, a trust relationship development model is proposed. To evaluate the validity of the proposed model, the thesis applies it to compare three existing trust management systems: TrustCoM, ECOLEAD and Pilarcos.

The thesis fcuses on supporting human intervention in the existing Pilarcos trust management system. The proposed trust relationship development model, Nielsen's guidelines and cognitive theories for designing user interfaces are used for designing and implementing a trust decision expert tool. The trust decision expert tool is evaluated on four dimensions: information sufficiency, usability, user performance and quality.

The master thesis contributes to the existing knowledge by providing guidelines for designing and implementing trust decision expert tools handling human intervention in the domain of inter-enterprise collaborations. The proposed trust decision expert tool provides a basis for developing similar expert tool for other trust management systems.

Keywords: Cognitive strategies, human behavior, inter-enterprise collaboration, trust, trust decision making, trust management systems, user interface

Language: English

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Puneet Kaur

Abbreviations and Acronyms

BDT	Behavioral Decision Theory
BNM	Business Network Model
BP	Business Process
BPM	Business Process Model
BPMN	Business Process Model and Notation
B2C	Business to Consumer
B2B	Business to Business
CFT	Cognitive Fit Theory
CLT	Cognitive Load Theory
CINCO	Collaborative and Inter-operatable Computing
ELS	Elaboration Likelihood Model
ECT	Expectation Conformation Theory
EN	Enterprise Network
GVOA	General Virtual Organization Agreement
GWT	Google Web Toolkit
HCI	Human Computer Interaction
SLA	Service Level Agreements
SOA	Service Oriented architecture
SET	Social Expectancy Theory
NMA	Network Management Agent
TAM	Technology Acceptance Model
TPB	Theory of Planned Behavior
TRA	Theory of Reasoned Action
TuBE	Trust based on Evidence
UTAUT	Unified Theory of Acceptance and Use of Technology
VBE	Virtual Breeding Environment
VO	Virtual Organization

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Chapter 1

Introduction

This thesis work is carried in collaboration with the Collaborative and Interoperatable Computing (CINCO) group at University of Helsinki and Department of Computer Science and Engineering at Aalto School of Science. The work is primarily assisted and supported by the Trust based on Evidence (TuBE) project at CINCO, University of Helsinki.

1.1 Research Motivation

Inter-enterprise collaboration is a popular term that has been studied widely in the last few years [2]. Inter-enterprise collaboration is defined as the network of autonomous enterprises, providing a composed service to the end-users. Enterprises enter into collaborations with each other in order to gain mutual benefits with reduced overhead in them in terms of cost, resources and complexity. Inter-enterprise collaborations enable delivery of better services to end users with reduced cost and production cycle duration.

Inter-enterprise collaborations especially benefits small and medium-sized enterprises. The concept of inter-enterprise collaborations is one of the essential drivers for the growth of European economy. The European economy consists of more than 98 percent of the small and medium sized enterprises [17, 43]. The small and medium sized enterprises, competent in their area of expertise, have limited resources for establishing themselves in domains dominated by large enterprises. Hence, it is beneficial for them to collaborate with other enterprises to attain competitive edge in the domains out of their individual scope. Inter-enterprise collaborations provide opportunity to small and medium sized enterprises to flourish beyond their individual reach by focusing on their own area of expertise. Inter-enterprise collaborations, using Internet as a channel, are growing segments of the e-commerce [55].

Trust management is one of the important parameter for the establishment and functioning of inter-enterprise collaborations. 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"* [49]. To attain competitive edge in current business situation, enterprises are required to swiftly adopt and become members of multiple open business networks simultaneously supporting their own business strategies [39, 48]. However, the requirement to associate and interact with previously unknown and little known enterprises creates risk and high level of uncertainty. The structure involving the inter-dependence among autonomous enterprises, together with risks posed by interaction with previously unknown enterprise generates the need for trust. The existence of trust among collaborating enterprises provides stability and functionality to inter-enterprise collaborations. Therefore, managing trust is important for inter-enterprise collaborations. But, trust management aiming autonomous enterprises is challenging.

The Pilarcos trust management system performs automated trust management. The use of an automated system helps in attaining efficiency and desired degree of flexibility in establishing inter-enterprise collaborations. The Pilarcos middleware helps in establishment of open service inter-enterprise collaborations by automating various activities involved in the process such as partner discovery and selection, interoperability management, contracting and decision making [25]. The Pilarcos trust management system provides a facility for making fast, contextual and dynamic automated trust decisions based on past actions and behavior [48, 49]. It automatically accepts or rejects the decisions of participating in inter-enterprise collaborations. But, it requires human intervention for decision making in case of uncertain situations. The problem of how humans will interact with the system for making confident trust decisions is such a situation in an open issue in an otherwise automated Pilarcos trust management system.

Inter-enterprise collaborations use automation for attaining efficiency in the establishment and operation of inter-enterprise collaborations. However, automation is applicable only for the routine cases. It is not applicable for unexpected situations. Hence, human intervention is required for handling unexpected situations. There are possibilities of occurrence of unexpected situations in the case of inter-enterprise collaborations, operating in open and distributed environment. Therefore, understanding and solving the problem of human intervention for trust decision making in the domain of inter-enterprise collaborations is important.

1.2 Problem Statement

The Pilarcos trust management system makes private and contextual automated trust decisions throughout the life-cycle of the collaboration. The trust decisions are made at two points during the collaboration life-cycle - joining and continuing the collaboration. The Pilarcos trust management system makes trust decisions comparing risk estimation against risk tolerance. The risk estimates are based on reputation, whereas risk tolerance estimation is based on the strategic importance of the collaboration to the business of the enterprise. Based on the results of risk estimation and risk tolerance comparison, two different types of decisions are possible - namely automated trust decision and manual trust decision.

The Pilarcos trust management system performs automated trust decision making according to the pre-defined policies during the establishment of the inter-enterprise collaborations. The pre-defined policies; decided locally by all the collaborating enterprises; define three different ranges for automatic acceptance, rejection and human intervention. For example, all the enterprises may decide to following the division between automatic accept, reject and manual trust decision making. All the collaborating enterprises may locally decide the ranges for automatic acceptance, rejection and manual trust decision making.

Automated trust decisions are made in the cases resulting in either clear acceptance or clear rejection. The cases satisfying the ranges for clear acceptance and rejection are referred to as routine cases. On the other hand, the cases that do not satisfy either of automated acceptance and rejection criteria require human intervention for trust decision making. These cases can be referred to as special cases. Handling special cases is an open issues in an otherwise automated system. The thesis topic focuses on these special cases. The main research question of the thesis is:

"How will human users interact with the system when trust decision power is assigned to them?"

The research question will be addressed from different aspects - such as human trust decision making, human users' needs for the information required for trust decision making, presentation of the information required for trust decision making and enhancing the experience of the user by reducing the number of needed human interventions. The research question will be addressed from various aspects through the course of the thesis. The main objective of the research is to solve the problem of interaction between

the human user and the Pilarcos trust management system for the special cases in a quick, easy and efficient manner.

1.3 Thesis Scope

The thesis will scope itself around the human intervention aspects in Pilarcos Trust Management System. The main research question will be addressed from different aspects, such as:

- *human trust decision making in an online environment*;
- *information needs of the users for making trust decisions*;
- *appropriate way of presenting the information to the users*;
- *reducing the frequency of requests for human interventions.*

All these aspects contribute to designing a solution for dealing with the open issue in the existing Pilarcos trust management system. The thesis proposes a *Trust Decision Expert Tool* for enabling interaction between human user and the Pilarcos trust management system for dealing with special cases. In addition to designing the trust decision expert tool, the thesis also presents a cognitive model of human decision making and a trust relationship development model in the domain of inter-enterprise collaborations.

The outcomes of the master thesis will contribute to the existing research field of collaborative and interoperability computing by proposing solutions for handling the special cases where human intervention is required for trust decision making.

1.4 Research Approach and Methodology

The study presented in this thesis is both explorative and constructive in nature. The implementation and usability evaluation of the trust decision expert tool and creation of the cognitive model of human trust decision making represents the constructive approach behind this thesis. Furthermore, the comparison of three different trust management systems supporting inter-enterprise collaborations present constructive approach regarding the thesis. On the other hand, exploratory literature review on trust in B2C and strategies governing human behavior, tries to find the human decision making patterns in online environment, information needs of the users for making trust decisions, presenting information to users and reducing the frequency

of necessary human intervention in context with inter-enterprise collaborations.

In Chapter 2, the problem environment behind this thesis is discussed by reviewing the existing literature on the Pilarcos middleware and the Pilarcos trust management system. In Chapter 3, both intensive and extensive literature related to human preferences on trust decisions in context to inter-enterprise collaborations is studied using heuristics. This type of exhaustive review process is the starting point for the trust decision expert tool. Salo et al. [52] and Zhang et al. [64] is helpful during the starting phase due to similar research approach but focus is on Business to Consumer (B2C) trust decisions. However, I focused mainly on the trust decision making in context to inter-enterprise collaborations. In Chapter 4, comparison of existing trust management systems is presented by using heuristic analysis. The basis for this comparison were different resulting parameters from Chapter 3. The comparison results are presented as Table 4.1 and Table 4.2 (see Section 4.2).

Based on the literature review in Chapter 2, information needs of the proposed trust decision expert tool are extracted. From the domain of Human Computer Interaction (HCI) and usability principles in context to designing user interfaces are transformed to develop design goals for the trust decision expert tool. Based on the design goals and information needs, architecture and workflow of the trust decision expert tool is defined. At the end of the chapter, the trust decision expert tool is implemented and extends the existing Pilarcos trust management system (see Chapter 5). Furthermore, the usability evaluation of the trust decision expert tool is performed in order to judge the efficiency of the tool and further improve its design (see Chapter 6).

1.5 Contributions

The main contribution of the thesis is to solve an open issue of supporting human interventions in the Pilarcos trust management system. As noted already, routine trust decisions are automated by the Pilarcos trust management system, but human intervention is needed for special cases. The thesis introduces the trust decision expert tool and a cognitive model of human trust decision making in the field of inter-enterprise collaborations.

The thesis intends to provide a user friendly trust decision expert tool for enhancing the working of the existing Pilarcos trust management system. The trust decision expert tool provides assistance for trust decision making whenever human assistance is needed in the establishment and functioning of inter-enterprise collaborations. The trust decision expert tool enables inter-

action between the human user and the Pilarcos trust management system. The presented trust decision expert tool is evaluated on four dimensions: information sufficiency, usability, user performance and quality.

The trust decision expert tool can be seen as a remarkable enhancement of the existing Pilarcos trust management system. Furthermore, this contribution is novel as the need for having user interface to handle human queries is often discussed in the literature but has not been implemented in practice [37, 62]. In the course of doing so, I have analyzed existing systems supporting inter-enterprise collaborations such as Pilarcos, ECOLEAD and TrustCoM from the trust management perspective. The trust management analysis provides guidelines for the proposed tool.

As previously noted, the thesis studies and applies the existing literature on trust in business to consumer, traditional organizations in addition to human behavioral and cognitive strategies governing trust decision making to the domain of inter-enterprise collaborations. Based on the analysis of the existing literature, the thesis develops the human cognitive model of trust decision making and the trust relationship development model in the domain of inter-enterprise collaborations. The human cognitive model and the trust relationship development model is considered as a base for trust relationship development in designing trust decision expert tool for inter-enterprise collaborations. The user interface of trust decision expert tool is designed based on the presented models of human trust decision making.

I also performed the literature review of the existing systems supporting inter-enterprise collaborations - namely Pilarcos, TrustCoM and ECOLEAD. The thesis also presents the comparative analysis of the all these systems against the presented models of trust decision making in the domain of inter-enterprise collaborations.

1.6 Thesis Outline

Based on the discussed motivation, objectives and research questions, the structure of the thesis has been organized as follows:

Chapter 2 covers the problem environment for trust decision expert tool. It discusses in detail the working of the Pilarcos middleware and the Pilarcos trust management system. It also presents the concept of inter-enterprise collaborations. The need for trust and trust management in inter-enterprises collaboration is also discussed.

The empirical part of the thesis starts from Chapter 3. This chapter presents detailed analysis of trust in online environment. The strategies, elements and factors affecting human trust decision making and trust devel-

opment are described in detail. It presents the cognitive model of human trust decision making and the trust relationship development model in the domain of inter-enterprise collaborations.

Chapter 4 analyses the systems supporting inter-enterprise collaborations: TrustCoM, ECOLEAD and Pilarcos against the proposed trust relationship development model presented in Chapter 3. The comparative evaluation of different inter-enterprise collaboration systems aims at evaluating the findings of Chapter 3 and finding out the extent to which these systems satisfy human needs in their functioning.

Chapter 5 gives an overview of the design and implementation of the trust decision expert tool. It discusses the design goals, architecture, workflow, system design, components and implementation details of the trust decision expert tool.

Chapter 6 covers the evaluation of the trust decision expert tool. The evaluation is conducted on four dimensions: information sufficiency, usability, user performance and quality.

Chapter 7 discusses the relevance and importance of the contributions made by the thesis in context with the existing body of knowledge. The achieved results and outcomes are analyzed from various perspectives.

In Chapter 8, a summary of the thesis and conclusion is drawn based on the overall research. Furthermore, ideas for the future research are presented.

Chapter 2

Problem Environment

The emergence of networked business and trend of service oriented computing has created opportunities for the inter-enterprise collaborations [22]. This chapter presents the problem environment of the thesis. The idea behind inter-enterprise collaborations and problems of interoperability and trust management are discussed in Section 2.1. However, the main focus of the thesis is trust management so, interoperability is left out of the scope of the thesis. Furthermore, the components and the workflow of the Pilarcos middleware are presented in Section 2.2. Trust concepts and trust management aspects are discussed in Section 2.3. The Pilarcos trust management system making private and dynamic automated local trust decisions is elaborated in detail in Section 2.4. It discusses the working and structure of the Pilarcos trust management system. The chapter concludes by presenting summary in Section 2.5.

2.1 Inter-Enterprise Collaborations

Inter-enterprise collaborations are defined as a network of autonomous enterprises, providing a composed service to the end-users. For example, online travel agency which enables the users to book flight and hotel itinerary, car renting and other added services specific to the location. In this case, all the services are developed by online travel agency but, the services are provided by third parties such as: car rental, flight booking agency, hotels and credit card payment processing.

Inter-enterprise collaborations come into existence in six phases: infrastructure establishment, identification, formation, operational and evolution, termination and post-termination [6, 63]. The infrastructure established in the first phase is used for identifying the potential partners for the inter-

enterprise collaborations. The formation phase leads to the establishment of inter-enterprise collaboration, marking the beginning of the operational phase. The inter-enterprise collaborations evolve during the operational phase reacting to the changing circumstances. Finally, the collaboration ends in the termination phase. However, the final termination of the inter-enterprise collaborations occurs after all the final operations are completed in the post-termination phase. Enterprises collaborate with each other in order to gain mutual benefits. The inter-enterprise collaborations helps the enterprises to [6, 47]:

1. attain competitive edge in fields dominated by large enterprises;
2. expand their business;
3. have more influence than what they would have separately;
4. reduce production life-cycle.

The current trend and demand of collaborating with enterprises outside the existing strategic networks is especially beneficial for small and medium sized enterprises. Apart from gaining mutual benefits and reduced overheads, there are other expectations from the inter-enterprise collaborations as well. The additional requirements are maintaining the autonomous nature by the enterprises and freedom of making local trust decisions [50].

The concept of inter-enterprise collaborations is especially useful for small and medium sized enterprises. As already mentioned, the majority of the European economy is driven by small and medium sized enterprises [17, 43]. The small and medium sized enterprises have limited resources - such as money, hardware, software and human power. The enterprises want to focus on their own resources by entering into collaborations with other enterprises having similar strategic interests [22]. Therefore, in order to progress and gain outside their individual scope, they need to collaborate with other enterprises having similar strategic interests but different areas of expertise [17]. For attaining real benefits, enterprises need to move out of their existing strategic niches to more open and distributed environments [47, 48].

The desire to collaborate with other enterprises for gaining mutual benefits outside the existing networks in the open and distributed environment poses challenges. The open and distributed operational environment is one of the major reasons of concern. It supports collaboration with previously unknown, little known or known enterprises. Interaction and collaboration with previously unknown or little known enterprises poses interoperability and trust management challenges [48].

The usage of different information systems arises the challenge of interoperability. Interoperability [48] is defined as *"the capability to collaborate, means effective capability of mutual communication of information"*. There are three different types of interoperability: technical, semantic and pragmatic [48]. Technical interoperability deals with connectivity and technical issues ensuring reception and delivery of messages among participating enterprises. Semantic interoperability considers content, its representation and order of the messages for ensuring the uniformity in message perceiving. The concept of pragmatic interoperability includes willingness and capabilities of the enterprises to perform the action in addition to the needs and benefits of performing the action. Maintaining the autonomous nature of enterprises in context with local decision making and managing their enterprise policies is also a problem faced by inter-enterprise collaborations. Interoperability and autonomy are inter-related with each other as provision of autonomy should be compensated with some method ensuring interoperability at the same time [50].

Trust management is another major problem faced by inter-enterprise collaborations [47, 48]. It is made difficult due to involvement of diverse information systems together with the requirement of preserving the autonomous nature of the enterprises. Preserving mutual trust is important for the existence and feasibility of inter-enterprise collaborations [33]. The research conducted in the field of inter-enterprise collaborations focuses on solving these challenges.

There are different systems supporting the establishment and functioning of inter-enterprise collaborations: Pilarcos [48], ECOLEAD [33] and TrustCoM [43]. All these systems follow their individual approaches for supporting the inter-enterprise collaborations. Pilarcos follows an automated middleware approach for assisting inter-enterprise collaborations [23, 25, 55]. ECOLEAD uses plug and play and pay-per-use ICT infrastructure for the establishment and operation of inter-enterprise collaborations [43]. TrustCoM employs a conceptual and architectural framework for addressing trust, security and contractual aspects of inter-enterprise collaborations [63].

All these systems make trust decisions during the establishment and operation of the inter-enterprise collaborations. The collaborations needs to be established among previously unknown, little known or known enterprises. Therefore, trust decisions need to be made during the establishment of inter-enterprise collaborations. On the other hand, during the operation whenever more resources need to be committed or new enterprise needs to be added in the existing enterprise, again trust decision needs to be made. The cost and time parameters of inter-enterprise collaborations needs to be balanced with the benefits earned from them. These challenges are exaggerated by

the absence of trusted third parties guaranteeing the credibility of the involved partners. Automation of the trust management including trust decision making is used for ensuring for ensuring the efficiency of inter-enterprise collaborations. However, automation is possible only in routine cases and human intervention is required for unusual cases.

As noted before, trust management is the major challenge faced by the inter-enterprise collaboration. Considering the scope of the thesis, I am focusing on trust management specifically as compared to interoperability. The next section discusses trust and trust management in the domain of inter-enterprise collaborations.

2.2 Trust in Inter-Enterprise Collaborations

In the context of inter-enterprise collaborations, Ruohomaa et al. [49] have defined trust 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"*. Trust is one of major factor which needs to be addressed in the domain of inter-enterprise collaboration. The strength of trust among participating enterprises affects the overall efficiency and outcomes of the collaboration.

The need for trust is made more critical by the desired open and fully distributed environment for establishment of inter-enterprise collaborations. As mentioned previously, the open and distributed environment provides the opportunities of collaborating with different unknown or known enterprises outside individual well-weathered strategic networks of the enterprises [48]. Furthermore, trust refers to the motivation and willingness of the autonomous enterprises to cooperate with the other previously unknown or little known enterprises. As noted before, in inter-enterprise collaborations enterprises need to work in collaboration with each other in order to gain mutual benefits. The collaborating enterprises involve some degree of interdependence on each other. Trust is required to make inter-enterprise collaborations setup stable and functional [33]. This is made possible by mitigating the uncertainty and risk involved in situations lacking direct physical interaction and control over the other previously unknown or little known enterprises involved in the collaboration [57].

The need for trust is also generated by the structure of the inter-enterprise collaborations. The enterprises enter into collaboration with other potential enterprises leading to the formation of self-directed teams. To make the working of such inter-enterprise collaborations structure possible, dependence on other enterprises in terms of power and control is required. Giving control

and power in the hands of others makes the collaboration situation risky. In such a situation trust refers to acceptability and willingness to bond together despite the fact that the enterprises have no control over the given situation [63].

The importance of trust for the existence and operation of inter-enterprise collaborations creates the need for trust management systems. The trust building strategies can take over months or years for forming networks of strategic partners. The trust building and management strategies are quite slow and inefficient [49]. Moreover, diverse information systems and requirement of preserving the autonomous nature of enterprise, makes trust management a challenging task.

There are two approaches to trust management - namely static and dynamic trust management [46]. In static approach to trust management trust establishment is done only at the initial stage, for example while entering the collaboration. The same decision is continued throughout the collaboration despite changing circumstances. On the other hand, in dynamic approach to trust management, trust establishment is performed throughout the collaboration life-cycle at various points. For example, entering the collaboration and committing more resources during the operational phase. The dynamic approach for trust management is suitable for the open and distributed environment since there is always a fear and difficulty of predicting the opportunistic and disruptive behavior of the other participating enterprises.

Automated trust management systems might be required for the establishment and functioning of inter-enterprise collaboration. This is due to the reason that carrying out the estimation of the trustworthiness of the several enterprises in the inter-enterprise collaborations is difficult and time consuming to carry out manually. However, there are problems with automated approach to trust management as well since human assistance is needed for trust management in the case of new and unexpected situations.

In this thesis, the establishment, operation and trust management of inter-enterprise collaborations is studied from the point of view of Pilarcos. Furthermore, the proposed trust decision expert tool is an extension of the trust management system of the Pilarcos middleware. Therefore, I am first discussing the important characteristics and working of the Pilarcos middleware.

2.3 Pilarcos Middleware

The Pilarcos middleware attempts to provide solution to the interoperability and trust related problems arising in the establishment, operation, control and termination of inter-enterprise collaborations. Architecture of the Pilarcos middleware is based on Service Oriented architecture (SOA). The Pilarcos middleware leads to the creation of federated, interoperable and dynamic constellation of enterprises that are governed and managed by e-contracts [21, 23, 24]. The existence of autonomy of participating enterprises together with established interoperability is one of the main characteristics of the Pilarcos architecture middleware [50].

The Pilarcos middleware operates in an open service ecosystem where previously little known or unknown service providers, willing to participate in the collaboration, publish their services. It provides support for all the activities of collaboration life-cycle right from partner discovery and selection, interoperability management, e-contracting, reputation based trust decisions, constant local monitoring till the termination of the collaboration [25].

The infrastructure of the Pilarcos middleware uses five components for the establishment and working of the inter-enterprise collaboration. These five components are: information repositories, populator, network management agent, e-contract and monitor.

Information repositories [21] comprise of the base services which can be provided by third parties. Information repositories provide meta-information required for the establishment and operation of the collaboration (see Figure 2.1). It consists of three repositories: Business Network Model (BNM) repository, service type repository and service offer repository. The BNM repository holds the templates for the possible collaborations. The templates define the structure of a virtual enterprise by specifying various roles and the interaction among them in addition to the policies based on the legal and regulatory systems of the strategic business domain under consideration. Service type repository is the storage house of the set of properties defining syntactic structure of interfaces, semantics of the information that need to be exchanged during collaboration and service behavior. Service offer repository holds all the offers published by enterprises willing to participate where the service offer needs to contain all the information elements enabling the comparison and matching for ensuring the interoperability among the collaborating services [21].

Populator is the middleware agent whose main task is to find potential partners for the collaboration, acceptable in terms of interoperability [21, 22]. The populator is provided as a part of basic infrastructure and enterprises

do not need to have their own. It is active during the identification of the potential enterprise for the collaborations establishment. The populator gets activated upon receiving the call from an initiator enterprise interested in establishing the collaboration. Populator fills the roles in the collaboration based on the specified constraints and suggestions by interacting with all the three repositories. It also performs the secondary task of proposing the first version of the contract which is directly based on the information provided in the template provided by BNM.

Network Management Agent (NMA) [25, 31] represents the enterprise in the inter-enterprise collaboration. It interacts with the populator and peer NMAs for initiating the call for the establishment of the e-contract managing the inter-enterprise collaboration. Apart from representing the enterprise, the NMA is responsible for configuring the local middleware to follow agreed rules and regulations in the contract and provide a contract life-cycle management interface for internal applications [31]. NMA is implemented in such a way that the enterprise can participate simultaneously in more than one collaboration.

Contract is an active and distributed agent. It is also defined as the meta-information layer that consists of rules and regulations responsible for dynamically governing the established virtual enterprise [21, 31]. It addresses social and behavioral requirements of the collaboration in addition to runtime collaboration life-cycle management which includes interoperability testing and monitoring [31]. The initial version of the contract is directly retrieved from the information present in BNM template. The contract is refined further by negotiation among the potential enterprises interested in participating in the collaboration. The final contract consists of elements, such as collaboration structure, its partners, service behavior, means of recovery and ways for changing the contract itself. Contract is a part of contract repository of the enterprises.

Monitor [31] [25] is the local agent which is responsible for enforcing the contract, by acting as a part of the communication channel. The rules and regulations required for monitoring the conformance to the agreed service behavior are provided by local NMA agent. The monitor performs its job by either being pro-active, passive or active. It actively stops the messages from being sent during the pro-active state. In the active state the deviation is reported to NMA whereas, in passive state just deviation logs are maintained.

The working of the Pilarcos middleware is divided into four phases - namely population, negotiation, operational and termination [22, 31] (see Figure 2.1). The working of different phases of the Pilarcos middleware is explained in the following paragraphs.

Population phase [21] is the identification phase of the inter-enterprise col-

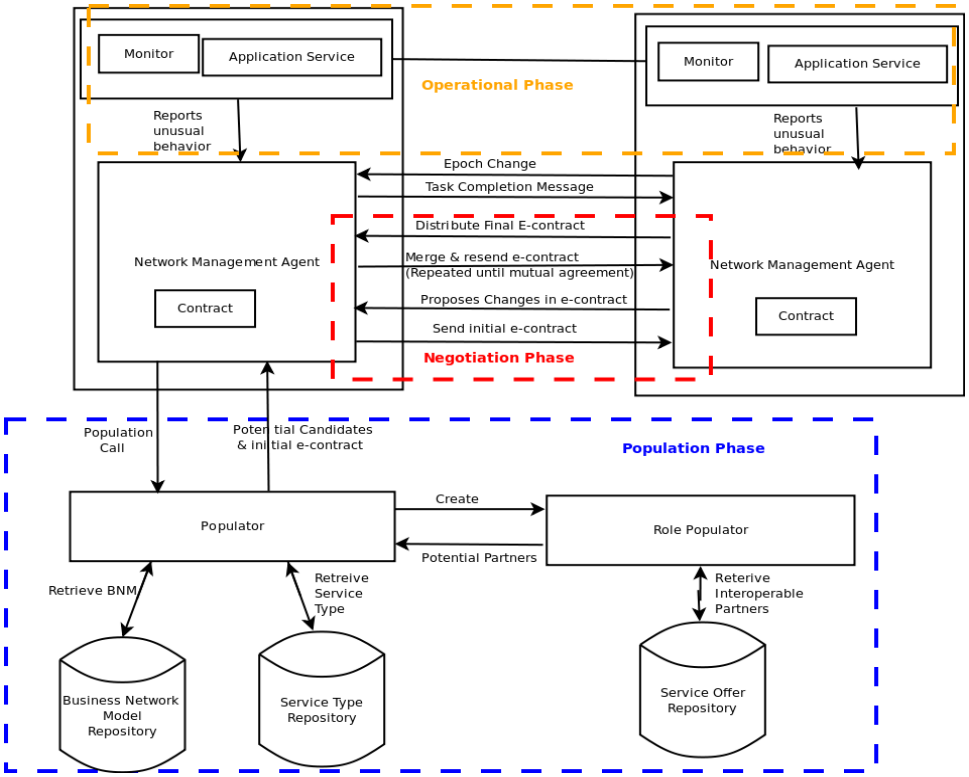

Figure 2.1: Working Model of Collaboration Life-Cycle.

laborations establishment (see Figure 2.1). The population phase includes searching and selecting the potential candidates for the collaboration using populator as an active agent. The semantic and technical interoperability are tested during the population phase. The population phase is initiated when populator receives the population call from NMA of the interested enterprise. The population call contains information about: BNM model along with some basic guidelines - such as allowed time for population, number of required responses; suggestions or constraints for selecting the potential partners for the collaboration and information about utility functions that encode and score preferences [21]. The utility functions are used for ascertaining the benefits of including a particular service or enterprise in the collaboration.

Upon receiving the request, populator interacts with BNM and type repository for retrieving the referenced service types for the roles and BNM. For filling in the missing roles, populator creates the role populators for each role specified in BNM and sets utility functions corresponding to each of them. Depth first search is used for finding the potential partners by ensuring their interoperability from the list of matching service offers received as

response to the request sent to the service offer repository. The final list of the potential partners is returned to the initiator along with the e-contract proposal. The population can be terminated at two points during the population phase itself. Firstly, if the properties of retrieved service type does not match with the one specified in the population call and secondly, when the services pre-selected by the initiator are not interoperable.

Negotiation phase [22] is the formulation phase of the inter-enterprise collaboration establishment (see Figure 2.1). It ensures pragmatic interoperability among the participating enterprises. The initiator of the collaboration sends the proposed e-contract to all the potential partners returned by the populator. The NMAs of the contacted enterprises can accept, reject or negotiate the contract further for refining it with or without the need for human assistance. The decision of entering or refraining from participating in the collaboration involves multi-dimensional trust decision based on the reputation and strategic importance (see Section 2.4). All the enterprises interested in collaborating and desiring to change some terms and conditions negotiate with other involved enterprises. All the negotiation responses are sent to the initiator who merges all the responses in the contract and sends the latest version of the contract to all the participants again. This procedure is adopted till the all the interested enterprises are satisfied with the contract. Once the final contract has been agreed upon, the initiator sends the separate request to all the enterprises to configure their services for the collaboration. Upon receiving the positive response from them, the message conveying the establishment of contract and working of the collaboration is sent out. The established contract is distributed to all the enterprises, which is embedded in their contract repository.

Operational phase [31] is the performance and the evolutionary phase of the inter-enterprise collaborations life-cycle (see Figure 2.1). All the involved enterprises start working on their tasks in accordance with the agreed role in the collaboration. The operational phase of the collaboration includes two protocols - namely Global State Management Protocol and Breach Management Protocol [31].

The progress of the enterprise is tracked using *"Global State Management Protocol"*. The enterprise informs completion of the task to the other members using *"UpdateTaskState message"* containing the contract id, task id, used session and enterprise signature for identification purposes. When all the enterprises respond with the same message, then the synchronized epoch change is introduced to the collaboration. It is the job of the monitor to call *"UpdateEpochState operation"* from NMA. These network epoch changes can also be considered as the relevant points of re-considering the decision of participating the collaboration. The structure of the collaboration

can change based on the progress of the collaboration. For example, some of the enterprises might decide to leave to the collaboration, transition needs to be made in BNM or a new partner that is not populated before might be needed for the next stage. Whenever the local monitor comes across a significant deviation by one or more partners of the collaboration in terms of expected behavior, then *"Breach Management Protocol"* is activated. In case of major breach detection affecting the whole collaboration, the violating partner might need to be removed. This again calls for the epoch change which needs to be synchronized. All these situations occurring as a result of the epoch changes again need the re-population, re-negotiation and interoperability checks. The Pilarcos middleware attempts to make the evolution of the collaboration smooth and seamless by automating it through the use of monitors, contracts and NMAs.

Termination phase [48] is defined as the phase that successfully puts end to the established inter-enterprise collaboration. The fulfillment of all the desired objectives of the collaboration marks the arrival of termination phase of the collaboration. The local reputation information gathered by the monitors during the operation phase is aggregated in order to use it for establishment of future collaborations.

The Pilarcos middleware leads to automated establishment of inter-enterprise collaborations in a flexible manner. However, the established collaborations might be endangered by risks occurring due to vulnerabilities introduced in the ecosystem [22, 24]. The risks include making wrong collaboration decisions or reacting too quickly to the occurring changes. These risks can be prevented through the use of meta policies, which define when and how the decision needs to be made. There are four different meta-polices based on: (i) strategic orientation of the enterprise, (ii) trustworthiness of the elements added by automation, (iii) correctness and quality of the meta-information used decision making and (iv) privacy policies determining the acceptance and rejection based on information flows [22, 24].

In the Pilarcos middleware, trust management during the establishment and operation of the inter-enterprise collaboration is done by the Pilarcos trust management system. The next section discusses, the Pilarcos trust management system which provides fundamental basis for understanding the requirements for the proposed trust decision expert tool.

2.4 Pilarcos Trust Management System

The Pilarcos trust management system is responsible for trust management during the establishment and operation of inter-enterprise collaborations in

the Pilarcos middleware. It follows the dynamic trust management approach where trust management is performed throughout the collaboration life-cycle. The Pilarcos trust management system performs two main tasks: making the trust decisions based on risk-benefit analysis and upkeeping the reputation information [47, 49].

Pilarcos trust management system automates the local trust decision making during the course of the collaboration. Trust decisions are made at two points during the collaboration - namely entering the collaboration and during the collaboration whenever more resources need to be committed. The trust decisions are based on the available reputation information and strategic analysis of the action [47, 48]. The Pilarcos trust management system makes calculative trust decisions based on a comparative analysis of the risks and benefits of making a positive trust decision in the given situation [47, 48].

The process of trust decision making involves taking into consideration information from various parameters as input for providing decision as the output. Pilarcos trust management system depends on seven parameters for making the trust decisions - trustor, trustee, action, risk, reputation, importance and context [47, 49].

Trustor is an entity that needs to make the trust decision. The entity that needs to be trusted is denoted by **trustee**. The **action** represents the task that needs to be performed together with the partners through the means of the collaboration. It involves the decision points where trust decision needs to be made, such as committing more resources or providing confidential information.

Risk represents the probabilities of different outcomes of the action under consideration. The calculation of the risk estimation is based on the reputation parameter.

Reputation represents the view of the trustor about trustee - on its past behavior [47]. It contains information from both local and external sources. Reputation information from both the sources have uniform format. The reputation information is stored in the form of experiences representing six outcomes of the actions for each asset. The outcomes formulating and categorizing experiences are:

0: Unknown outcome

1: Major negative

2: Minor negative

3: No change

4: Minor positive

5: Major positive

Unknown outcome and no change are different from each other as former represents outcomes that reveal no information such as delayed payment that cam still arrive. On the other hand, no change asset represents no effect situation where nothing is gained nor lost. The exact definition of major or minor change depends on the enterprise. The quality of the reputation information is ensured by using reputation epochs [45]. An epoch represents the significant changes in the behavior of the involved enterprises. Epochs visualize the consistency in the behavior of the trustee.

Importance parameter brings in the strategic value of the action during trust decision making. It guides the trust decision making by considering incentives of the positive trust decisions independent of the risks involved. It forms the basis for analyzing the risk tolerance while making trust decisions.

Context parameter provides flexibility to trust decision making process by enabling the possibility of making temporary changes depending on the current situation. The context information comes from three sources: internal state of system of the enterprise, state of business of the enterprise and state of business network the enterprise is involved in [47, 49].

The workflow of the Pilarcos trust management system is presented in Figure 2.2. It visualizes that the Pilarcos trust management system takes all the parameters, explained above, as input and employs different components for making the trust decision. There are three different components of the Pilarcos trust management system: monitor, data processing and reputation management component.

Monitor as a component performs the task of intercepting the service request message and retrieve the relevant information required for making the trust decision. It fetches the information about trustee, action and its parameters and passes this information to data processing unit. Monitor plugin makes the final trust decision based on the risk estimate and constraint set information provided by data processing component. The *data processing component* is responsible for computing risk estimation and generating the set of constraints that represent the level of risk tolerance and sending them to guard. For generating risk estimation and constraint set it takes input from action, context and experience repositories and applies it to risk, reputation, importance and context evaluator. The *reputation management component* performs the task of aggregating the local and external reputation information. The local reputation information is collected from Pilarcos monitors where as external information is taken from reputation networks by

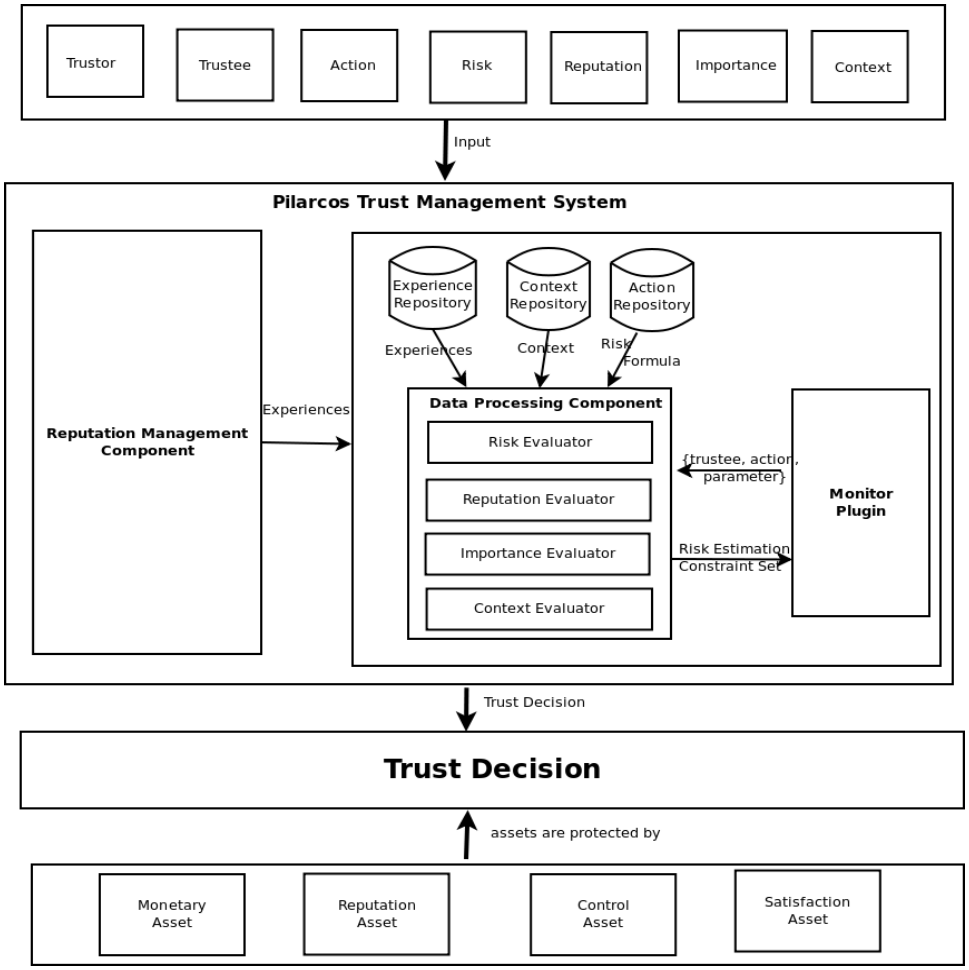

Figure 2.2: Pilarcos Trust Management System.

the agents representing the trustor enterprise in these networks. The reputation management component sends the aggregated reputation information to data processing unit through experience repository.

The made trust decisions are intended to protect the assets of the involved enterprises. There can be various assets depending on the individual enterprises such as - money, their employees, their customers, and reputation. But, the Pilarcos trust management system considers all these assets by grouping them into four main classes. The four standard asset classes are: monetary, reputation, control and satisfaction [47, 48]. The assets have been standardized in order to increase interoperability, add clarity and prevent any loss of information due to uncertain or vaguely defined assets [47]. The main aim of the trust decisions made by the Pilarcos trust management sys-

tem is to protect these assets due the possibilities of vulnerabilities inherent in inter-enterprise collaborations.

Monetary asset denotes everything that can be represented in the monetary form. It is simple and straightforward to calculate as compared to others. One way of the getting the monetary value for the asset in uncertain cases would be to see what amount the trustor is ready to pay for the target service [47]. **Reputation asset** represents the good reputation of the trustor comprising of their public relations, appearance in the media, attitude of their partners and their customers towards it [47]. **Control asset** represents the need of the enterprise of protection in terms of security, privacy and other aspects dealing with its autonomy. In general, control asset involves protecting the confidential information from being spread or misused and safeguarding the tangible and intangible assets of the enterprise such as people, equipments, and reliability. **Satisfaction asset** represents the degree of fulfillment of the expectations of the trustor from the trustee. The expectations from the trustee could be regarding quality of the service being offered and finishing the contracts on time as opposed to leaving agreements undone or leaving significant tasks undone.
The detailed working of Pilarcos trust management system is presented in Figure 2.3. It visualizes various steps involved in the working of the Pilarcos trust management system. The processes can be divided into three activities: identification of trust target, making contextual decisions and observing the collaboration operation for reputation management.

The first activity is the **identification of target** of the trust which is performed by monitor plug-in. The working of the Pilarcos trust management system is initiated when a message requesting the service application is received. Monitor intercepts the message and retrieves important parameters - trustee, action, action parameters required for trust decision making. It sends these parameters to data processing component. The data processing component uses these parameters for accomplishing the second activity of **making contextual decision** by calculating risk and generating the constraint set for risk tolerance. The formula for calculating default risk estimate is fetched from action repository. The default risk estimate is adjusted by reputation evaluator and context evaluator based on the information available in experience and context repositories. After computing the risk estimate, the asset specific constraint set representing risk tolerance for the concerned action or the business situation is generated by the data processing component.

The situation where the risk estimates either fall completely within and outside the bounds of ranges of automatic acceptance or rejection for all the assets are referred as routine case [48]. All those situations, where risk estimate do not satisfy the ranges for either automatic acceptance or rejec-

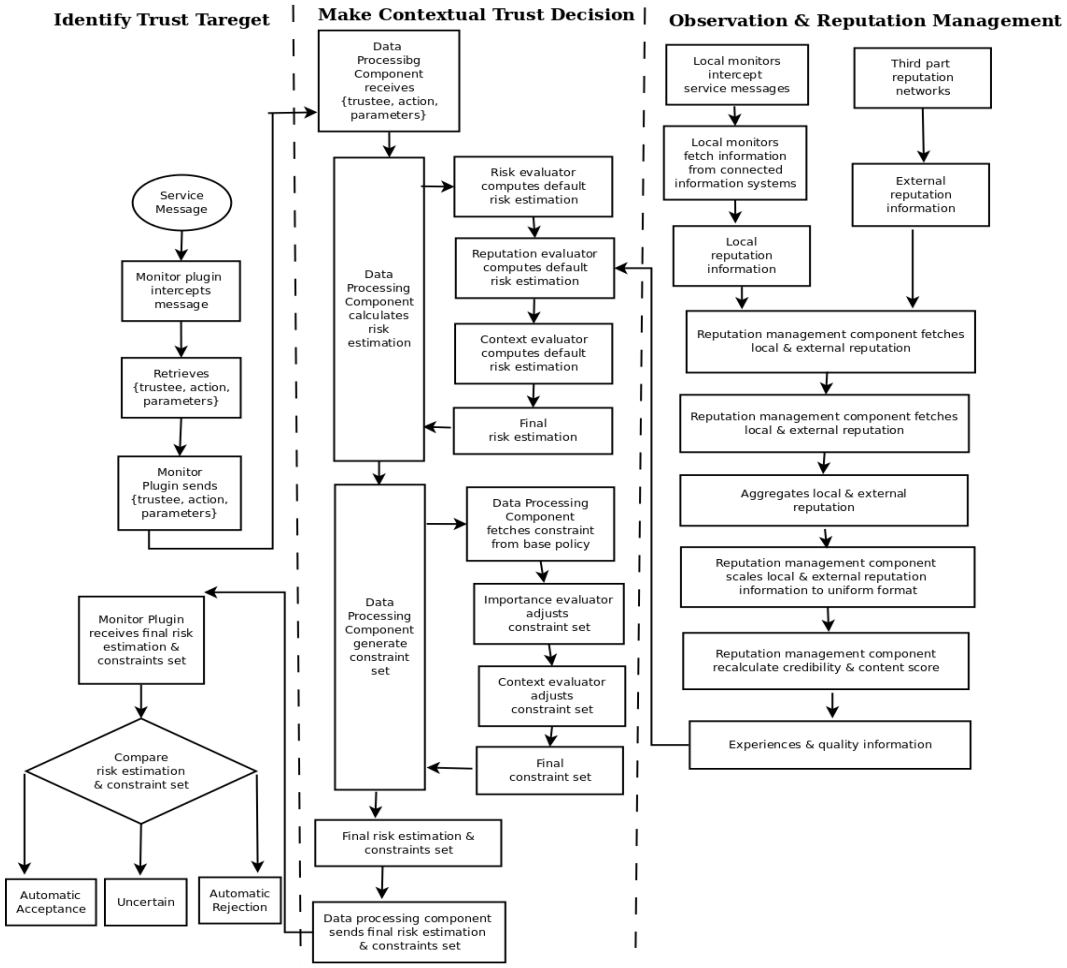

Figure 2.3: Flowchart showing the Working of Pilarcos Trust Management System.

tion need human intervention [48]. The problem of interaction of human users with the system for making confident trust decisions is an open issue in the otherwise automated Pilarcos trust management system. The thesis addresses this open issue by proposing a trust decision expert tool enabling interaction between human user and the Pilarcos trust management system.

The experience constituting reputation information is important factor for making the risk estimations. The experience information is upkept in the system during the third activity which takes place continuously throughout the collaboration life-cycle. This third activity can be referred as **observation**. The observation is done mainly by the local monitors. Finally, the reputation management component fetched the reputation information from

the local monitors and external reputation networks and translates them to the local format. The merged reputation information is continuously fed into experience repository of the data processing component for upgraded future trust decisions.

2.5 Summary

This chapter has presented the problem environment on which the thesis is based. It discusses about inter-enterprise collaborations in general and their trust issues, the Pilarcos middleware and the Pilarcos trust management system. This chapter presents the challenges faced by inter-enterprise collaborations along with the benefits offered by them. Inter-enterprise collaborations suffer from interoperability and trust management challenges. The challenges occur due to - (i) technical and semantic incompatibility of the information systems used by the enterprises and (ii) insufficient prior interaction among the participating enterprises. The Pilarcos middleware attempts to resolve these challenges by automated interoperability testing and trust management throughout the collaboration life-cycle. The different phases of operation and components used by the Pilarcos middleware are presented in this chapter. The component of the Pilarcos middleware that handles trust management automatically is also discussed extensively. The working of the Pilarcos trust management system in performing the two basic tasks: making the local trust decision and upkeeping the reputation information required for decision making is visualized and explained. The need for human intervention for trust decision making in situations where automation is not possible is also addressed. The need to prompt human users is an open issue in the existing Pilarcos middleware. The thesis addresses this open issue by proposing the trust decision expert tool enabling interaction between human users and the Pilarcos trust management system.

After understanding the problem environment for the implementation of the trust decision expert tool, it is important to comprehend the concepts of trust and trust decision making in the online environment. It is important to infer human preferences on trust and trust decision making in the domain of inter-enterprise collaborations for designing of the trust decision expert tool. The next chapter discusses about human preferences in the domain of inter-enterprise collaborations.

Chapter 3

Human Preferences on Trust Decisions

This chapter presents the human cognitive model for trust decision making that further helps in building trust relationship development model for the domain of inter-enterprise collaborations. In Section 3.1, first the nature of trust is explained by examining different types of trust in inter-enterprise collaborations. Section 3.2 presents elements of trust decision making and different approaches in human trust development. The metrics of trust decision making describing trustor metrics, trustee metrics, contextual metrics and collaboration specific metrics are presented in Section 3.3. The strategies to human trust decision making comprising of human behavioral and cognitive strategies governing the designing of user interfaces are discussed in Section 3.4. Based on the discussion, I propose a human cognitive model for trust decision making and a trust relationship development model for inter-enterprise collaborations in Section 3.5. Finally, the chapter concludes with the summary in Section 3.6.

3.1 Nature of Trust

Trust can be compared to the mental state of the human beings reflecting their willingness to take the risks inherent in the situation, leading to the actual action. Mayer et al. [27] have defined trust based on thorough review of trust literature as the *"willingness of a party to be vulnerable to the actions of another party based on the expectation that the other party will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party"*.

The concept of trust has been studied by multiple disciplines: sociol-

ogy, economics, marketing, psychology, political science and computer science [33]. The research on trust by different disciplines has made the literature on trust somewhat fragmented. Therefore, there is a need for a comprehensive model of trust. The comprehensive trust model visualizes the process of trust development and different factors influencing the process. Furthermore, it helps in understanding the phenomena governing the trust development and trust decision making pf users in the online environment. Some comprehensive models addressing human aspects related to trust for B2C e-commerce exist [1, 5, 12, 18, 30, 33], but there is no comprehensive trust model for inter-enterprise collaborations especially from perspective of users. The aim of this chapter is to propose a comprehensive trust model from perspective of human users for the domain of inter-enterprise collaborations.

Trust is evolutionary in nature. Usually, the development of trust is a challenging task, especially in the case of previously unknown or little known enterprises. But, it strengthens slowly with time by repeated interactions even in case of previously unknown enterprises. In addition, trust in online environment is also complex in nature as it involves establishment of trust in the use of third parties and information systems, in addition to trust relationship between the trustor and trustee. Furthermore, the complexity of the situation increases when human beings emerge into the picture especially for the purpose of trust decision making.

Mayer et al. [27] have discussed the problems contributing to the complex nature of trust. First, the field of trust is lacking one universal definition of trust applicable in all the situations and in all the disciplines. However, there are commonalities in the definitions of trust given by different disciplines such as, implicit and explicit mention about the involvement of trustor and trustee, confident expectations about the trustee in terms of intentions, abilities and willingness to put something potential on stake or being vulnerable [44]. Second, lack of clarity in the relationship existing between different referents of trust and between trust and risk. Trust referents are defined as the different perspectives required for trust establishment such as: social, economical, psychological, and organizational. Unspecified trust referent leads to confusion in analysis due to failure in considering both trustor and trustee. Ambiguous analysis directly effects trust relationship. Lastly, unclear relationship between the trust antecedents and its outcomes also adds to the complexity of the trust [27].

Trust has been classified by different researchers in the trust literature [4, 19, 36, 44]. The different trust classifications found in the literature provide different distinctive viewpoints for trust decision making in the environment of inter-enterprise collaborations. The different types of trust are:

(i) **Calculative Trust** - Calculative trust [4, 44] provides an economical

viewpoint towards trust. It relies on the comparison of perceived risks against the potential gains for making trust decisions. Calculative trust has been a dominant type of trust since traditional times.

In the domain of inter-enterprise collaborations, enterprises rely on weighing anticipated gains against potential risks while making a decision of collaborating with other enterprises. However, as noted before, the open and distributed environment for the establishment and functioning of inter-enterprise collaborations provides the option for collaborating with previously unknown or little known enterprises. In such a situation, the comparison of potential gains versus risks is quite beneficial for trust decision making in case of previously unknown, little known and even known enterprises. Therefore, calculative trust plays crucial role for trust decision making and trust establishment in the domain of inter-enterprise collaborations.

(ii) **Relational Trust** - Relational trust [4, 44] provides social viewpoint towards trust. It relies on formation of trust based on previous interactions with the trustee. Relational trust is build over time based on the knowledge gained through direct interactions with the target entity. It relies on the temporal nature of trust.

Relational trust plays a significant role in the domain of inter-enterprise collaborations. In the case of previously known enterprises, relational trust comes into action through the experiences gained by past direct interactions. But, in the case of previously unknown or little known enterprises, relational trust comes into picture only after series of direct interactions with the target enterprises. In the case of inter-enterprise collaborations, the information gained through direct interactions is especially crucial for making trust decisions regarding continuation or committing more resources in an ongoing collaboration. Therefore, in a way relational trust is applicable only in the case of previously known entities.

(iii) **Competence Trust** - Competence trust [36] addresses the organizational viewpoint of trust perspectives. It provides an organizational perspective to trust from the viewpoint of the capabilities, expertise and skills of the concerned trustee. In addition to expertise and abilities, other dimensions of competence trust entail the quality of service in terms of correctness, availability, reliability, security and survivability.

Competence trust plays significant role in the domain of inter-enterprise collaborations. The information regarding the skills, expertise and quality of service provided by the target enterprises influences the process of trust decision making regarding participation in inter-enterprise collaborations. This is applicable in all the cases: previously unknown, known and little known enterprises. Usually, competence trust is beneficial for finding the potential partners during the establishment of the collaboration. In the case of pre-

viously unknown or little known enterprises, information about competence trust is gathered from the published service offer and reputation networks. But, experiences gained from past direct interactions with the trustee provide information in the case of known enterprises.

(iv) **Intentional Trust** - Intentional trust [36] provides a psychological viewpoint to trust. It refers to trust on the intentions of the other entity to be trusted that they will not behave in the opportunistic manner. Furthermore, the intentional trust is also based on the adherence to the made commitments and promises. Intentional trust leads to formulation of belief on a trustee in terms of different dimensions of trustworthiness - such as benevolence, integrity and predictability.

The intentional trust is influential in the domain of inter-enterprise collaborations. The intentions of the trustee affect the process of trust decision making of the enterprises regarding their participation in the collaboration. The benevolent and honest intentions of the trustee affect the trust decision making positively whereas the possibility of opportunistic behavior makes negative attitude towards participation in the collaboration. In the domain of inter-enterprise collaborations, the establishment of intentional trust is based on the availability of first hand or external reputation information for assessing the trustworthiness of the trustee. Therefore, it is applicable in all the cases: previously unknown, little known or known enterprises.

(v) **Institutional trust** - Institutional trust [4, 44] provides organizational viewpoint towards trust. The institutional trust is different from competence trust as it is based on governance and non-governance factors facilitating trust between the trustor and trustee. The examples of such factors are: contracts, legal terms and conditions, shared beliefs, standards and relationships.

The institutional trust leads to trust generation in the situations lacking prior interaction and possibility of face to face interaction. Therefore, institutional trust is especially beneficial for trust development, in the case of previously unknown and little known entities in the online environments. Furthermore, Kim et al. [19] mention that institutional trust also helps in strengthening the formulation of calculative and relational trust. However, I believe that it also helps in facilitating the generation of trust in the case of competence and intentional trust in addition to calculative and relational trust. The existence of all the legal and non-legal structures mentioned above, lead to enhancing faith and trust generation on all the other aspects such as intentions and competence as well.

Institutional trust is also dominant in the domain of inter-enterprise collaborations as the aforementioned facilitating factors formulate the basis of perception about trust on the enterprises involved in the situation requiring

trust establishment. It has significant impact on the process of trust decision making regarding participation in the collaboration in the case of previously unknown, little known or known enterprises. In such a situation, factors aiding institutional trust act as the indicators of the normality of the situation leading to generation of positive attitude to trust development and decision making.

All the different types of trust discussed above present a complete picture of trust from different perspectives. They all play a significant role in the establishment of trust in the field of inter-enterprise collaborations. The next section presents different elements of trust decision making and approaches to human trust development. The different elements of trust decision making and approaches to human trust development help in understanding the process of human trust decision making and trust development in the domain of inter-enterprise collaborations.

3.2 Trust Decision Making

Trust is an essential component required in the situations containing interdependencies, risks and uncertainties. The establishment of trust involves making a decision regarding trusting the other entity. The decision based on subjective evaluation of the trustor on whether to trust other entity or not is called trust decision [47].

Trust decision making is based on different elements discussed in Section 3.2.1. All the discussed elements of trust decision making directly impact human behavior while making trust decisions. This is mainly due to the fact that all these different elements affect the cognitive thinking of human user involved in the act of trust decision making. Different approaches to trust development are presented in Section 3.2.2. The approaches to trust development are correlated with the elements for trust decision making because movement between different stages and cycles of trust development requires trust decision making. Therefore, the understanding of trust decision elements together with trust development approaches is needed to give a complete picture of the process of trust evolution.

The process of trust evolution presented in this section address the methods and factors working behind trust development in the case of previously unknown or little known entities in the open service ecosystems. Hence, this section helps in grasping the process of human trust development and trust decision making in context with inter-enterprise collaborations.

3.2.1 Elements in Trust Decision Making

McKnight et al. [28] have proposed six different elements of trust decision making are presented below. These elements have direct impact on the behavior of the end user while making a trust decision. The discussed trust elements provide overview of the process of trust decision making, which helps in understanding the transition from ambiguous to unambiguous mental state leading that inturn results in confident trust decisions.

Trusting Belief: Trusting belief reflects the cognitive state of the human user in relation to trust in inter-enterprise collaborations. McKnight et al. [4] define trusting beliefs as a faith of the trustor that the trustee is trustworthy. The trustor assesses trustworthiness of the trustee by evaluating ability, benevolence, integrity and predictability of the trustee [27]. Trusting beliefs are formulated based on the characteristics of the trustor and trustee enterprises. Trusting beliefs lead to the establishment of trusting attitude. Trusting attitude reflects the positive or negative viewpoint or judgment of the trustor towards the trusting behavior and its outcomes.

For example, if enterprise A, B and C desire to enter into collaboration with each other, then the human users administering these enterprises will take their decision to enter into collaboration with each other based on certain factors. The different factors affecting the formation of trusting belief are: perception of outcomes in the view of society, emotional state, propensity to trust formed as a result of previous experiences, competence, integrity and benevolence. In such a situation, all the before mentioned factors help the human users administering the enterprises in formulating trusting belief and thus, positive or negative trusting attitude, impacting their decision to enter into the collaboration with each other. In the domain of inter-enterprise collaborations, trusting belief acts as the foundation stone of the process of the trust decision making regarding participating in the collaboration.

Trusting Intention: Trusting intention reflects the willingness of the trustor to trust and take the risks inherent in the situation for attaining future gains. The human users administering the enterprises reach the stage of willingness to trust as a result of the positive trusting attitude towards the situation at hand. Trusting intention motivates the trustor to actual behavior despite the possibilities of negative consequences. McKnight et al. [29, 52] have given five factors aiding in the formulation of trusting intention. These are negative consequences of responding positively to the situation, dependence on other party in terms of power, perception about security, context and lack of reliance of control mechanisms. All these factors come into picture of trust

decision making only after the trustor has evaluated trustee enterprise on the basis of its competence, integrity, predictability and benevolence during the formulation of trusting belief and trusting attitude. I believe that the majority of the factors affecting trusting intention varies from situation to situation. This means that, if the gains made as a result of the collaborating are important for the enterprise, then it might be willing to compromize on security and control.

For example, if enterprise A wants to enter into collaboration with enterprise B, then enterprise A will consider all the aforementioned factors affecting trusting intention. The perception of enterprise A about not gaining anything, negatively affects its willingness to enter into collaboration with enterprise B. On the other hand, possibilities of gaining as a result of collaboration in addition to guaranteed security, flexibility and the presence of required control mechanisms positively affect the willingness of enterprise A to enter into collaboration with enterprise B. Hence, trusting intention contributes to the domain of inter-enterprise collaborations by acting as the driving force behind actual behavior of participating or not participating in the collaboration.

Trusting Behavior: Trusting behavior refers to the position of the trustor where they actually take the risks inherent in the situation based on the trusting beliefs and intentions. Trusting behavior leads to final outcomes, which could be positive or negative. Depending on the outcomes of the trusting behavior, trustor formulates the experiences directly affecting trusting beliefs for the future interactions with the same trustee.

For example, consider that enterprise A shares its confidential information required for the accomplishment of the objectives of the inter-enterprise collaboration with the other collaborating enterprises. In this case, sharing of the confidential information with other participating enterprises represents the trusting behavior. The positive or negative outcomes of this trusting behavior rely on the honest or opportunistic behavior of the other collaborating enterprises. In the case of inter-enterprise collaborations, trusting behavior is crucial because it provides the basis for relational trust, continuity in the ongoing collaboration and future collaborations with current partners. In addition, trusting behavior acts as the ladder for trust evolution by either enhancing or degrading the existing trust levels.

System Trust: System trust reflects the level of trust that the trustor has on the system, which directly affects trusting intentions. McKnight et al. [4] proposed two components of system trust: structural assurances and situational normality. Structural assurances refer to the impersonal structures such as guarantees, safety nets, legal contracts and regulations, which help

in generating trustworthiness when dealing with uncertain situations [4, 64]. On the other hand, situational normality [53, 64] denotes the normality of the situation in which the trusting behavior is going to take place. Normality represents the presence and proper ordering of everything required for the inter-enterprise collaboration to successfully take place and generate the desired results. Pavlou [38] has later added a third component called facilitating factors to the existing components of system trust which refers to non-governance factors such as common standards and cultures.

For example, if enterprise A wants to enter into collaboration with previously unknown enterprise B and C, then components of system trust will aid the trust decision making. Enterprise A can make a decision to enter into collaboration with enterprise B and enterprise C based on the terms and conditions mentioned in contract. A contract is defined as a protocol or a document which specifies the roles that will be played by all the collaborating enterprises in addition to the rules and regulations that need to be maintained during the collaboration. In this case, contractual terms and conditions represent the basis for system trust. System trust plays a pivotal role in the trust development and trust decision making during the establishment and operation of the inter-enterprise collaborations.

Dispositional Trust: Dispositional trust refers to the expectation of the trustor about trust. It is composed of two factors: propensity to trust and trust stance. Propensity to trust deals with the general tendency of the trustor in trusting the humanity. The belief that all the entities are reliable and trustworthy based on the prior experiences leads to positive propensity to trust. Trust stance represents the rational choice for making the trust decision. The rational choice could be based on for example, probabilistic weighing of gains versus risks. Trust stance exerts more impact on trust intentions as compared to propensity to trust [64].

For example, if enterprise A wants to make a decision to collaborate with previously unknown enterprise B and C, then propensity to trust and trust stance play significant role in the trust decision making. If enterprise A is having positive experiences of participating in previous inter-enterprise collaborations, then gained experiences will lead to formulation of positive propensity to trust. Positive propensity to trust in addition to gaining possibilities of gaining will generate positive attitude towards the situation and motivate enterprise A to enter into inter-enterprise collaboration. Dispositional trust is important since it stimulates the process of trust decision making in the inter-enterprise collaboration environment.

Situational Decision to Trust: Situational decision to trust refers to the intention of the trustor in trusting target entities in similar situations

irrespective of the faith in the characteristics of the specific trustee.

For example, if enterprise A is having positive experience from its past collaborations then it will have an intention to trust other entities for a given simple task even if it involves previously unknown enterprises. In the case of inter-enterprise collaborations, situational decision to trust indirectly represents the trust on the ecosystem facilitating inter-enterprise collaborations.

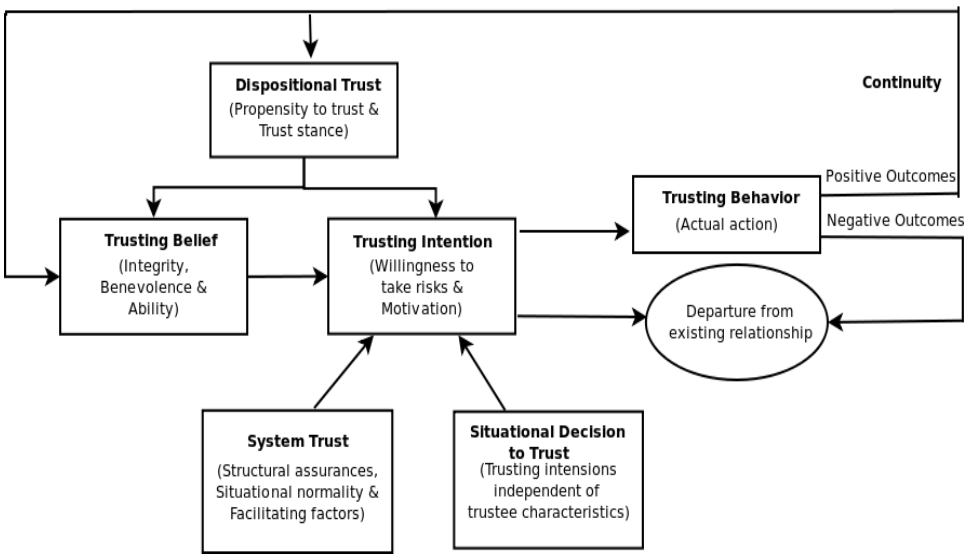

Figure 3.1: Adapted Model of Elements of Trust Decision Making.

Figure 3.1 presents different trust elements of trust decision making and their contribution in the formulation of the intention for actual behavior. Bold phrases represent the trust elements while phrases in parenthesis reflect their constituents. Trusting beliefs initiates the process having direct affect on the trusting intentions. The trusting beliefs are, inturn, affected by dispositional trust, which is made evident by its constituent elements: propensity to trust and trust stance. Both the constituents of dispositional trust denote the psychological state of human mind while making trust decisions. Apart from trusting belief, trusting intentions are directly affected by dispositional trust, system trust and situational decision to trust. The trusting intention finally makes the positive or negative decision regarding the situation requiring trust decision. The positive decision leads to an intended trusting behavior. On the other hand, negative decision leads to departing from the situation. The posutive or expected outcomes lead to continuity of the existing inter-enterprise collaboration whereas the negative outcomes motivates the human user to depart.

3.2.2 Approaches of Human Trust Development

There are two approaches to online trust development discussed in the existing literature on trust: cyclic and staged.

Cyclic Approach: The cyclic approach to trust formation is based on the satisfaction of the prior expectations about the outcomes of the trusting behavior. The satisfaction gained from the previous interactions builds the confidence of the trustor, leading to the formulation of positive attitude towards trustee. The positive attitude serves to be the input for generating willingness to take risks and indulging in future interactions with the trustee. On the other hand, dissatisfaction at any point in the cyclic approach lowers the existing trust levels.

Fung et al. [12] introduced a cyclic approach to trust development addressing the B2C domain. Their model of cyclic approach presents the factors: information quality, interface design and reputation contributing to initial trust development in the case of Internet shopping. The initial trust established as a result of these factors represents the starting point of the cycle of the trust development, as it motivates the user to either agree or deny performing the first transaction. If the users engage themselves into the first transaction, then it is evaluated to ascertain the satisfaction levels. The positive outcomes of the evaluation generate high trust. On the other hand, negative consequences create distrust and departing out of the situation. However, I believe the model of cyclic trust development approach given by Fung et al. has two weaknesses. First, the list of factors affecting initial trust formation is not sufficient when considered from the perspective of inter-enterprise collaborations. There are other factors as well - governing and non-governing factors such as contracts, legal terms and conditions in addition to shared standards and beliefs - which play significantly important role in initial trust development. Second, the model does not state the criteria behind distrust and departure clearly. It shows that the negative evaluation generates distrust and hence, departing out of the situation. It does not clearly state, if only one negative evaluation or continued negative evaluations lead to departing. I believe that departure from the any situation depends on the effect of the negative evaluations on the enterprise. For example, if the evaluation of only one transaction creates huge losses for the enterprise, then they will drop out immediately. But, if the effect is trivial, then continuity and persistence of the negative evaluations becomes the basis for dropping out.

On the other hand, Deelman et al. [5] proposed an elaborated model of cyclic approach to trust development based on the model of Fung et al. The model given by Deelman et al. addresses the domain of Business to Business

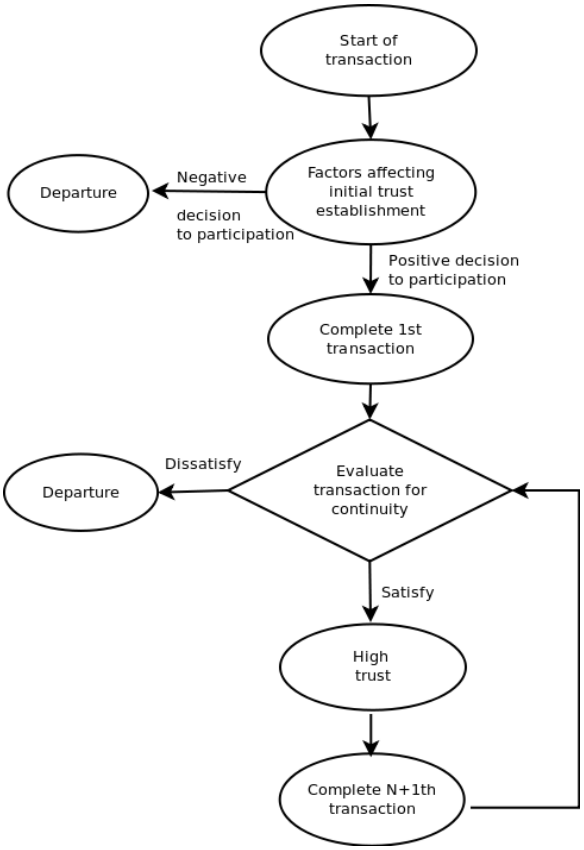

Figure 3.2: The Cyclic Trust Formation Approach.

(B2B). They also give 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. The trust is developed through the evaluation of all aforementioned factors in a fixed sequential order only once during the starting of the transaction. The evaluation of the transaction on satisfaction leads to strengthening of trust, lowering of trust or departing out of the situation. However, I believe that the list is still insufficient. As already mentioned, it does not take into consideration the governing and non-governing factors. All the factors required for initial trust development are better addressed by different elements of trust decision making (Section 3.2.1). In addition, I do not agree with their viewpoint stating that the factor list is followed in the given fixed sequential order as it depends on the subjective preference of human users on what order they follow. Moreover, their model also suffers from the unclear departure criteria as discussed in the case of the model given by Fung et al.

I have brought together the understanding of Fung et al. [12] and Deelmaan et al. [5] for demonstrating the working of cyclic approach more clearly. The working of cyclic trust development approach is shown in Figure 3.2. The process of trust development is activated by the initiation of the transaction. The initiation of the transaction is marked by either low trust in the case of little known enterprises. On the other, in the case of previously unknown enterprises, initiation of the transaction lacks existence of any kind of trust. At this point, different factors; listed above; affecting initial trust development come into action. These factors affect the decision of human user to involve in the first transaction or not. The cyclic approach completes its first cycle only when human user decides to complete the first transaction. On the other hand, denying to engage in first transaction leads to departing out at this stage. The evaluation of the completed transaction is done to ascertain the levels of satisfaction, which are determined by the fulfillment of the expectations of the trustor. The satisfaction of all the expectations leads to the building of high trust. However, the dissatisfaction of expectations leads to departure. The high trust build as a result of the satisfaction of the expectations motivates the human users to engage in future transactions. The decision of participation in the future transaction is completely based on the satisfaction of the expectations from the previous transactions. The same procedure of evaluating the completed transaction is followed for all the future transactions. The positive outcomes lead to the strengthening of the trust further. However, dissatisfaction at any stage leads to departing out the existing relationship. The continuity in the collaboration based on the satisfaction of the prior expectations contributes to the cyclic nature of trust development.

Staged Approach: The staged trust development approach is based on the assumption that online trust is formed in different stages. The different stages of trust formation are based on the level of interaction and relationship among the participating entities.

Different researchers have proposed two- and three-staged models for trust formation. Shapiro et al. [54] and Ba et al. [1] have proposed three staged trust formation models. The different stages in three staged model given by Shapiro are: deterrence based, knowledge based and identification based. On the other hand, Ba et al. have given following three stages to trust development: calculus based, information based and transference based.

The deterrence based trust development is based on the measures preventing the occurrence of misbehavior among the collaborating enterprises. However, Ba et al. are of view that calculus approach of comparing risks versus gains is the initial stage to trust development. I also agree with the viewpoint of Ba et al. because analysis of potential gains versus possible

losses plays a crucial role during the initial stage of trust formation in the domain of inter-enterprise collaborations. This approach is in conformance with the human behavioral theories of trust decision making as well [3, 64]. Hence, I think that calculus based trust should be the first stage of trust development. At the same time, even calculus trust provides deterrence for preventing misbehavior through analysis of possible gains. In the domain of inter-enterprise collaborations deterrence based trust is enforced in the forms of contracts and policies preventing opportunistic behavior [43, 48, 62]. Both models are of the same view regarding information or knowledge based trust to be the second stage to trust development. But, I think that their view on the usage of knowledge or information trust is limited. According to me, knowledge or information based trust can also be used during the first stage of trust formation with calculus based trust in the domain of inter-enterprise collaborations. At this stage, the main source of information can be reputation networks [48]. Identification or transference based trust represents the highest level of trust which comes as a result of the repeated interactions with the collaborating enterprises. However, the main weak point in their model is that they do not consider the effect of misbehavior or opportunistic behavior at any stage during the process of trust development.

The two-staged models of trust development are given by Kim et al. [18] and McKnight et al. [30]. The different stages in two-staged models are initial or exploratory and commitment stage. Initial, or exploratory, stage represents the initiation phase marked by either no trust or very little trust on the trustee. On the other hand, commitment stage represents the stage marked by high trust where the trust relationship of the trustor-trustee is based on the prior direct interactions with each other. The model proposed by Kim et al. does not clearly state the criteria behind shift from initial to robust trust and departure. For example, the occurrence of significant deviations from the accepted terms and conditions is stated as the criteria behind departure from the inter-enterprise collaboration [48, 62]. Moreover, the model also does not provide the precise list of factors affecting trust formation during the initial and committed stage. In contrast, the model proposed by Mc Knight et al. does not discuss departure from the trust relationship at any stage. This is unrealistic since priorities of the enterprises can change at any time. On the other hand, they may still have relationships even is they refuse to collaborate.

There are similarities among the stages of two and three staged models of trust developments. The initial/exploratory stage of two-staged trust development is equivalent to calculus, deterrence and knowledge or information based trust. This stage leads to trust formation in the situations marked by lack of knowledge about the trustee due to absence of prior relationship and

direct physical interaction. In this stage, expectations about gains leads to trust formation, the provision of the measures preventing misbehavior and reputation information of the trustee gathered from the reputation networks impacts trust development. On the other hand, commitment stage of two stage model is analogous to knowledge or information based and identification or transference based stages of three staged trust development models. The trusting behavior or actually taking the risks on the basis of initial trust formation directs from the initial stage to the commitment stage. Commitment stage involves direct interaction with the trustee which aids in accumulation of experiences about the trustee in terms of their integrity, ability and benevolence. A continuous positive outcome of the expectations leads to transference of uncertainty to certainty, thus generating identification with trustee.

The adapted model from the existing two- and three-staged trust development models is presented in Figure 3.3. The association among different stages of the presented staged models leads to the conclusion that in general there are two different stages of trust formation. These two stages are - **initial** and **committed stage**.

Similar to the cyclic approach, the process of trust development is activated by the initiation of the transaction in the staged approach as well. As mentioned before, the initiation of the transaction represents the initial stage marked by either lack of trust or low trust in the case of first time interaction with the unknown or little known enterprises respectively. The initial stage is comprised of calculus, knowledge and deterrence based trust. Failure in establishment of all initial trust lead to departure. The staged approach accomplishes the first stage when human user decides to complete the first transaction. The evaluation of the completed transaction is done to check the level of satisfaction and dissatisfaction of the expectations. The satisfaction of all the expectations generates high trust. However, the dissatisfaction of expectations leads to departure. The high trust build as a result of the satisfaction of the expectations leads to committed stage. The same procedure of evaluating the completed transaction is followed for all the transactions done in the committed stage. The positive outcomes lead to the strengthening of the trust further. As noted before, committed stage consists of knowledge and identification based trust.

The main difference between the cyclic and staged approach to trust development is in their focus. Moreover, it can be noted that staged approach to trust development also has cyclic nature of evaluating the transactions for satisfaction, similar to cyclic trust development approach. Both, different elements of trust decision making and human trust development help in having a concrete glimpse of the phenomena of human trust decision making

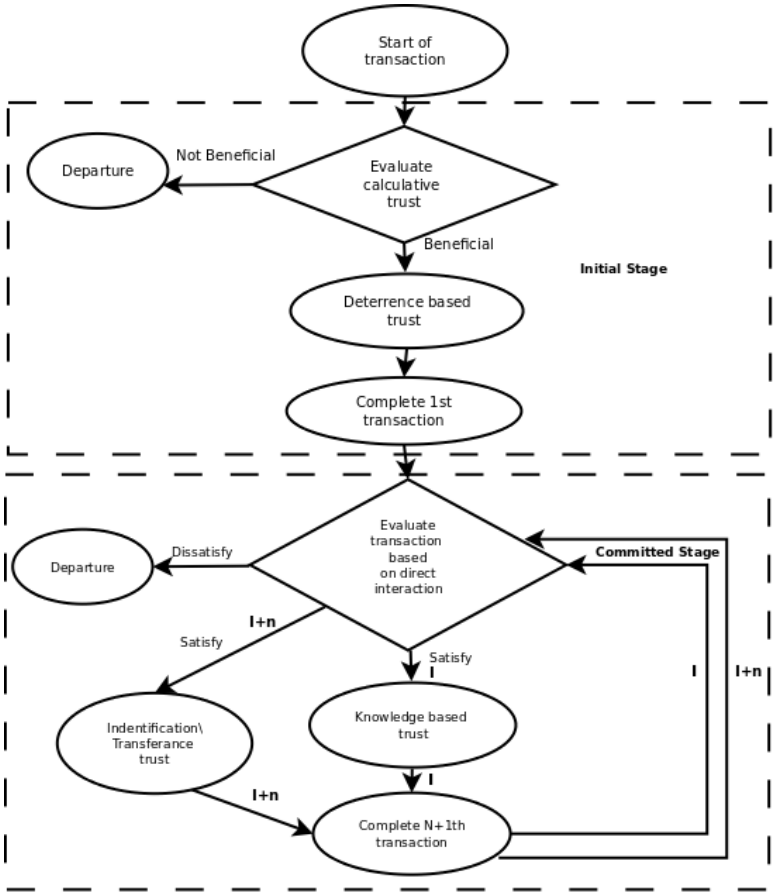

Figure 3.3: The Staged Trust Formation Approach.

and trust development. They will be used for building trust relation development model and human cognitive model of trust decision making (see Section 3.5). In the next section, different metrics of trust decision making are discussed. The different metrics of trust decision making gives the list of parameters required by human users for trust decision making in the domain of inter-enterprise collaboration.

3.3 Metrics of Trust Decision Making

Decision making in any domain is based on the existing and available information concerned with the situation under consideration. This section discusses different metrics of trust decision making. Metrics are defined as the different parameters of the information required for decision making in a particular situation [27, 52, 64]. For example, for decision making in the

B2C e-commerce domain, the required information parameters for decision making are: trust actors, institutional, website and environmental factors. The different information parameters called trust decision metrics help in analyzing the current situation whenever the decision needs to be made. The clarity, accuracy and usefulness of information provided by different metrics is important in the case of decision making with previously unknown entities lacking possibilities of direct interactions [12]. Similarly, in the domain of inter-enterprise collaborations, different metrics for decision making are: trustor, trustee, contextual and collaboration-specific. The understanding of different metrics for trust decision making helps in understanding the human decision making process completely.

3.3.1 Trustor Metrics

As noted earlier, trustor is the entity who needs to trust other entity in a given situation. Trustor metrics discuss attributes of the trustor having direct impact on the process of trust decision making. Understanding trustor metrics is important for attaining comprehensive understanding of human trust decision making because they address different characteristics of the trustor; responsible for trust decision making; affecting the process of trust decision making. There are three different trustor metrics impacting trust decision making: propensity to trust, emotions and culture.

Propensity to trust is a human behavioral trait referring to their general expectations or attitude about trusting humanity [18]. The general attitude to trusting humanity is related to the personality of the human user responsible for decision making. They are built based on the favorable actions and experiences in the past right from the infancy stage of the human user. It is the dispositional approach to trust which human users carry from one situation to other [27]. The general propensity makes human users risk-seeking, risk-aversive or risk-neutral. For example, a human who is risk-seeking will be willing to trust others and take the risks involved in the situation at hand regardless of other contexts. The propensity to trust plays a significant role in the establishment of initial trust in the case of previously unknown or little known entities [4]. In the domain of inter-enterprise collaborations, propensity to trust reflects the willingness of the trustor enterprise to trust target enterprise purely based on their inherent willingness to trust others, independent of any information about trustee characteristics.

So far, the propensity to trust has been considered at the human level only. But, according to my understanding, this metric also exists at the enterprise level. The existence of propensity to trust is quite evident when the human user is responsible for making the risky decisions on the behalf of their

enterprise. However, I believe that it is also present in the case of automated decision making systems making decisions on the behalf of the enterprises. The systems supporting automated trust decision making are based on the private, local or mutually decided and negotiated policies, contracts, rules and regulations by the collaborating enterprises. The propensity to trust of the enterprises is reflected through the policies, rules and contracts governing inter-enterprise collaboration. However, these policies and contracts are decided by the either human or configured machine agents. The configurations of these machine agents are set by the human users administering the enterprises during the negotiation phase of the collaboration establishment. Therefore, the propensity to trust of human users also affects the working of the automated trust decision making systems as well.

During the initial and committed stage of trust development the propensity to trust depends on the current situation requiring trust decision making as shown in Table 3.1. The situational dependency is created by the past experiences of human users responsible for decision making or formulating rules and terms for automated trust decision making. For example, if an enterprise is having positive experiences from the past inter-enterprise collaborations, then it will be more willing to collaborate with other previously unknown or little known enterprises during the initial stage. But, in the case of committed stage, the trust decision depends on the experiences gained through direct interactions with the collaborating enterprises in the inter-enterprise collaborations.

Emotions are defined as the cognitive approach used for trust decision making which is independent of trustee or situation requiring a trust decision [7, 10]. Emotions of the human being govern the process decision making in risky situations. They dominate the process of decision making by formulating perceptions about the available information and the current situation. Emotions are responsible for *"temporal irrationality"* during the process of decision making. For example, emotions can instigate the trustor to take the risks involved in the situation which does not offer any trust guarantees [10]. Such an emotional state of human dissipates on reception of negative experience through violation of trust by trustee.

The literature available on emotions and trust [7, 10], discuss emotions in context with human users, but I believe that it exists at enterprise level. For example, the emotions based on past experiences or current emotional mood effect the process of trust decision making either directly or negotiating the terms and conditions during the establishment of the collaboration.

Emotions also vary with time during the initial and committed stages of trust development as shown in Table 3.1. As previously noted, emotions influence trust decision making by affecting the perception of the human

Components			Intial stage	Commited stage
Trustor Factors		Propensity to trust	General past experiences	Experiences gained through direct interaction
		Emotions	Emotional state & general past experiences	Emotional state & experiences gained through direct interaction
		Culture	Stable , but might change in the case of long term collaborations	Stable , but might change in the case of long term collaborations
Trustee Factors		Reputation	Percieved from third parties	Percieved from direct interaction
Contextual Metrics	System Trust	Structural Assurances	Perception about trust, gurantees, legal & regulatory complaince	Experiences gained from direct interaction through monitoring, feedback & legal bonds
		Situational Normality	Expectations & impersonal structures	Experiences gained from direct interaction, expectations & impersonal structures
		Facilitating Factors	Perception about integrity & adherence to commitments	Perception about integrity & adherence to commitments
	User Interface	Interface Design	Navigational easiness, friendly interface	Interactivity
		System Reliability	Less errors and fast access	zero errors and correct transaction
		Information Quality	Clarity, correctness	usefulness
		Percieved Usefulness	Absent	develops over time
	External Envirionmental	Factors affecting trust like social, economic, technology problems	Vary with time	Vary with time
Collaboration-specific Metrics		Objectives	Vary with time	Vary with time
		Perspectives	Stable	Stable

Table 3.1: Comparison of Metrics of Trust Decision Making.

users. The perception in turn is affected by the past experiences of the human users similar to the case of propensity to trust. In addition, emotions also depend on the emotional state or mood of the human beings leading them to temporal irrationality. For example, if they are happy during the moment of decision making, then they are liable to make positive decisions.

Culture is defined as the personality trait of the trustor affecting the process of trust decision making. The task versus relationship dimension of the culture strongly affects the process of trust decision making in the case of previously unknown or little known enterprises [10]. For example, task oriented cultures seem to be more risk seeking and willing to take risk inherent in the situation. Furthermore, culture also affects the above mentioned trustor metrics: propensity to trust and emotions by influencing their

attitude in perceiving the available information for decision making.

Culture is also assumed and discussed typically as a human characteristic, similar to propensity to trust and emotions. However, I believe that it also exists at the enterprise level. At the enterprise level, culture is also influenced by the nature of the enterprise involved in the act of decision making in addition to the human influence during the process of trust decision making and configuring. For example, small and medium sized enterprises will be less willing to take risks as compared to large enterprises due to lack of sufficient available resources. Furthermore, culture plays significant role in the process of trust decision making at the enterprise level in the same way as propensity to trust and emotions.

Culture remains stable during the both initial and committed stages of trust formation at the enterprise level but changes with time at the human level as shown in Table 3.1. The influence of nature of enterprise remains stable. For example, small and medium sized enterprises will always be risk aversive in contrast to large enterprises which are risk taking. On the other hand, the basic culture of the human beings formulated as result of their societal and family background changes with time and past experiences made by the human users.

3.3.2 Trustee Metrics

As previously mentioned, trustee is the entity who is to be trusted by the trustor in the trust decision making process. Establishing trust on the previously unknown entities is a challenging task, especially in the case of open and distributed environment for the establishment of inter-enterprise collaborations. It is necessary to trust the target entity to balance the risks inherent in the situation. Reputation information of the trustee enterprise acts as the trustee metric required for establishing trust on the trustee.

Reputation information is defined as the knowledge about the past and present behavior of the trustee enterprise [33, 48, 52]. It provides a basis for making the predictions about the future behavior of the target enterprise. The establishment of trust relationships with other involves predicting benefits and gains based on the future behavior of the target enterprise as a result of mutual collaboration.

The reputation information aids in the assessment of trustworthiness of the target enterprise. Trustworthiness is defined in terms of three high level classes: ability, benevolence and integrity [27]. Ability is defined as the skills and expertise possesses by the trustee within some specific domain. Benevolence is defined as the extent to which trustee or trustor behave well and perform according to the expectations of each other either for satisfying

their selfish rational or selflessly. Integrity is defined as the extent to which the trustee accepts and adheres to the rules and regulations set and predefined earlier in context to behavior and quality of service. The general expectations and attitudes towards the trustee enterprise are built on the basis of direct interaction with the trustee or gaining information about the trusted reputation networks.

As shown in Table 3.1, source of reputation information changes from initial stage to committed stage of trust development but the criteria of establishing trustworthiness remains same. In the case of inter-enterprise collaborations operating in the open and distributed environment, initial stage of trust development constitutes collaboration with the previously unknown and little known enterprises. Furthermore, such an environment lacks the possibility of face to face interactions with the target enterprises even for the first time. Therefore, trusted reputation networks are the main source of reputation information during the initial stages of trust development. On the other hand, the committed stage of trust development is based on the past direct experiences of the trustor with the target enterprises. The above argumentation holds true for trust decision making at both the levels - human and enterprise.

The reputation information should provide causal information about past and present behavior. The causal information provides assistance for analyzing the relation between the occurrence of past, present and future activities [33]. The causal information provides cause and effect knowledge behind the behavior of the enterprises. It gives logical sense making of the actions of the target enterprise in the past, present and future. However, I believe that the current reputation information provides only the effect information and does not contain information about the causes behind the action causing the adverse effects.

3.3.3 Contextual Metrics

The contextual information represents the information which changes depending on the current situation. The current situation impacts the process of trust decision making. The contextual information affecting trust decision making is a given situation is dependent on three aspects: system trust, user interface of trust management system and external environmental factors.

3.3.3.1 System Trust

As discussed in Section 3.2.1 system trust consists of three components proposed by Mc Knight et al. [4] and Pavlou [38]. Furthermore, from the second

perspective one more component can be added to the existing components of system trust named inter-enterprise collaboration systems. The changing nature of these factors makes system trust contextual in nature.

Structural Assurances refer to the impersonal structures which help in generating trustworthiness while dealing with uncertain situations [4, 64]. Structural assurances constitute legal and governmental impersonal structures for example, guarantees, safety nets, legal contracts and regulations, legal bonds and accreditation. The component of structural assurance exists at both human and enterprise level. Humans and automated trust decision making systems make use of similar impersonal structures for establishing trust and ensuring trustworthiness of the trustee enterprises.

Structural assurances differ during the initial and committed stages of trust development as shown in Table 3.1. During the initial stage of trust development perceptions about trust, guarantees, legal and regulatory compliance act as the basis for trust development and trust decision making [64]. On the other hand, during the committed stage, experiences gained from the direct interactions with the trustee gained from monitoring, feedback and legal bonds affect trust decision making. The perception at this stage are based on the impression of the trustor formulated as result of the direct interaction with the trustee in terms of conformance of the transactions, promises and claims made during the initial stages of the trust development.

Situational Normality refers to the belief or assumption of the trustor that the situation at hand is safe and positive for gaining desired benefits by entering into collaboration with other enterprises [4, 64]. Structural assurances and perception of the human beings contribute in formulating the belief of positive or negative sensing of the situation. Situational normality also exists at both human and enterprise level. Moreover, the basis of formulating the belief regarding situational normality is also same for both the levels.

As shown in Table 3.1, situational normality differs in both the stages of trust formation. In the case of inter-enterprise collaborations, during the initial stage of trust formation expectations of gaining benefits and structural assurances help in making a positive perception towards the current situation [52, 53]. However, in the case of committed stage, direct experiences with the target enterprises also contribute in the formulation of the perception about situational normality in addition to the factors existing during the initial stage

Facilitating Factors [38] are defined as the factors referring to the perception about the integrity or adherence of the trustee to the general and unanimously established rules, regulations and commitment regarding the transaction. Facilitating factors are non-governing in nature for example,

shared standards, protocols, relationships, goals and beliefs [41]. It also exists at both human and enterprise levels similar way as other components given by McKnight et al.

The facilitating factors remain same for both the initial and committed stages of trust formation. Perception about integrity and adherence to the made commitments act as facilitating factors during the both the stages of trust formation. In the case of inter-enterprise collaborations, most of the facilitating factors are checked during initial trust establishment as they have significant impact on the feasibility of the collaboration. For example, existence of shared standards and protocols ensures the feasibility of collaboration. Hence, they should not be changed during the collaboration as it might affect the operation of the inter-enterprise collaboration. However, the sources of information about these factors differ during both the stages.

3.3.3.2 User Interface of Trust Management System

User interface of the trust management system is responsible for presenting the information required for making the trust decisions regarding participation in the inter-enterprise collaboration. The main contribution of the master thesis is the trust decision expert tool, running over Pilarcos trust management system, provides a user interface, so this is particularly relevant as shown in Table 3.1.

The systems supporting inter-enterprise collaborations have user interfaces for making human queries. For example, the tested prototype of the ICT infrastructure of the ECOLEAD [43] provides list of potential enterprises for the collaboration to the human users in response to their query. Human users are required to make selections from the information presented on the user interface. In such a situation format and quality of the information presented, system reliability and interface design contribute to ease of use affect trust development [12]. The quality of the information presented for decision making should promote transparency. Transparency builds trust in the system thus enhancing the system reliability. Ease of use in terms of navigation and finding information embedded in user interface design also contribute towards strengthening trust. All these factors enhance the perceived usefulness of the system. The factor of user interface of the trust management systems exists only at the human level as it presents information to human users for trust decision making.

System reliability, intuitive user interface design and quality of the presented information affect trust in both initial and committed stages of trust development. During the initial stage, navigational ease, friendly interface, clarity, accuracy and reduced error rate. On the other hand, the factors such

as: interactivity, usefulness, accurate transactions together with zero error rates are dominant during the committed stage. The perceived usefulness built as a result of all these factors affect the trust development during the committed stage of trust formation and is absent during the initial stage.

3.3.3.3 External Environmental Factors

External environment is defined as set of factors, constituting social, economic and technological issues, affecting trust decision making. The external environmental factors are different from all the above mentioned metrics of trust decision making because they are independent of trustor, trustee and the other contextual aspects. They come into picture because of the current social, economic and technological conditions. External environmental factors exist at both the human and enterprise level. Just like trustor characteristics, they also exert their influence through the mutually decided, private or local rules and policies governing automated trust decision making.

For example, consider a situation where Enterprise A wants to enter into collaboration with other enterprises and establish an inter-enterprise collaboration for gaining mutual benefits. Enterprise A has evaluated all the other enterprises on the basis of trustworthiness and system trust. The positive evaluations motivate the manager of Enterprise A to make a positive decision regarding the participation of their enterprise in the collaboration. But, the manager has come across certain incidents of frauds in the domain of inter-enterprise collaboration through news. These incidents of recent frauds are independent of the current situation and the involved enterprises. But, still such social factors affect the trust decision making tendencies of the manager responsible for making decision regarding the participation of the Enterprise A in the collaboration.

At the human level, these factors might vary for initial and committed stages of trust. This is because of the reason that external environment factors keep on changing with time depending on the current situation. On the other hand, at the enterprise level, they might remain stable during the initial and committed stage. They will remain same if the mutually decided policies and rules governing automated trust decision making are not changed during the committed stage. Drastic social, economic and technological issues might force them to be changed.

3.3.4 Collaboration-Specific Metrics

Autonomous enterprises participating in the collaboration have their own individual objectives for participating in the collaboration. For example,

some of the enterprises participating in the collaboration have the objective of earning money, while others might have the objective of gaining reputation and customer satisfaction.

The target objective provides a specific perspective for the trust development. The perspectives help in deciding angel or viewpoint for trust development towards the trustee. There are different perspectives such as service [23, 33, 48, 63], organizational [33, 48, 63], social [33, 48], economical [33, 48], psychological [62, 63], behavioral [33, 48, 62, 63] and technological [33, 48]. For example, the collaboration where the objective is to make profits and earn money, the perspective for trust formation is economic. Thus, the perspective and objectives behind the collaboration play significant role in the establishment and working of the inter-enterprise collaborations. These objectives and perspectives vary in nature specific to the involved enterprises. Therefore, it is important that comprehensive model of trust addressing inter-enterprise collaborations should address multi-objective and multi-perspective nature of trust [33, 48].

The different metrics plays a key role in the human cognitive model for trust decision making discussed in Section 3.5. All the above mentioned different metrics of trust decision making influences trusting beliefs of human users. In the next section, different strategies of human trust decision making are discussed. The discussed theories also contribute in the development of the trust relationship development model from human perspective (see Section 3.5).

3.4 Strategies in Human Trust Decision Making

The process of human trust decision making is a complex phenomenon, as it is influenced by different aspects such as sociological, personality, psychological, economical and physiological. The different startegies presented in this section, explore and discuss different renowned strategies of trust from the disciplines of psychology, business, social science and computing. These strategies are analyzed and applied to inter-enterprise collaboration environment. The presented strategies are essential for studying human trust behavior which will in turn help in developing human cognitive model of trust decision making in context to inter-enterprise collaborations.

As previously mentioned, trust decision making involves situations including collaborations with unknown or little known entities. Such situations are dominated by risk and uncertainty. The risk and uncertainty is created due

to vulnerable situation endangering assets such as reputation and money. In such situations, human users experience mixed feelings. They do not want to risk the potential possible gains out of the collaboration and at the same time even do not want to suffer losses. Therefore, humans make use of some logics providing confidence to them for making decisions in such situations. These logical and rational thinking employed in such a situation is governed by human behavior, information and its presentation formats. To fulfill this, human behavioral and cognitive strategies influencing human trust decision making must be studied and applied.

I have selected important strategies considering the scope of the thesis. The main aim of the thesis is to design trust decision expert tool for facilitating human trust decision making in inter-enterprise collaborations. The supported reasons behind the presented strategies are: 1) inter-enterprise collaborations involves humans in certain queries and mentioned strategies involve behavioral and cognitive aspects of human so there is a clear connection between the presented strategies and trust decision making; 2) trust is affected by several internal and external factors of the expert tool system and the mentioned strategies also discuss similar aspects in detail.

3.4.1 Human Behavioral Strategies

Human behavioral strategies address social, economic, psychological and cognitive factors governing human behavior. The discussion on human behavior strategies aims at sketching human behavior and its underlying motivations from the standpoint of making decisions in the risky and uncertain situations in inter-enterprise collaborations. The process of human decision making traverses from cognitive to behavioral state through three inter-related activities: intelligence, design and choice [60]. The whole process starts with intelligence activity which involves gathering and processing of the relevant information, followed by analyzing the likely outcomes of the decision against the goals in the design activity. Finally, the process culminates with making final decision based on analysis done during the design activity.

Human behavior strategies help in understanding the guiding factors behind human decision making. The guiding factors takes human beings all the way from cognitive to behavioral state. Understanding human factors governing decision making contributes to the domain of inter-enterprise collaborations for handling special cases requiring human intervention for trust decision making. Different human behavior strategies shown in Figure 3.4 are presented below.

Social Expectancy Theory (SET) states that human beings tend to enter into contractual relationships with other entities with the aim of gaining

in future, in return of their inputs [64]. The motivation of gaining benefits, for themselves, in return of their investments guides human beings to enter into relationships with other entities. This theory is applicable in the case of establishment of relationship with previously known or unknown entities. Establishing relationship with prior unknown entities generates the need for trust [64]. The expectation about making benefits out of the mutual relationship turns out to be one of the pillars for generating trusting behavior.

In the domain of inter-enterprise collaborations, SET is also applicable whenever enterprises need to make decisions regarding their continuation in the ongoing collaboration. However, the decision regarding continuation involves other aspects as well arising from experiences gained by direct interaction with the other collaborating enterprises. Therefore, SET is one of those aspects affecting trust decision making while making continuation decision.

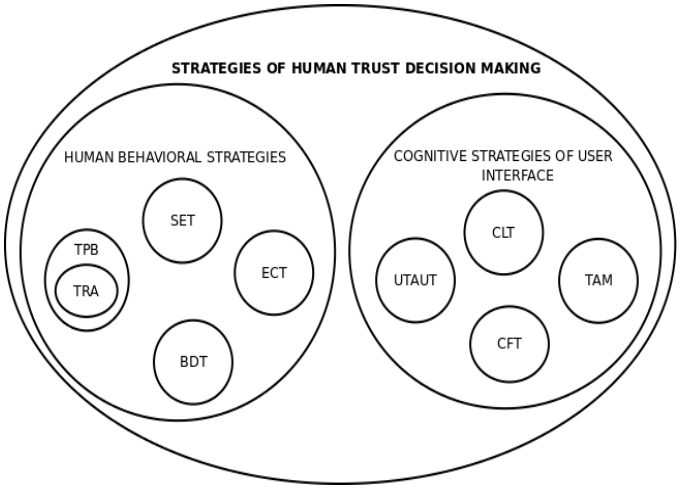

Figure 3.4: Different Strategies in Human Trust Decision Making.

Behavioral Decision Theory (BDT) states that human beings make decisions by incorporating probabilistic weighing of one entity over the other. This theory, which relies on traditional decision making patterns, is used in economic transactions where human beings weigh risk against gains. The value of the probability generates the perception about the utility of the decision outcomes. The perception about utility influences human cognitive thinking while making their decisions [3].

The high probability of gaining instead of losing due to the inherent risks motivates the human beings to respond positively to the decision of joining the collaboration in the case of previously unknown or little known enterprises. This motivation creates expectations of attaining positive outcomes

from the collaboration. These positive expectations turn out be the basis of generating trust between the collaborating enterprises. BDT also influences trust decision making regarding continuation in an ongoing inter-enterprise collaborations just like SET.

Theory of Planned Behavior (TPB) states the logic behind human decision making and the factors contributing to it [64]. TPB is the extension of Theory of Reasoned Action (TRA). TRA proposed two factors contributing to the logical flow of human decision making. According to TRA, factors such as belief about the behavior and subjective norms lead to the formation of trusting intentions. The trusting intention later ultimately culminates into actual human behavior. Beliefs lead to the formulation of specific attitude towards behavior. As mentioned previously, attitude towards behavior is defined as the positive or negative viewpoint towards the consequences of the behavior depending on their desirability. On the other hand, subjective norms are formulated based on the social pressures or beliefs about the consequences of the behavior in view of the society. TPB added a third dimension to TRA called perceived behavior control. This additional parameter denotes the belief of the users about the control that they will have in the given situation. The perception about the control also affects the behavior intention and thus actual behavior.

TPB and TRA based human decision making logical flow is also applicable to inter-enterprise collaborations. In the case of previously unknown or little known enterprises, the experiences gained from the direct interaction with the collaborating enterprises also affects trust decision making during the continuation stage. However, in the case of previously known enterprises, past collaboration experiences also affect trust decision making during the joining of the collaboration as well.

Expectation Conformation Theory (ECT) highlights the human psychology of formulating positive expectations from the consequences of their behavior. The expectations can be either positive or negative depending on the perception of human users regarding behavioral outcomes. The expectations are built as a result of the attitude of the human user towards the actual behavior and its outcomes. They impact the behavioral intentions leading to actual accomplishment of the expectations through human behavior.

ECT is applicable to the establishment and continuation phases in the domain of inter-enterprise collaborations. In the case of previously unknown and little known enterprises, the belief about confirmation of the expectations govern the decision making during the establishment phase. On the other hand, experiences gained from the direct interactions with the collaboration enterprises become dominant factor during the continuation stage in inter-enterprise collaborations. However, it brings the element of trust in

human decision making for future collaborations with the previously known enterprises.

3.4.2 Cognitive Strategies of User Interface

The cognitive strategies provide insight into human preferences about format and quality of the presented information required for human trust decision making. Information presentation formats adds quality of the information which plays important role in designing functional and affective user interfaces required for decision making in the online environment [12]. The importance of user interface design in terms of information presentation is considered as one of main factors behind the success of B2C e-commerce. Therefore, the presented cognitive strategies can be used for designing user interfaces of expert tools in the domain of inter-enterprise collaborations.

The presented cognitive strategies are also applicable in context of choosing information formats and designing user interfaces in the domain of inter-enterprise collaborations as well. As noted before, quickness and efficiency in establishing inter-enterprise collaborations are one of the desired features [48]. Reducing human intervention through automation is one of the solutions for providing efficiency to the establishment and operation of inter-enterprise collaborations. But, even the use of automation requires human intervention in unusual situations [49]. Effective user interface in terms of quality of the information and its presentation format is required in case of collaborations between previously unknown, little known and known enterprises. They serve to be the basis of trust formation towards the system and the ecosystem providing infrastructure for supporting the establishment and functioning of inter-enterprise collaborations. Therefore, understanding human psychology regarding preferred information formats and way information processing is done by humans is important for designing user interfaces in the domain of inter-enterprise collaborations. Different user interface cognitive strategies are shown in Figure 3.4.

Cognitive Fit Theory (CFT) and **Cognitive Load Theory** (CLT) state that the presentation of the information required for solving the task and the nature of the task itself significantly effects human performance [56, 59]. The inter-relation between information presentation formats and task itself helps in building the positive attitude towards the concerned enterprises. The inter-relation reduces the cognitive load on human for information processing which directly enhances their efficiency.

Hence, inter-relation should also be considered while designing user interfaces of trust decision expert tools supporting inter-enterprise collaborations. This will enhance the user performance in decision making for resolving the

task.

Unified Theory of Acceptance and Use of Technology (UTAUT) states that the user behavior and behavioral intention are affected by facilitating conditions, social influence, performance and effort expectancy [58].

In the case of inter-enterprise collaborations facilitating conditions, performance and effort expectancy are direct determinants of user behavior and usage intentions. Quality and positioning of the information enhancing the knowledge presentation formats serve to be the facilitating conditions in context with inter-enterprise collaborations. The satisfaction of the facilitating conditions will reduce the performance and effort required from the users. Thus, UTAUT has significant impact on designing user interfaces for decision making with regard to inter-enterprise collaborations.

Technology Acceptance Model (TAM) states that the perceived usefulness and ease of use help in the formation of behavior intentions thus culminating into actual behavior [61]. For example, human users can be termed as *"cognitive misers"*, who always strive to minimize the effort required for decision making as they are weak at integrating large amounts of information [14].

TAM plays a crucial role for designing user interface of expert tool. The suggestions made by TAM lead to the designing of optimum user interfaces having clarity in information presentation. Intuitive user interfaces and clarity in information presentation lead to ease of use and strengthening of perceived usefulness having positive impact on trust decision making.

In section 3.5, the cognitive model of human trust decision making and the trust relationship development model are presented and explained.

3.5 Trust Relationship Development Model

In the existing literature, different conceptual trust models have been proposed dealing with initial trust development in B2C e-commerce. These conceptual models discuss the role of trust development from the human perspective which in turn affects human trust decision making [3, 27, 52]. The research on human aspects of trust relationship development is one of the important research dimensions of B2C e-commerce. This is mainly because of the reason that B2C e-commerce implies buying and selling of the products and services by humans in the online environment. On the other hand, in the case of inter-enterprise collaborations, enterprises are explicitly involved in the exchange of products and services. But, the domain of inter-enterprise collaboration also implicitly involves the intervention of human users for decision making purposes. Due to implicit involvement of

human users, the domain of inter-enterprise collaborations lacks conceptual trust model that takes into consideration the human perspective. Keeping into consideration the weaknesses in the existing literature, I will first discuss the existing relevant conceptual models in B2C e-commerce and later adapt these conceptual models in the domain of inter-enterprise collaborations.

Salo et al. [52] have divided the factors that affect trust into two categories: external and internal. External factors include factors outside the online environment for example, consumer background, product or service characteristics, cultural and market differences and risk perceptions. Internal factors are the ones that are directly related with the online environment for example, general attitude to trustworthiness, reputation, perceived usefulness and ease of use and legislation. Past experience is part of both external and internal factors. The internal and external factors stated by Salo et al. match with the metrics of trust decision making which are in-turn related to trust development model. In the case of inter-enterprise collaborations, consumer background, cultural and market differences in addition to general attitude to trustworthiness fall under the category of trustor metrics whereas perceived usefulness and ease of use are user interface metrics. Similarly, all the other factors match with the trustee, collaboration specific and system trust metrics.

The concept of Elaboration Likelihood Model (ELS) has been extended to the domain of trust by Hung et al. [3]. The abilities and motivation of the trustor towards the situation at hand aids in the elaborating the available information. ELS give two routes for forming and changing the attitude - central and peripheral. Most of the factors affecting trust development fall within these two routes. Peripheral route includes processing of following information: reputation, website quality, disposition to trust, situational normality and structural assurances. This route is chosen in case of unknown or little known enterprises when limited information is available. This is particularly suitable for initial trust development. On the other hand, the central route involves scrutinizing website quality, ability, benevolence and integrity. This route is adopted in the case of known entities because it is dependent on the expriences gained from direct interaction. Elaboration of the central route involves careful rational analysis. The routes specified by ELS lead to the formulation of trusting attitude, finally leading to the actual behavior producing the outcomes. The model proposed by Hung et al. based on ELS matches with the requirements of inter-enterprise collaborations to some extent. First, the usage of two routes matches with the stages of the human trust development in the domain of inter-enterprise collaborations since its working maps with initial and committed stage of trust development. Second, the information elements governing trust attitude formation

fall under the category of different elements and metrics of trust decision making discussed in context to inter-enterprise collaborations. However, factors specified by Hung et al. does not completely match with either the category of elements and metrics of trust decision making (Section 3.2.1 and Section 3.3). Therefore, the model of Hung et al. does not completely fit in the domain of inter-enterprise collaborations.

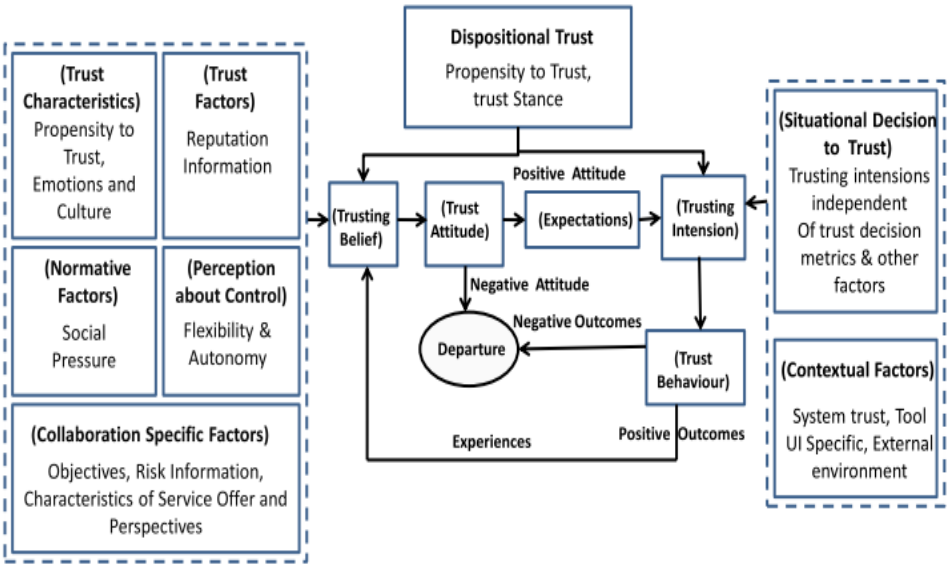

Figure 3.5: Cognitive Model of Human Trust Decision Making for Inter-Enterprise Collaborations.

Mayer et al. [27] gave two antecedents to trust: trustor factors and trustee factors. The trustor factors include propensity to trust whereas trustee factors includes ability, benevolence and integrity. Trustee factors leads to formulation of the perception about the trustworthiness of the target entity. A number of different factors effecting the formulation of trustworthiness are found in the trust literature. But; ability, benevolence and integrity formulate the high level classes for all the trust antecedents. For example benevolence is a high level class for all these trust antecedents such as: loyalty, openness, receptivity, availability, fairness, and reliability. The usage of propensity to trust, ability, benevolence and integrity are also considered as metrics affecting trust decision making in the domain of inter-enterprise collaborations [27].

Based on above discussed conceptual models in the domain of B2C e-commerce [3, 27, 52], I have proposed a trust relationship development model for inter-enterprise collaboration shown in Figure 3.6. The trust relationship

development model provides a comprehensive view of trust development in the domain of inter-enterprise collaborations. Trust decision making is an integral and important part of human trust development. The levels of human trust affects the decisions of the human user regarding the situation under consideration. Furthermore, the human decision of participating in the collaboration enhances or degrades the existing trust levels. Therefore, human trust decision making and trust development are strongly co-related with each other. Hence, I will first discuss the cognitive model of human trust decision making shown in Figure 3.5 before presenting the trust relationship development model.

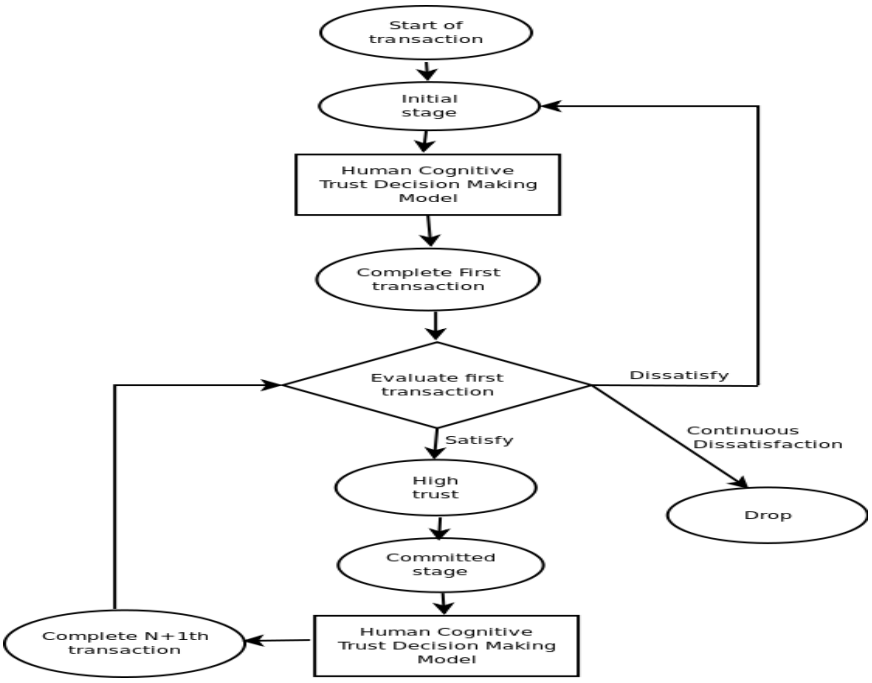

Figure 3.6: Trust Relationship Development Model for Inter-Enterprise Collaborations.

The cognitive model of human trust decision making is based on different elements of trust decision making (Section 3.2.1), trust decision metrics (Section 3.3) and strategies of trust decision making (Section 3.4). The basic human trust decision making process moves across different phases starting from trusting belief to trusting behavior. Dispositional trust, trustor, trustee, collaboration-specific and normative metrics in addition to perception about the control that the user has in the concerned situation facilitate the formation of the root of human trust decision making called trusting belief. Trusting belief leads to the formation of trust attitude. Trusting attitude

provides the basis for formulation of the expectations about the outcomes of the actual behavior. Positive expectations lead to the building of trust intentions of success, which ultimately leads to actual behavior. In addition to positive expectations, trusting intentions are also influenced by dispositional trust, contextual metrics and situational decision to trust. On the other hand, negative expectations lead to the dwelling of negative trust intentions leading to the departing out of the situation under consideration. Similarly, negative outcomes of the trusting behavior also forces the enterprises to departure. The positive behavioral outcomes influence trusting belief for future collaborations.

The conceptual model of trust for inter-enterprise collaborations has been presented in Figure 3.6. The conceptual model presents the hybrid approach for human trust development. The hybrid approach to trust formation is the combination of cyclic and staged trust formation approaches. The hybrid approach is developed to overcome the weakness of the both the existing development approaches. Furthermore hybrid approach accumulates the benefits of both cyclic and staged approaches.

Figure 3.6 presents the working of the trust relationship development model. At the start of the transaction, there is no or low trust especially in the case of previously unknown or little known enterprises. This stage is referred as initial stage of trust development. At this stage, cognitive model of human trust decision making comes becomes functional. The process of human trust decision making starts from trusting beliefs which are transformed into trust attitude with the input of relevant information required for decision making. The trusting attitude leads to the formulation of expectations from the outcomes of the trusting behavior. These expectations in turn leads to the building of the trusting intentions about taking the risks involved in the situation or not. These trusting intentions later actually culminate into trusting behavior leading to the first transaction with the target enterprise. The results of the transaction are then evaluated to proceed further. The satisfactory results lead to the strengthening the human trust for future transactions. The dis-satisfactory results lead to the departing out the decision of further collaborating with the target enterprise. The satisfaction of results brings the human trust to the next stage in the trust development process called committed stage. This input from the previous transaction together with the human decision strategy again comes into action leading to the next transaction. Again, satisfaction of the outcomes provides robustness to human trust whereas dis-satisfaction brings them back to the initial stage of trust formation now with low trust. On the other hand, dissatisfaction at any point leads to departing out of the relationship. This is how the working of the trust relationship development model goes on whenever human users

are involved in the process. Understanding of this model will help in rendering human approach to automated trust decision making which will lead to the success of the underlying system providing supporting services for the establishment and operation in the domain of inter-enterprise collaborations.

3.6 Summary

This chapter presents the human cognitive model and trust relationship development model for the domain of inter-enterprise collaborations. Both these models are based on the findings from the literature review of: different constituent elements, metrics and strategies of trust decision making in addition to approaches to human trust development in the online environment. The findings from all the before mentioned topical areas are mapped to the domain of inter-enterprise collaboration.

The next chapter presents the comparative analysis of three existing trust management systems against the findings of this chapter. Performing the comparative analysis is essential for evaluating the findings of this chapter in the domain of inter-enterprise collaboration against the process of automated trust decision making. Furthermore, it also helps in evaluating these systems in terms of the extent to which they satisfy human users as the trust decisions are being made in their behalf.

Chapter 4

Evaluating Trust Management Systems

Trust management system is an important element of the systems supporting inter-enterprise collaborations. Trust management is required for the stability and functionality of inter-enterprise collaborations. This chapter focuses on three different trust management systems: TrustCoM, ECOLEAD and Pilarcos. In Section 4.1, thesis presents three example trust management systems. Section 4.2 compares different trust management systems against the different human preferences in trust decision making presented in Chapter 3. Furthermore, all the presented trust management systems are also compared on three additional basis: focus areas, architectural foundation and system purpose.

4.1 Trust Management System

The management of trust is required as it enhances the motivation and willingness to cooperate with other unknown or little known enterprises. The Collaboration with little known or unknown enterprises creates a risky and uncertain situation leading to the need for the existence of trust and its management. Furthermore, the self-directed structure of inter-enterprise collaborations creates a need for trust management.

For inter-enterprise collaborations, the process of trust management is based on three entities: an ecosystem providing the infrastructure or platform for its establishment and operation, different enterprises providing the services and Internet as a channel providing basis for their existence and feasibility. All these entities constitute the fundamental elements required for the existence of inter-enterprise collaborations. Hence, trust management

systems must take into consideration all the aforementioned entities.

There are different trust management systems in existence supporting the working of inter-enterprise collaborations. The thesis discusses three trust management systems: TrustCoM, ECOLEAD and the Pilarcos trust management system. I have chosen the before mentioned trust management systems for comparison because all these trust management systems address the domain of inter-enterprise collaborations from the perspective of small and medium sized enterprises. These three trust management systems are mentioned several times as related work therefore, I discuss them in the thesis. Furthermore, there has not been a systematic comparison of these trust management systems. Before discussing them extensively I give their brief overview.

TrustCoM

TrustCoM is a European Union project that researches inter-enterprise collaborations. The main contribution of the TrustCoM project is the conceptual and architectural framework addressing trust, security and contractual aspects of inter-enterprise collaborations [62, 63]. TrustCoM is of the viewpoint that establishing and maintaining trust among enterprises in the inter-enterprise collaborations is one the significant challenge.

There are two trust decision points in the TrustCoM framework: joining the collaboration and, if required, adding a new enterprise to the collaboration during the operational phase [62]. The TrustCoM framework considers trust as a goal-based and temporal concept [62, 63]. Trust as a goal-based concept means that all the TrustCoM framework components: knowledge base, tools and architectural details aim towards establishing trust formation. Temporal nature of trust represents the evolution of trust with time. The intensity of trust reduces or increases due to direct interaction with the trustee enterprise over time.

ECOLEAD

ECOLEAD is also a European Union project aims to support inter-enterprise collaborations. ECOLEAD has proposed a platform-independent and secure ICT infrastructure for the establishment and operation of inter-enterprise collaborations [43]. The ICT infrastructure is plug and play in nature and follows pay-per-use and on demand model for the management of inter-enterprise collaborations. The main aim of ICT infrastructure is addressing interoperability, trust, security, transparency, and affordability [43]. ECOLEAD also recognizes the significance of existence of trust for the stability, functionality and feasibility of inter-enterprise collaborations.

Considering the scope of the thesis, ECOLEAD views trust from five perspectives: organizational, social, economical, technological and behavioral [33]. The trust management approach of ECOLEAD divides trust in two types: base trust and specific trust [33]. The base trust is represented as the pre-conditions which all the enterprises willing to collaborate need to satisfy such as organizational strength, capital, financial stability, technology standards, and financial standards. On the other hand, specific trust refers to the collaboration specific terms and conditions particular to the collaboration situation at hand. The collaboration specific terms and conditions required for the establishment of specific trust needs to be fulfilled by all the enterprises that are willing to collaborate. These conditions can be specific to one particular perspective or more than one aforementioned perspective. While the base trust is established during the building the ecosystem, specific trust is considered for each collaboration when trust formation among enterprises willing to collaborate needs to be assessed.

Pilarcos

Pilarcos is a project being carried out by CINCO group at University of Helsinki. The Pilarcos middleware aims to provide a solution to ecosystem evolution, interoperability and trust related problems arising in the establishment and operation of the inter-enterprise collaborations. The Pilarcos middleware considers trust and interoperability management as the biggest challenges in the domain of inter-enterprise collaborations. I have focused on the trust management system specifically.

In Pilarcos, trust management and trust decision making are handled by the Pilarcos trust management system, orginally developed in the TuBE sub-project. As previously mentioned, the Pilarcos trust management system performs automated local and context-aware trust decisions at two points: joining and continuing the collaboration. The trust decisions are made by producing risk estimations and comparing them to risk tolerance [47, 48]. As mentioned before, the risk estimates are based on reputation, whereas risk tolerance is based on the strategic importance of the collaboration to the business of the enterprise [47, 48].

The Pilarcos trust management system performs automated trust decisions according to pre-defined policies, which are local and decided mutually by all the collaborating enterprises during the establishment of collaboration. In addition, there are some mutually decided shared policies encoded in contracts. Automated trust decisions are performed in routine cases leading to either clear acceptance or rejection. While human users are prompted for trust decision making during cases that fall into gray area between routine accept or reject.

4.2 Comparison

Three different trust management systems: TrustCoM, ECOLEAD and Pilarcos, are compared based on the human preferences on trust decision making (Chapter 3), system purpose, architecture and focus areas. This comparison aids in providing a comprehensive view of the approach and working of the trust management systems. The focus areas represent the positions where these systems require trust management whereas, the system purpose helps in bringing out basic differences in the vision of these systems towards inter-enterprise collaborations. Furthermore, architecture of these systems gives the basic foundation of these systems, which aids in building the basis for understanding the high level working of these systems.

4.2.1 Trust Definition

All the three trust management systems have defined trust from their own perspective. The definitions of trust given by the different trust management systems helps in understanding their viewpoint towards trust and the way they deal with trust management.

In TrustCoM, *"trust is the intention to accept vulnerability (often inherent in VO), and based upon positive expectations of the intentions or behavior of another"* [63]. TrustCoM perceives trust from the psychological point of view. It follows the theory of encapsulated interest model of trust relationships [62, 63]. The encapsulated interest model of trust relations states that the motivation of satisfying personal interests creating mutual interdependence acts as the main force behind establishment of trust relationships between enterprises. The element of willingness to accept vulnerabilities by trusting others, emphasises that trust should not be considered similar to legal obligation. However, it also realizes the role of social factors in the establishment of trust. The social factors include the past behavior of the enterprises in collaborating with other enterprises, satisfying the made agreements and inclination in engaging in disputes.

ECOLEAD defines *"trust as the objective-specific confidence of a trustor to a trustee based on the results of fact-based assessment of trust level of the trustee"* [34]. The term 'objective-specific' means that ECOLEAD establishes trust among interested enterprises from different perspectives, such as social, economical, technological, behavioral and organizational. The perspectives chosen for trust establishment depend on the objectives and current situation under consideration. On the other hand, 'fact-based assessment' means that quantification of the trust levels is done based on the relevant factual charac-

Comparison Criteria	TrustCoM	ECOLEAD	Pilarcos
Trust [Definition]	*"Trust is the intention to accept vulnerability (often inherent in VO), and based upon positive expectations of the intentions or behavior of another."* [63]	*"Trust as the objective-specific confidence of a trustor to a trustee based on the results of fact-based assessment of trust level of the trustee."* [34]	*"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."* [49]
Types of Trust	Calculative [63], Competence [32], Relational [63], Intentional [62], Institutional [62]	Calculative [33], Competence [40], Relational [33], Intentional [33], Institutional [40]	Calculative[47], Competence [25], Relational[48], Intentional [47], Institutional [48]
Approaches to Trust	Cyclic	Staged	Hybrid
Focus [Areas]	(i) between collaborating enterprises and (ii) between enterprises and infrastructure	(i) between VBE members, (ii) between VBE members and administrators of VBE and (iii) between customer and VBE	(i) between collaborating enterprises and (ii) between enterprises and ecosystem
Architectural Foundation	Strategic partners entering EN satisfy acceptable policies for ecosystem.	Strategic partners entering VBE are already trusted.	Membership in the open service ecosystem is dynamic.
System Purpose	Framework addressing trust, security and contractual aspects	ICT infrastructure addressing interoperability, trust, security, transparency and affordability	ICT infrastructure supporting processes for automated collaboration management, interoperability and trust management aspects in addition to ecosystem evolution

Table 4.1: Comparison of Three Trust Managements Systems.

ters of the chosen perspective. In the case of technological perspective of the

performance of the network, for example downloading speed and number of severs are the factual characters for the fact-based assessment of trust levels.

As mentioned previously, the Pilarcos trust management system defines trust 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"* [49]. The definition given by Pilarcos is the most appropriate for the domain of inter-enterprise collaborations. The main supporting reasons are: 1) it explicitly mentions about all the entities and their role involved in the process of trust establishment; 2) it gives a holistic view by pointing out various risks and incentives involved in context to the current situation and 3) it is easy to interpret as compared to the definitions provided by TrustCoM and ECOLEAD.

4.2.2 Types of Trust

There are five different types of trust in context to trust decision making in inter-enterprise collaborations (see Section 3.1) are presented below.

Calculative trust is defined as the comparison of perceived risks against potential gains for trust decision making. In TrustCoM framework literature, there is no explicit reference to the use of calculative trust. At the same time it has been mentioned explicitly like *"risk is the main basis of decisions"* and *"risk needs to be quantified and judged by business decision makers"* [63, pg. 2,4]. These statements clearly show that TrustCoM focuses on calculative trust.

Similar to TrustCoM, ECOLEAD also considers calculative trust for trust decision making. For example, ECOLEAD mentions that *"trustor must know and have access to trustee's information such as financial, economic strategical plans, gains and losses from participation in VO"* [33, pg. 17]. Furthermore, metrics in the hierarchical trust development approach represents gains and losses involved in the collaboration. For example, if trust in the inter-enterprise collaboration is considered from technological perspective and downloading speed is one of the important factors for trust decision making, then the values of downloading speeds represents the possibility of anticipating gains and losses for trust decision making.

In contrast to TrustCoM and ECOLEAD, the Pilarcos trust management system contains data processing component which is responsible for making calculative trust decisions based on producing the risk probabilities and comparing risks versus benefits in any given situation [47, 49]. Hence, the calculative trust is one of the primary pillars for trust decision making in the Pilarcos trust management system.

Relational Trust refers to the formation of trust based on knowledge attained over time based through direct interaction with the trustee.

The TrustCoM framework employs relational trust by performing monitoring of the operation of the collaboration. In the TrustCoM framework, the application service providers provide status information to the Business Process (BP) Enactment at the checkpoints during the operation of the collaboration [32]. The provided status information acts as the monitoring information. In normal cases, this information is provided to Enterprise Network (EN) during the dissolution phase to be used for the establishment of future collaborations. But, in the case of severe disobeyance and deviations, the status information acts as the basis for taking actions against the concerned enterprise in the ongoing collaboration.

The ICT infrastructure of ECOLEAD also relies on relational trust. The information required for relational trust is gained from monitoring of the operation of the collaboration. A Business Process (BP) engine performs the monitoring of the operation of inter-enterprise collaboration [40]. The results of the monitoring are stored by the Virtual Breeding Environment (VBE) which are later used by the enterprises during the establishment of future collaborations.

The Pilarcos trust management system also considers relational trust by monitoring the inter-enterprise collaboration during its operational phase [31]. Every collaborating enterprise has a monitor which is responsible for performing the observation of the inter-enterprise collaboration for significant deviations and violations of the contract terms. Therefore, it plays important role in trust decision making process during the establishment of the future collaborations and continuation phase of the current inter-enterprise collaboration.

Competence trust refers to trust based on the capabilities, skills and expertise of the enterprise in addition to the quality of service.

The TrustCoM framework considers competence trust for trust decision making. The capabilities and skills of the enterprise and quality of service acts as one of main factors for the selection of potential partners for the collaboration [62, 63]. Hence, competence trust is used by the TrustCoM framework in its functioning.

In the case of ECOLEAD, the information about the capabilities and reliability in terms of quality of service provided by the enterprises is acquired during the establishment of base trust via a base trust questionnaire filled out by the enterprises willing to engage in collaborations in future and monitoring of the operation of the collaboration [33]. The ICT infrastructure considers

these aspects under the organizational and behavioral perspectives during the establishment of specific trust. Therefore, they also consider competence trust indirectly for the trust decision making.

The Pilarcos trust management system uses reputation information as a means for determining information required for competence trust [48]. The monitors and third party reputation networks provide information about quality of service provided by the enterprise, which indirectly reflects the capabilities and skills of the enterprises. Hence, the Pilarcos trust management system also considers competence trust for trust decision making regarding the collaboration.

Intentional trust refers to the intentions of the other party to be trusted in addition to adherence to the made commitments and promises (Section 3.1).

The TrustCoM framework uses intentional trust for trust decision making and trust management. In addition to the factors affecting selection of potential partners for competence trust, the TrustCoM framework also considers information about integrity and benevolence of the enterprises [62]. The information about past experience of the enterprise regarding engaging in collaborations, operating under contracts and tendency to engage in disagreements provides basis for intentional trust in the working of inter-enterprise collaborations [62, 63]. This information is also gained by the monitoring of the collaboration during the operational phase.

The ICT infrastructure of ECOLEAD considers the intentional trust under behavioral perspective for trust decision making. In addition to monitoring, the information about intentional trust comes from the base trust questionnaire filled by all the enterprises during their entry in the EN [33]. Specifically, integrity, benevolence, quality and adherence to delivery dates provides information required for intentional trust.

The Pilarcos trust management system also uses intentional trust for trust decision making regarding inter-enterprise collaboration. Similar to competence trust, reputation information gained from monitors and third party reputation networks provides information about integrity and benevolence required for intentional trust for calculating risk probabilities aiding in trust decision making [47, 48].

Institutional Trust refers to governance and non-governance factors of trust such as contracts, legal terms and conditions, shared beliefs and standards facilitating trust among the enterprises.

As stated before, the TrustCoM framework provides support to the General Virtual Organization Agreement (GVOA) and Service Level Agreements

(SLA) contracts governing the operation of the inter-enterprise collaborations. In addition to this, the framework also considers similar communication standards to be one of the dimension for measuring trustworthiness [62]. Therefore, the TrustCoM framework employs institutional trust in its working.

The ICT infrastructure of ECOLEAD also uses institutional trust for supporting the functioning of inter-enterprise collaborations. The e-contracts, containing rules and regulations regarding governing of the collaborations, are established during the creation of the virtual organizationÌ£ [40]. The beliefs of the participating enterprises also come under scrutiny during the negotiation phase of the establishment of the inter-enterprise collaboration. On the other hand, the plug and play infrastructure provides synchronization of processes and systems of the participating enterprises [43].

Similar to the other two systems, the Pilarcos infrastructure also relies on the usage of institutional trust. The participating enterprises mutually negotiate and establish policies and contracts which will govern the trust decision making and operation of the inter-enterprise collaborations. All the shared policies are encoded in the contract. The Pilarcos infrastructure also ensures checking of shared standards and beliefs during the search and selection of potential partners during the population and negotiation phase [48].

4.2.3 Approaches to Trust

The approaches to trust refers to trust development during the uncertain and risky situations. The approaches to trust development deal with the process of trust evolvement during the operation of inter-enterprise collaborations. Understanding the process of trust development in the case of uncertain and risky situations is important because the collaborations in open service ecosystems usually involves possibilities of interacting with previously unknown or little known enterprises.

TrustCoM framework follows a cyclic approach to trust formation [62, 63]. The TrustCoM framework performs monitoring of the inter-enterprise collaboration during the operational phase. Whenever any enterprise disobeys the agreed rules and regulations or violates the reputation badly, then all the policies stated in the GVOA and SLA are activated to deal with this situation. The necessary actions activated are such as increasing the level of monitoring, restricting access control, fining or expelling the concerned enterprise from the inter-enterprise collaboration. Furthermore, all the other collaborating enterprises are updated about the misbehavior of the concerned enterprise. All the aforementioned stated actions are carried out during the ongoing collaboration in order to avoid any further risks and security breaches [62, 63].

The main focus of the TrustCoM framework of incorporating the breach and misbehavior information by taking the necessary measures to deal with created situation during the operational phase of the ongoing collaboration makes it cyclic in nature.

ECOLEAD follows a staged approach to trust formation. The establishment of specific trust among willing enterprises is done in a hierarchical manner which makes it stage based in nature [33, 34]. The process of trust establishment starts by specifying the objectives which are further characterized into different perspectives depending on the objectives. Then, the selected perspective is further divided into the requirements needed for satisfying the applicable perspectives. The final stage specifies the value measuring scales and constraints for the measurable elements stated in the previous hierarchical stage. Each perspective will have its own hierarchical stage flow. The flow of one perspective can be further be divided into different staged flows based on different requirements and measurable elements. On the other hand, non-measurable elements are converted into measurable format using some logical strategy based on the results of the individual assessment. The ICT infrastructure of ECOLEAD performs monitoring of the behavior of the collaborating enterprises against the measurable elements used for trust establishment. The results of the monitoring of the operation of the inter-enterprise collaboration are updated to the VBE during the termination phase. This information is used during the establishment of future collaborations. This information is not incorporated during the operation of the ongoing inter-enterprise collaboration. Therefore, it is not cyclic in nature.

The Pilarcos trust management system follows a hybrid approach to trust formation during the establishment and operation of the inter-enterprise collaborations [47, 48]. As already noted, there are two trust decision points where the Pilarcos trust management system becomes functional: joining and continuing the collaboration. The first trust decision point is equivalent to initial stage of trust development. The open service ecosystem makes the initial stage represent either no or low trust. In the case of Pilarcos also, there is no trust in the case of previously unknown enterprises and low trust for the little known enterprises. Therefore, establishment of the collaboration with the previously unknown or little known enterprises is characterized by initial stage of trust development. On the other hand, second trust decision point is similar to committed stage, where decision is made based on the direct interaction experience with the concerned enterprises. This continuation point comes whenever more resources need to be committed or significant reputation changes occur during the collaboration. The Pilarcos middleware also performs monitoring of the operating inter-enterprise collaboration using monitors. Whenever significant deviations in terms of behavior

and contractual commitments are noticed, all the participating enterprises are notified and necessary actions are taken during the working of the collaboration itself. In the case of significant deviations, the responsible enterprises can even be replaced by new enterprise in the inter-enterprise collaboration. The information about deviations constitutes local reputation information. The local reputation information is fed to the reputation management system of the Pilarcos trust management system during the termination phase. This local information together with external reputation information is considered for risk evaluations for future establishment and operation of inter-enterprise collaboration. Thus, local reputation information, which is more credible, serves input for trust decision making during the initial stage for the little known or unknown enterprises. The usage of local information for handling deviations during the collaboration makes the working of the Pilarcos trust management system cyclic in nature. On the other hand, two decision points representing the two different stages of trust formation makes the Pilarcos trust management system staged in nature also at the same time. Therefore, it can easily interpreted that the working of the Pilarcos trust management system is hybrid in nature.

4.2.4 Focus Areas

Focus areas of trust management are defined as the areas where trust management is performed by different systems responsible for managing trust during the establishment and operation of the inter-enterprise collaborations. It is required to understand the different trust management areas and the process followed to manage trust by different systems. This will help in having comprehensive view of working of different trust management systems.

TrustCoM mainly focuses on two areas: between the collaborating enterprises and between the enterprises and the infrastructure [62, 63]. The TrustCoM framework focuses on trust, security and contractual issues between the collaborating enterprises during the establishment and working of inter-enterprise collaboration. Different enterprises enter the Enterprise Network (EN) by accepting the policies, terms and conditions of the TrustCoM ecosystem. All the enterprise register the services that they want to offer with the EN registry. Whenever an enterprise initiates the collaboration process, then automated search is performed over the EN registry for selecting the potential partners of the collaboration. Trust between the potential partners is established on the basis of business process models, contracts, previous behavior in terms of capabilities, integrity and benevolence. Security is based on security tokens, roles based access control and policy based security [62, 63]. The contractual issues are handled by mutually established GVOA

and SLA which are discussed later in Section 4.2.7. On the other hand, the TrustCoM framework is also focuses on trust between enterprises and infrastructure. This is ensured by publishing the framework and minimizing the flow of important information [62, 63].

ECOLEAD mainly studies trust among organizations within VBE, desiring to collaborate with other enterprises. There are three focus areas of trust in ECOLEAD are trust between VBE members, between VBE members and its administrations and between customer and VBE itself [33]. Trust among VBE members is based on requirements of the specific trust. The trust among VBE administration and constituting enterprises is based on components, policies and value system measurement techniques of VBE in addition to trusting the VBE as a whole. Customers represent either the enterprises who create the opportunity in the market or consumers of the product produced by inter-enterprise collaborations.

Pilarcos has two main focus areas concentrating on issues between collaborating enterprises and between the ecosystem and the constituting enterprises [48, 51]. The trust among collaborating enterprises is mainly carried on during the establishment of inter-enterprise collaborations and during the operational phase if the need for replacing an enterprises appears. Trust is mainly established by comparing risk probabilities against risk tolerance. On the other hand, trust among ecosystem and enterprises is also implicitly managed based on the established rules and regulations of the ecosystem. Even though, an open service ecosystem is used which has dynamic membership but, enterprises publishing the service offers and retrieving the services still need to satisfy or follow the rules and regulations of the ecosystem. The enterprises who violate these rules and regulations are thrown out of the ecosystem for ensuring safe and successful inter-enterprise collaborations.

4.2.5 Architectural Foundation

Architectural foundation defines the basic foundation of the existence and working of the different trust management systems. I differentiate the different trust management systems on this in order to understand the basic foundation of these systems which aids in building the platform for conceiving the high level working of these systems. The architectural foundation of the all the three trust management systems is different.

In the case of the TrustCoM framework, any enterprise desiring to offer a service or use the services provided by enterprises in EN can become part of EN. The only criteria that governs the entry of the enterprises is the rules and regulations of the TrustCoM framework regarding service offer publishing and its usage. Therefore, the strategic partners entering EN must satisfy

the policies stated by it, but they are not trusted by default[62, 63]. The required trust is later established among the collaborating enterprises during the establishment and negotiation phases.

In ECOLEAD, the strategic partners are required to fill the questionnaire testing base trust criteria for gaining entry in the VBE [33]. The base trust questionnaire filled by all the enterprises contains questions covering different perspectives required for trust establishment between the collaborating enterprises, administrator and customers such as organizational strength, community participation, community compliance, financial stability, ICT infrastructure, technology standards, platforms, VO collaboration behavior and reliability. Therefore, the enterprises available for establishing inter-enterprise collaborations are already trusted during their entry in VBE. However, as previously mentioned, the collaboration specific trust is established later when enterprises actually need to collaborate with each other.

In contrast, the Pilarcos infrastructure is more advanced in its approach because it considers the open and distributed environment for the establishment and operation of inter-enterprise collaboration [48, 51]. The membership in the open service ecosystem is dynamic. The dynamic membership means that the any enterprise can any time join the ecosystem by satisfying its terms and conditions regarding publishing and using of the services. But, at the same time any enterprise can also be shut out of the ecosystem through a bad reputation in case of its engagement in significant deviations and disobeyance of rules and policies.

4.2.6 System Purpose

System purpose defines the objectives of the trust management systems. Even though all the three trust managements systems aim to facilitate the trust related issues in the establishment and functionality of inter-enterprise collaborations, still they vary slightly in their system purpose. For example, establishment of interoperability among collaborating enterprises is not a priority in the case of ECOLEAD [43] while it is considered important by Pilarcos [48].

The purpose of TrustCoM is to propose a framework addressing trust, security and contractual aspects of inter-enterprise collaborations. TrustCoM handles these issues by applying measures such as role based access control, constant monitoring, reputation management and policy based security [42, 62, 63]. All these measures aim at reducing and managing the risks inherent in VO, which is the main basis of the made decisions.

The ICT infrastructure proposed by ECOLEAD aims at addressing interoperability, trust, security, transparency and affordability factors for easing

the establishment and operation of inter-enterprise collaborations [42, 43]. The trust is dealt through the previously discussed base and specific trust during the establishment of the VBE and inter-enterprise collaboration. Interoperability is considered only as an "enabler" of the collaborations and not a priority. The ICT infrastructure deals with security in terms of authentication, authorization and accountability. The transparency is brought into the picture by bringing in the clarity to the process of measurement of trust. The pay-per-use and on-demand model of ICT infrastructure addresses the affordability factor.

Lastly, Pilarcos proposes an ICT infrastructure supporting the processes of automated collaboration management, interoperability and trust management issues in addition to ecosystem evolution [24, 48]. The Pilarcos middleware automates all the activities involved in the inter-enterprise collaboration life cycle right from establishment of the collaboration till the termination. It performs automated search for potential partners upon receiving the initiation request from the initiator. It automatically handles all the three different types of interoperability: semantic, technical and pragmatic. In addition to interoperability management, it also handles e-contracting and trust management issues arising during the establishment and operation of inter-enterprise collaborations. Furthermore, the Pilarcos infrastructure automatically manages ecosystem evolution. As noted before, Pilarcos runs in the open and distributed environment where the membership is dynamic in nature. It efficiently, seamlessly and transparently aims to automate the process of dynamic membership.

4.2.7 Trustor Metrics

Propensity to Trust

The propensity to trust is defined as the characteristics which make the enterprise or human risk-seeking, risk-neutral and risk-aversive. Propensity to trust is crucial in the process of trust decision making since it reflects the willingness of trustor; either human or enterprise; to enter into collaboration. Hence, propensity to trust affects the process of trust decision making in inter-enterprise collaborations.

In the case of the TrustCoM framework, GVOA and SLA contracts reflect propensity to trust [9, 62, 63]. The GVOA contains the policies that give the general legal framework governing the working of the inter-enterprise collaboration. On the other hand, SLA consists of the policies providing the legal framework pertaining to each service provided by the collaborating entities.

In the ICT infrastructure of ECOLEAD, the e-contracts and criterion

Comparison Criteria			TrustCoM	ECOLEAD	Pilarcos
Trust metrics	**Trustor metrics**	Propensity to Trust	General Virtual Organization Agreements (GVOA) & Service Level Agreements (SLA)	Criterion governing specific trust	Policies and contracts
		Emotions	Not considered in automated functioning but present in user decision making process	Not considered in automated functioning but present in user decision making process	Trust decision expert tool
		Culture	Business Process Model (BPM) defining different roles & interactions among them	Depends on the administrator	Business Network Model defining different roles & interactions among them
	Trustee metrics	Reputation	• Through characteristics of the service mentioned in the published service offer • Information about the past behavior of the enterprises stored with the Enterprise Network (EN)	• Base trust established when enterprises enter VBE through a questionnaire • VBE storing information about the past behavior of the enterprises in the earlier collaborations	Experiences gained from earlier collaborations, first hand information from monitors and shared through reputation networks. The reputation information is represented in the form of assets: monetary, reputation, satisfaction & control.
	Contextual metrics	System Trust	GVOA, SLA, communication standards, monitoring, contract negotiation possibilities & avoidance of information transmission	Hierarchical approach to specific trust, EN consists of enterprises certifying base trust, & monitoring	Contract, possibility of contract negotiation, existence of interoperability measures, & monitoring
		User Interface	Portlets for interaction with user	Portlets for interaction with user	User interface of trust decision expert tool
		Environmental Factors	Social context	Social perspectives	Contextual repository
	Collaboration-specific metrics	Perspectives	Psychological, Social & Behavioral perspectives	Organizational, Economical, Social, Technological and Behavioral perspectives	Services, Economical, Technological, Behavioral & Risk analysis of threatened assets.
		Objectives	Shared and Enterprise specific objective	Shared and Enterprise specific objective	Shared and Enterprise specific objective

Table 4.2: Comparison of Different Systems against Metrics of Trust Decision Making.

governing the operation and establishment of trust during the establishment of the collaboration acts as the propensity to trust [40]. The policies and contracts are negotiated by all the enterprises during the VO formation phase. On the other hand, the criterion governing trust establishment is based on the perspective towards trust formation.

In contrast, the policies and contracts established during the negotiation phase act as the propensity to trust in the case of Pilarcos [21, 22, 25]. The contract is defined as the active and distributed agent containing meta-information constituting of all the rules and regulations responsible for dynamically governing the established virtual enterprise [21, 25]. All the collaborating enterprises have their copy of the contract which has all the mutually decided policies encoded in it. It uses policies for evaluating risk, tolerance, automated trust and interoperability management in addition to managing reputation information. For example, the contract contains the ranges governing automatic acceptance and rejection during automated trust decision making.

Emotions

Emotions refer to the cognitive approach to trust decision making. They are mainly responsible for governing the trust decision making in risky situations. They formulate perceptions about the available information and situation. Hence, they affect the process of trust decision making (see Section 3.3.1).

The TrustCoM framework involves eLearning portlet; a kind of user interface; in a scenario demonstrator helping users in finding best suitable service [41]. Emotions of the human users come into picture through these portlets.

The ICT infrastructure of the ECOLEAD, provides support for portlets for interaction with the users [43]. In their implemented test prototype providing prototype service for partner search and selection, they have web and mobile portal for presenting the list of potential partners for the collaboration. The portlets involves human users in trust decision making. Hence, emotions come into picture.

In Pilarcos, the trust decision expert tool implemented as a part of the thesis brings humans and their emotions in the process of trust decision making. The emotions of the users can be affected by the information content and way it is presented. The emotions are also affected by recent past experiences which might completely unrelated with the trust decision making as a whole. The trust decision expert tool has been explained in detail in Chapter 5.

Culture

Culture is defined as the personality trait of a trustor that can be any enterprise or a human, affecting the process of trust decision making (see Section 3.1). Culture plays significant role as it directly affects the trust decision

making process in inter-enterprise collaboration. Culture is represented differently by different trust management systems.

In TrustCoM framework, Business Process Model (BPM) represents the culture for trust decision making in inter-enterprise collaboration [62, 63]. BPM is defined by the initiator enterprise who wants to establish the collaboration for gaining benefits from the opportunistic situation. The initiator enterprise defines the BPM in terms of the business processes and roles together with their functional requirements that are required to be performed for achieving the goals of the collaboration.

In ECOLEAD, administrator of the trust management system is responsible for defining the culture through a process call called "business opportunity characterization" [51]. The business opportunity characterization defines the roles that need to be performed by the enterprises in inter-enterprise collaboration. Therefore, business opportunity characterization defines the culture for trust decision making in ECOLEAD.

In Pilarcos, Business Network Model (BNM) defines the culture for trust decision making in inter-enterprise collaborations [21]. BNM defines the structure of the virtual enterprise in terms of the roles and interaction among them in addition to the policies based on the legal and regulatory systems of the strategic business domain under consideration.

4.2.8 Trustee Metrics

Reputation Information

Reputation information is defined as the knowledge about the past and present behavior of the enterprise [33, 48, 52]. The reputation information influences the process of trust decision making since it leads to prediction of future behavior of the enterprise based on its past and present behavior information. Moreover, it helps in the assessment of the trustee in terms of ability, benevolence, integrity and predictability required for the establishment of trust between collaborating enterprises.

In the case TrustCoM framework, reputation information is gained from two sources: information contained in the published service offer and from EN [62, 63]. The reputation is represented in the form of quality of service, time, cost, integrity, consistency, capabilities, benevolence and past experience of operating under collaborations or contracts in addition to engaging in disputes. In the case of unknown enterprises, trust establishment is based on the information about quality of service, cost and time mentioned in the service offer. Based on this information SLAs are generated during the VO formation phase. The established inter-enterprise collaboration is monitored during the operation phase. The monitoring is done for ensuring the

cost, time, security and quality of service commitments provided by the service against the established SLA. The information of significant deviations is recorded with EN at the end of the collaboration, to be used for establishment of the future collaborations.

The ICT infrastructure of ECOLEAD also relies on two sources for reputation information: base trust and VBE [33]. In the case of a new enterprises entering VBE, the reputation information is gathered via base trust questionnaire. It collects general reputation information about such as organizational setup, financial stability, past experience of operating under collaborations and reliability. In addition to this, results of the monitoring of the enterprises and the collaboration during the operational phase are stored by the VBE. The VBE provides this information to enterprises during the establishment of the future collaborations.

The main sources of reputation information are the experiences gained from earlier collaborations in the case of Pilarcos [48, 49]. The first hand reputation information is gathered by the monitors during the monitoring of the collaborations. In addition to local reputation information given by monitors, external reputation information shared by third party reputation networks is used for trust decision making regarding the participating in the collaboration during the joining and continuation. Both the local and external reputation information is scaled down to uniform format of number of experiences on a scale from major negative to major positive (see Section 2.4). The reputation information is represented through effects on assets: monetary, reputation, satisfaction and control.

4.2.9 Contextual Metrics

System Trust

System trust broadly refers to the beliefs or assumptions of the trustor about the normality of the situation, non-governing factors in addition to governmental and legal impersonal structures. System trust helps in promoting transparency, which in turn helps in generating trustworthiness among unknown, little known and known enterprises in the uncertain and risky situations. As previously mentioned, they are of three types: structural assurances, situational normality and facilitating factors (see Section 3.3.3.1).

The existence of GVOA, SLA, communication standards, monitoring, contract negotiation possibilities and avoidance of information transmission act as factors constituting system trust. Both GVOA and SLA are discussed in propensity to trust. Both these types of contracts together handle the overall functioning of the inter-enterprise collaboration. Furthermore, the monitoring the operation of the inter-enterprise collaboration is done for en-

suring the cost, time, security and quality of service commitments made by the enterprises during the establishment of the collaboration. TrustCoM framework also provides the possibility of negotiating the terms and conditions of the contracts during the establishment phase of the collaboration. Instead of transmitting the information, TrustCoM believes in having all the required information with all the participating enterprises before the collaboration becomes operational.

Contracts, contract negotiation possibility, hierarchical approach to trust formation, the established trustworthiness of the EN member enterprises and monitoring acts as the constituents of system trust in the case of ECOLEAD. As mentioned in the case of TrustCoM, contracts are enacted among collaborating enterprises through negotiation. Furthermore, all the strategic partners available for establishing the inter-enterprise collaboration are already trusted. All the enterprises who desire to enter the EN and gain benefits by collaborating with other enterprises, have to satisfy the base trust conditions such as organizational strength, financial stability and technological standards. Moreover, the hierarchical and systematic approach to trust formation during the establishment of inter-enterprise collaboration promotes transparency in the working of the infrastructure. The existence of monitoring of the operation of the inter-enterprise collaboration and the collaborating enterprises for checking misbehavior and deviations also promotes trustworthiness.

Similar to ECOLEAD and TrustCoM, contracts and possibility of contract negotiation also exists in Pilarcos. As noted before, contracts are created and negotiated during the negotiation phase of the establishment of the inter-enterprise collaboration. The contract negotiation is done in several iterations until all the collaborating enterprises are satisfied with the content of the contract. The existence of automated interoperability checking among the collaborating enterprises also contributes in generating a favorable attitude towards participation in the collaboration and trust decision making. The interoperability checking is performed during the selection of potential partners for the collaboration. Furthermore, monitoring of the collaboration for tracking deviations and misbehavior acts as a facilitating factor behind trust generation.

User Interface

User interface is defined as the interface providing information required for trust decision making to the users. As noted before, intuitive user interface design, ease of navigation and finding required information and quality of the information presentation formats play crucial role in trust generation.

The TrustCoM framework supports user interface through the means of the information providing portlets. Furthermore, they also realize the im-

portance of designing user interface but it falls outside the research scope of the TrustCoM framework [62, 63]. Therefore, the impact of website or tool and human user's characteristics as a trustor itself are not applicable.

The ICT infrastructure of the ECOLEAD, provides support for portlets for interaction with the users. In their implemented test prototype providing fake service for partner search and selection, they have web and mobile portal for presenting the list of potential partners for the collaboration [43]. They also provide support for human collaboration via computer supported collaborative work tools such as mails, chats, calendar, and notifications.

Lastly, the Pilarcos middleware provides support for trust decision expert tool for handling special cases, requiring human intervention for trust decision making. The trust decision expert tool has the user interface providing required information about risk, reputation, collaboration progress and contextual issues. The proposed trust decision expert tool (Chapter 5) has been designed based on the cognitive strategies of user interface (Section 3.4.2) and usability principles (Section 5.1).

External Environment

External environment refers to all the social, economical and technological factors which are independent of the trustor, trustee and contextual metrics of trust decision making. External environment considerably affects the process of trust decision making. They are liable to the change the decision of the enterprise regarding its participation in the collaboration even if trustor is risk taking, trustee has good reputation and all the components of system trust are present.

The TrustCoM framework does not appear to explicitly state about supporting the inclusion of external environmental factors. However, in context with trust among enterprises, they also hold the view that "trust is always set within a social context" [62]. Therefore, I assume that external environmental factors exist in the case of TrustCoM framework. Moreover, there are always certain external social, economic and technological factors affecting the enterprises.

The ICT infrastructure of ECOLEAD does not mention explicitly about supporting external environmental factors either. Furthermore, social factors are considered as one of the perspectives for assessing trustworthiness of the trustee [33]. This notion shows that social factors affect trust decision making indirectly. Therefore, I believe that external factors govern the process of trust decision making in ECOLEAD.

As already noted, the Pilarcos trust management system explicitly mentions the context as one of the parameters influencing automated trust decision making. The 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 [47, 49]. All these sources of information are affected by the external environment factors. For example, recession might affect the internal financial condition of the enterprise, which would in turn affect the decision of the enterprise to enter into the collaboration. Therefore, contextual information supported by the Pilarcos is related to the external environmental factors affecting the process of trust decision making.

4.2.10 Collaboration-Specific Metrics

Perspectives

Perspective is defined as the viewpoint of the trustor towards trust formation and is made from the objectives [33]. Different perspectives can have different impact on trust decision making. Therefore, it is important to understand the role of perspectives for trust decision making in the domain of inter-enterprise collaborations. Considering the scope of the thesis, there are mainly seven different types of perspectives: organizational [33, 48, 63], economical [33, 48], social [33, 48], technological [33, 48], behavioral [33, 48, 62, 63], psychological [62, 63] and service [23, 33, 48, 63].

The TrustCoM framework considers four different perspectives for trust decision making: service, psychological, social and behavioral [62, 63]. The service perspective for trust formation comes into picture because it matches the functional requirements, quality of service, trust and security parameters of the roles of the business processes with the information provided about these in the published service offer for trust establishment during the establishment of inter-enterprise collaboration. It also considers the psychological perspectives for trust formation as it focuses on encapsulated interest model of trust relations. Their focus on the behavioral integrity, behavioral consistency, benevolence, inclination of entering into disagreements and disruptions in addition to previous experience of working in collaborations and under contracts shows their behavioral perspective towards trust establishment. Apart from all these, they also consider the significance of social perspective through the usage of trust substitutes such as contracts, monitoring and security mechanisms to trust formation.

The ICT infrastructure of ECOLEAD follows five different types of perspectives for trust formation. It follows organizational, economical, social, technological and behavioral perspective to trust formation [33]. The objectives of the inter-enterprise collaboration determine the perspective towards trust formation. The organizational perspective takes into consideration the setup, size and competencies of the organizational as the basis for trust establishment. From the social perspective, the activities and contributions of

the enterprises in the social context are considered for trust establishment. The financial stability of the enterprise, required technological infrastructure, past experience of operating under contracts and collaboration becomes the economical, technological and behavioral basis for trust establishment.

The Pilarcos middleware and its trust management system also consider service, economical, technological and behavioral perspective to trust formation [21, 22, 47, 48]. Similar to the case of TrustCoM, 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 the service perspective to trust formation. The weighing of potential benefits versus possible losses and risks for making trust decisions shows their economical perspective to trust formation. Technical interoperability checking of technical and connectivity issues ensuring reception and delivery of the messages among participating enterprises becomes the basis of technical perspective. The consideration of reputation information including information about the past behavior of the enterprises becomes the basis for behavioral perspective to trust formation.

Objectives

Objective is defined as the pre-set goals of the inter-enterprise collaboration and its participating enterprises [33, 47, 62]. The objectives of the enterprises and the collaboration play a crucial role in the process of trust decision making regarding their participation in the inter-enterprise collaboration (see Section 3.3.4). In the case of inter-enterprise collaborations, the objectives provide perspective to the process of trust formation and trust decision making. For example, consider the case of an inter-enterprise collaboration whose objective is to earn money. All the enterprise who will participate in this collaboration would gain monetary benefits. But, participation in this collaboration involves putting reputation of the enterprise at stake. In such a situation, the enterprise whose objective is to make money despite reputation risks involved would make positive trust decision. On the other hand, the enterprise whose primary objective is to earn reputation will have negative attitude to participation in the collaboration.

The objectives are same for all the three systems. As discussed before, there are two types of objectives: shared objective of the inter-enterprise collaboration and individual objectives of the enterprise. It is evident that the objective of the inter-enterprise collaboration is same for all the collaborating enterprises, whereas the individual goals of the enterprises can be different from each other. Both these types of goals are applicable for all three systems. For example, the Pilarcos trust management system implicitly considers the objectives for example, earning monetary gains, reputation and consumer satisfaction, behind the collaboration while automatically finding potential

partners for the collaboration. On the other hand, it also considers the objectives of the collaborating enterprises during the negotiation phase and contract establishment.

4.3 Summary

This chapter presents three different trust management systems. First, all three trust management systems are discussed briefly followed by comparative analysis of these systems. All the three trust management systems are compared against human preferences presented in Chapter 3 in addition to system purpose, architectural foundation and focus areas. The comparison between the presented trust management systems helps in understanding the overall functioning of these systems in context to trust decision making and trust management.

After evaluating and comparing three existing trust management systems against found human preferences in literature, the next step is to employ them for designing the proposed trust decision expert tool. The next chapter presents the design and implementation of the trust decision expert tool.

Chapter 5

Design of Trust Decision Expert Tool

This chapter presents the design of the proposed trust decision expert tool. Section 5.1 presents the design goals of the trust decision expert tool. The design goals provide input for implementing a trustworthy and usable trust decision expert tool. Section 5.2 presents the information sources available by the Pilarcos middleware. After presenting the information sources, architecture and workflow of the trust decision expert tool are presented in Section 5.3. The system design visualizing the interaction among the different components of the Pilarcos middleware and the Pilarcos trust management system is presented in Section 5.4. The different information views of trust decision expert tool constituting user interface of the trust decision expert tool are presented in Section 5.5. Finally, the implementation details of the trust decision expert tool are presented in Section 5.6. The chapter concludes by presenting the chapter summary in Section 5.7.

5.1 Design Goals of Trust Decision Expert Tool

Design goals are guidelines which will provide direction for designing trust decision expert tool. The establishment of inter-enterprise collaborations should be made quick, easy and low cost. For example, if enterprises need to establish collaboration for the time period of three months only, than the establishment of the collaboration should take far less time. Similarly, the cost of the establishment of the inter-enterprise collaboration should also be far less as compared to the anticipated benefits out of the collaboration. Therefore, the systems taking more time and money for the establishment

of inter-enterprise collaborations as compared to expected gains would be failure. From this point of view, quick and economical establishment of the inter-enterprise collaborations is required.

Automation is one of the solutions for providing cost effective and quick collaborations. TrustCoM, ECOLEAD and Pilarcos use automation for the establishment of inter-enterprise collaborations. The Pilarcos middleware, for example, performs automated partner search and discovery, monitoring, contracting, management of trust and interoperability among the collaborating enterprises [25]. Despite the automation of all the major tasks in the establishment and continuation of the collaboration, human intervention is still required in special cases. The Pilarcos trust management system requires human intervention for making the decisions regarding the collaboration when all the risks are not within the assigned tolerance limits. Similarly, the test prototype of ECOLEAD allows users to search potential enterprises automatically and returns the results to them for final decisions [43]. Despite the automation of major tasks during establishment and operation of inter-enterprise collaborations, human intervention is still needed.

Considering the importance of trust decision making in the domain of inter-enterprise collaborations, there is a clear need for following the methodological approach to specifying trust specific design goals for any trust decision expert tool. The existing studies only contribute to trust design in the online environment but, very few attempts have been made to propose trust specific design principles [8]. However, Egger focuses on psychological, business and marketing related trust issues involved in the online environment. In contrast, the thesis specifically addresses information required during human intervention for trust decision making in the case of inter-enterprise collaborations. Therefore, all the other issues such as brand are out of the scope of the thesis. I have relied on guidelines provided by Nielsen and different cognitive strategies stating the human expectations from the user interface (see Section 3.4) for setting the design goals for the proposed trust decision expert tool.

Usefulness of the Presented information: Usefulness of the presented information is one of the most important design goals of the trust decision expert tool as it creates value and functionality for the users. The main task of the trust decision expert tool is to satisfy needs of the users so that they are able to produce high quality results. The trust decision expert tool enables its users to make trust decisions regarding their joining and continuing in the inter-enterprise collaboration. The user interface of the trust decision expert tool should aim to not present too little or too much information.

The lack of required information is dangerous as it might lead to serious losses in terms of money and reputation. On the other hand, presentation of unnecessary information might confuse the user in figuring out the exact information required for trust decision making.

Usable interface: Designing a usable interface for the trust decision expert tool is the second design goal. From the usability point of view, the trust decision expert tool needs to satisfy different aspects related with enhancing its usability [35].

Firstly, the expert tool should be *easy to learn* and *easy to remember*. This means that the user should be able to easily learn the tool in order to start using it without difficulties and confusions. At the same time, it should be easy to start using the tool again after some time gap. It is important for trust decision expert tool to be memorable because of infrequency in the need for human intervention. Memorability is the attribute which helps in using the tool easily even after long time intervals based on the prior usage. Human intervention is only needed when all the assets are not within the tolerance. In all the other cases, trust decision making is handled automatically. *Learnability* and *memorability* are required so that expert tool can retain the ease required for the establishment and working of the inter-enterprise collaborations.

Secondly, the trust decision expert tool should be *efficient*. The trust decision expert tool should enable the human users to quickly make confident trust decisions. This can be achieved by minimizing the effort required by the human users in making the trust decisions.

All these factors contribute towards enhancing the user experience of the trust decision expert tool by **minimizing the cognitive load**. *Easy to grasp, understandable, unambiguous and correlated* information presentation formats will reduce effort required by the users. This is especially true in case of human users as they are cognitive misers who always strive to minimize the required effort [14].

All the aforementioned design goals provide input for designing the proposed trust decision expert tool. The next section presents the information model of human users required for trust decision making in the context with inter-enterprise collaborations.

5.2 Information Sources of Trust Decision Expert Tool

As noted before, the Pilarcos trust management system automates decision making in routine cases but probes a human user for uncertain or special cases. Every now and then, collaborations emerge with a high level of uncertainty and risk between the involved enterprises. Trust mitigates the feeling of uncertainty and fear about associating and interacting with unknown or little known enterprises [57]. The information that is being presented to users about other enterprises is one of the tools for bridging the gap between trust and distrust caused by uncertainty and risk in the case of collaboration with previously unknown or little known enterprises. Providing the users with information that they expect to see in such a scenario will lead to a high degree of satisfaction, which in turn influences their decision making and attitude towards the system and collaboration [11, 15, 20, 26]. The information presented to the users for trust decision making should be clear, understandable and transparent in nature.

The information provided to the human users for trust decision making is gathered by a detailed literature survey of the existing Pilarcos middleware and the Pilarcos trust management system. Considering the scope of the thesis, literature related to the Pilarcos middleware and its trust management system is reviewed to accumulate the information that is available to be presented to human user. This strategy is adopted because the problem of making trust decision by human users needs to be solved in context with the already existing automated Pilarcos trust management system. It makes the contextual trust decisions throughout the collaboration life-cycle by automatically comparing estimated risk against risk tolerance. So, in order to have consistency and to make use of available information, the users are presented with the same information which is used by the system for making automated trust decisions. This strategy is complemented by taking into consideration the inquisitive character of the human users. This is due to the reason that collaborating with other enterprises in the online environment for human users, basically refers to human psychological state in terms of decision making [26]. The information model of the trust decision expert tool is discussed below:

Goals: Each collaboration has a goal and enterprises have their own strategic interests. In the Pilarcos trust management system all the enterprises who are selected as the potential partners of the collaboration contribute with

their specific skills and resources towards the collaboration goals. It would be easy for the human users to make the decision if they can clearly see the objectives of the collaboration and accordingly make their decision based on whether they actually agree with the enterprise goals [12].

Risk information: Risk is defined as the magnitude of the occurrence of adverse consequences [57]. The Pilarcos trust management system calculates a risk estimation in terms of probabilities using the reputation information about the other partners in the collaboration. The risk is estimated for each of the four assets. The probability values of risk estimation for different assets can have direct impact on the decision making cognitive process. Information about the risk that participation in the collaboration can infer for the enterprise has inverse relation with trust and decision making [57]. It is essential for the enterprises to see how the collaboration can affect them socially and economically.

Reputation information: Reputation information is defined as the information providing insight into the past behavior of the other participating enterprises. In the Pilarcos trust management system, the reputation information used for trust decision making is gathered locally as well as from external reputation networks. Research on trust from sociological point of view has revealed that humans are open to formulating an opinion regarding the future based on the past experiences [33]. Hence, reputation information plays a crucial role in predicting the future behavior based on the past behavior.

Risk tolerance: Risk tolerance is defined as the extent of risk bearing, and it has positive impact on the trust decision together with the risk estimation [60]. For the Pilarcos trust management system, risk tolerance depends on the strategic importance of the actions. The system uses risk tolerance function to verify if the estimated risk for all the assets falls within the required constraints. The decision is automatic acceptance for the cases satisfying the ranges for automatic acceptance and rejection. Otherwise, the decision making authority is passed to the humans. Risk tolerance assists in decision formation by making evident how and which assets of the enterprise are endangered by the collaboration.

Collaboration progress: Collaboration progress provides an overview of the current status of the ongoing inter-enterprise collaboration. In Pilarcos, progress of the collaboration is measured in terms of pre-set milestones. Achievement of one milestone leads to completion of one process epoch. These milestones sometimes also reflect the points where the decision regarding collaboration might be reconsidered. The status information about

the progress made so far in the collaboration can guide the decision making. The progress status information is relevant in the situation where trust decisions regarding continuation in the existing inter-enterprise collaborations need to be made.

Functional details: Functional details are defined as the details pertaining to the working of the inter-enterprise collaborations. The information about functional details of other partners has an effect on trust decision making. For example, the protocol that would be used during the collaboration for message exchange affects the collaboration decision. Pilarcos middleware takes into consideration the functional details while ascertaining interoperability among the participating enterprises. All the participating enterprises have the opportunity of negotiating with the functional details with others before making trust decision of joining or continuing the collaboration. Depending on the requirements, the enterprise can make its decision by either denying or negotiating with other partners in the collaboration. Therefore, clear presentation of functional details impacts trust decision regarding the collaboration.

Non-functional details: Non-functional details are defined as the information dealing with aspects having an indirect effect in the operation of the inter-enterprise collaboration such as security, privacy, and quality of service. Pilarcos supports non-functional constraints on two levels. On the shared contract level, the underlying collaboration model can specify non-functional requirements [25]. On the enterprise level, requirements of security and privacy are present in different levels of decision-making and the related monitoring [22]. The assurance of security and privacy of the exchanges information could lead to positive trust decision whereas their absence will have negative effect. Similarly, affirmation about providing high quality service also has positive effect on the though process leading to decision making.

Collaboration State: Collaboration state information provides information about the current state of the inter-enterprise collaboration. In the Pilarcos middleware, collaboration state information is used as a basis of trust decision making during the operation of the collaboration. For example, information about different roles in the collaboration, what are the responsibilities associated with them and which partner enterprise is playing which role are used as collaboration information in Pilarcos middleware. Collaboration state information promotes transparency which will lead to trust generation towards the system supporting inter-enterprise collaborations. Furthermore, various factors such as how the information is presented and how much detailed it is will affect the final decision made regarding the collaboration.

Active context: Active context is defined as the contextual information affecting trust decision making. The Pilarcos trust management system provides supports to the usage of active context for trust decision making. Active contexts contain the information that effect possibilities of trusting other enterprises despite risks involved. For example, information about insurance against monetary losses will affect trust decision making in a situation involving threats to monetary asset. Active contexts act as a recommendation agent which could help in quick and confident decision. Hence, it also affects decision making.

Refining policies: Refining possibilities refer to the opportunities or possibilities of proposing and making changes in the existing policies and e-contract of the collaboration. In the Pilarcos middleware, business network agent, representing enterprise in the collaboration, is allowed to propose changes in the policies and e-contract during the negotiation phase. Negotiations on changes are made before the final decision regarding collaboration is taken. On one hand, providing the option of refining policies to human users will ensure consistency in the system. As noted before, in the Pilarcos middleware, the collaborating enterprises have the flexibility of refining policies. Therefore, the consistency will be ensured if human users are also given with the provision of proposing amendments in the existing version of the contract. On the other hand, this option plays the role of facilitating factor enhancing trust towards the automated Pilarcos middleware and its trust management system. It provides the human users with the perception that they have the control in their hands, which enhances the trust levels. Hence, the possibility of refining policies acts as an indirect information need.

Assignment reason: Assignment reasons represent information about why the power of trust decision making has been delegated to the human user. Usually, Pilarcos trust management system makes the automated trust decision. So, when the decision making authority is handed over to humans, then they might prefer to know the reasons behind impossibility of automating the decision. Clear indication of the reasons would lead to better and faster understanding and analysis of the whole situation.

Deadline: Deadline as a piece of information will inform users about the time provided for making the trust decision. It will not have any impact on the trust decision itself but instead would add clarity to the process of trust decision making.

After gathering the information sources they are analyzed from the various perspectives like time, their role in decision making process, system constraints and use context requirements. Analysis of the information sources divided them into two main categories. The first category consists of infor-

mation sources aimed at solving the problem of decision making quickly with the just "yes" and "no" as the output. On the other hand, second category involved detailed information about the collaboration and possibility of negotiating as well. The first category fell under the domain of trust decision expert tool whereas second consists of information sources for a more extensive collaboration negotiation expert tool. Figure 5.1 below presents the categorization of information sources.

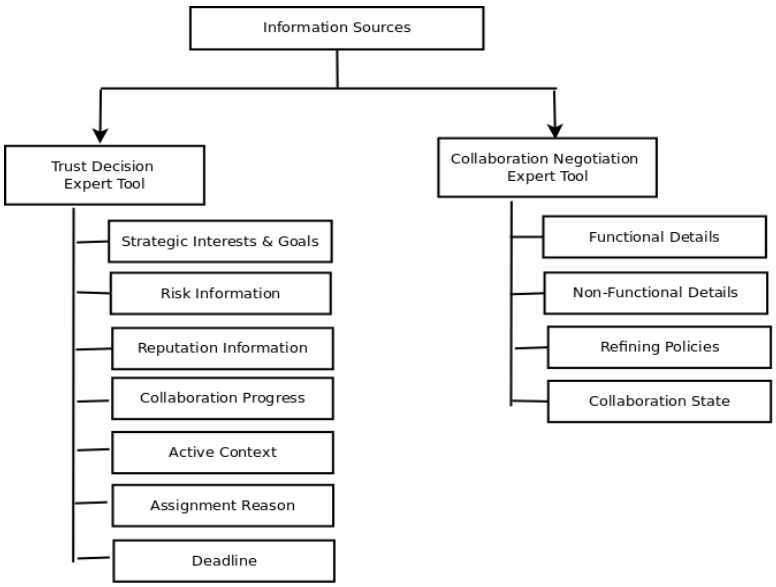

Figure 5.1: Information Sources of Trust Decision Expert Tool.

Most of the information sources fall under the domain of trust decision expert tool. The trust decision expert tool contains following information sources: strategic interests and goals, risk information, reputation information, active context, collaboration progress, assignment reason, and deadline. These information sources directly affect trust decision making. The collaboration negotiation expert tool presents information sources such as functional details, non-functional details, refining policies, and collaboration state. Furthermore, the collaboration negotiation expert tool can help in simulating new policies. These information sources present the detailed information about all the aspects of collaboration along with the possibility of refining and negotiating. They have indirect influence on the trust decision making of the users about the collaboration. Risk tolerance is not applicable in either of the cases, since humans are making the decisions themselves. They will be provided with risk estimation information, so it is left up to them to consider their risk tolerance limits.

After analyzing the information sources of the proposed trust decision expert tool, next section presents its architecture and workflow.

5.3 Architecture and Workflow of Trust Decision Expert Tool

The architecture of the trust decision expert tool presents two different components involved in its functioning: trust decision expert tool and Pilarcos trust management system. The interaction between different components provides insight in the working of trust decision expert tool. Figure 5.2 shows the architecture components of the trust decision expert tool. The workflow of the trust decision expert tool presents a sequential interaction between the architectural components.

The **trust decision expert tool component** of the architecture represents the proposed trust decision expert tool. I have designed and implemented the expert tool component consisting of two layers: user interface layer and transformation layer.

User interface layer is the main layer of the trust decision expert tool architectural component. This layer is responsible for presenting all the information to the human users required for trust decision making. The information and its presentation formats affect the human trusting beliefs by formulating the perception about trust, security and effort expectancy. The clarity in the presentation of the information reduces the performance time and effort required in understanding for making the trust decision. Thus, user interface layer plays important role in creating the usefulness for the trust decision expert tool.

Transformation layer is the second layer of the trust decision expert tool architectural component. Transformation layer performs the main task of fetching the data from Pilarcos trust management system and providing the fetched information to user interface layer for trust decision making. After receiving the required decision data, transformation layer transforms the data into the format required for presentation on the user interface layer. At the same time, transformation layer is responsible for feeding the decision by human user and its scope to Pilarcos trust management system for reducing the frequency of human intervention in future.

The **Pilarcos trust management system component** of the architecture represents the foundation for trust decision expert tool. As noted already, the Pilarcos trust management system component handles the trust management issues in Pilarcos middleware. It makes automated local trust

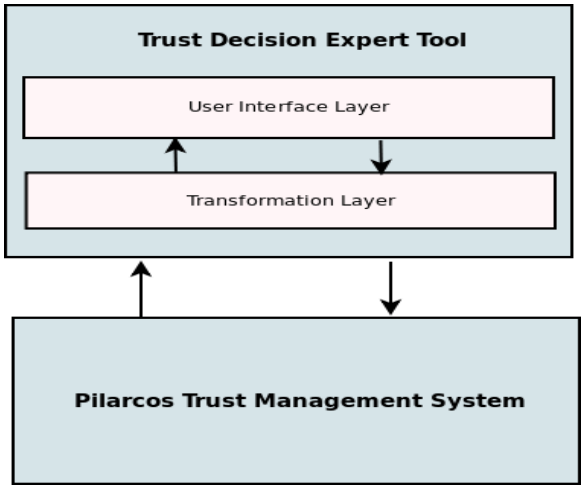

Figure 5.2: Architecture of Trust Decision Expert Tool.

decisions for the routine cases. However, it needs human intervention for decision making for special cases. In order to deal with special cases, it prompts a human user for trust decision making. For dealing with the human intervention issues, the Pilarcos trust management system component provides support for the implementation of trust decision expert tool.

The workflow of trust decision expert tool is presented in Figure 5.3. It visualizes the interactions between trust decision expert tool component and Pilarcos trust management system component of the trust decision expert tool architecture. The architectural components trust decision expert tool comes into action when the Pilarcos trust management system component requires human intervention for decision making.

The working of the trust decision expert tool is explained as follows:

1. The Pilarcos trust management system prompts transformation layer of the trust decision expert tool whenever human intervention is needed.

2. The transformation layer responds to the prompt by requesting data required for trust decision making.

3. The Pilarcos trust management component replies back with the requested data.

4. The transformation layer performs the transformations after receiving the data. For example, transformations layer fetches the probability values, total number of experiences of each outcome for all the assets, active contexts applicable to the current inter-enterprise collaboration

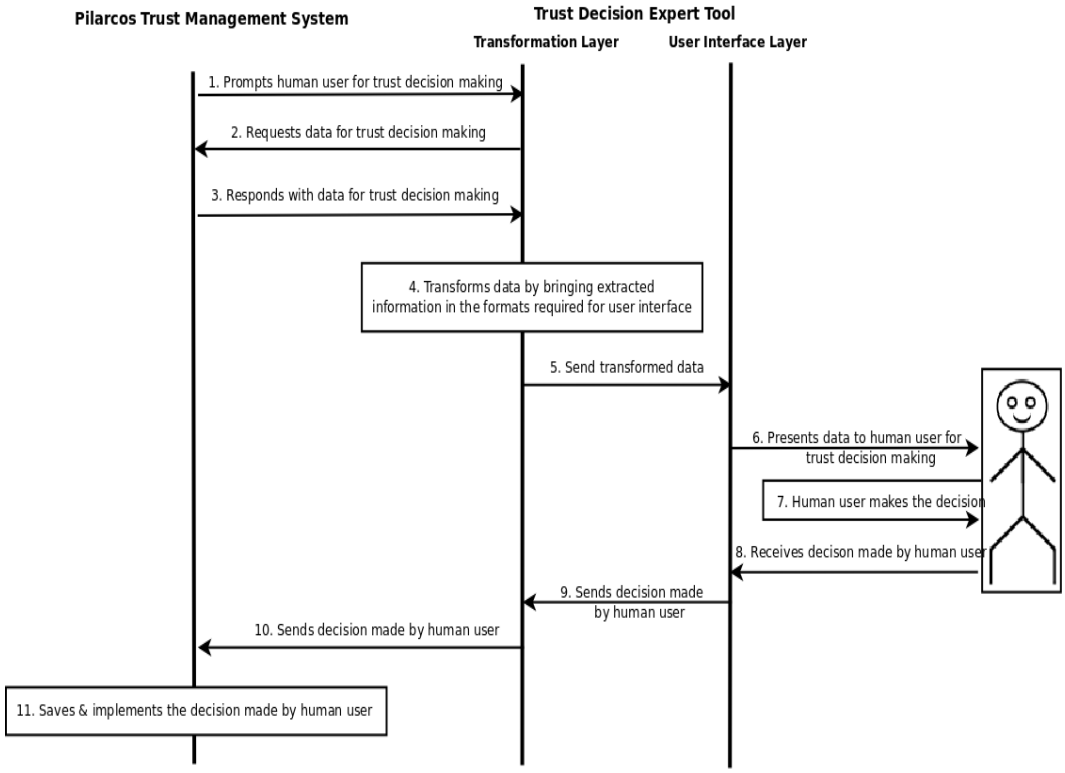

Figure 5.3: Workflow of Trust Decision Expert Tool.

decision, assignment reason and information related to network epochs such as the name of the current network epoch and progress made so far. The received values are then transformed into the presentation formats required to be shown on the user interface to the human users for trust decision making. For example, the extracted probability values are transformed into graphical bar charts for presenting risk information. Similarly, assignment reasons represented by endangered assets, total number of reputation epochs, experiences and credibility values are also transformed into graphical bar charts and their legends for visualizing the reputation view of the trust decision expert tool.

5. After all the transformations are accomplished, the transformation layer sends the transformed data for display to the user interface layer for trust decision making to the human users.

6. The human user views the information presented to him/her by the expert tool for trust decision making through its user interface.

7. Based on the presented information, human users make an appropriate

decision regarding their participation in the inter-enterprise collaborations.

8. The user interface layer receives the decision and its scope from the human user.

9. The user interface layer sends it to the Pilarcos trust management system component through the means of the transformation layer.

10. Finally, the Pilarcos trust management system saves the decision made by the human user. It also implements the decision for example, leaving or joining or continuing the inter-enterprise collaborations.

The Pilarcos trust management system makes use of the decision and its scope for making automated decisions in future whenever similar situations arise. Therefore, the Pilarcos trust management system does not need to probe human user for decision making every time similar uncertain situation arises in future. In this way, the trust decision expert tool also helps in semi-automating the existing Pilarcos trust management system.

The next section presents the system design of the trust decision expert tool.

5.4 System Design of Trust Decision Expert Tool

The system design visualizes the interaction between the Pilarcos middleware and the Pilarcos trust management. It shows how different components of the Pilarcos middleware and its trust management system communicate for enabling the human intervention for trust decision making. The information presented makes up the basis for its usefulness of trust decision expert tool. The user interface of the trust decision expert tool presents the information required for human trust decision making, thus satisfying the user needs. Considering the scope of the thesis, it is important to understand the needs of trust decision expert tool from the context of Pilarcos middleware and Pilarcos trust management system.

The system design shows three different types of interaction between Pilarcos middleware, Pilarcos trust management system and user interface of the trust decision expert tool. The three types of interactions are: interaction within the system, with user interface, and with the human user. The functioning of all three types of interaction is shown in Figure 5.4.

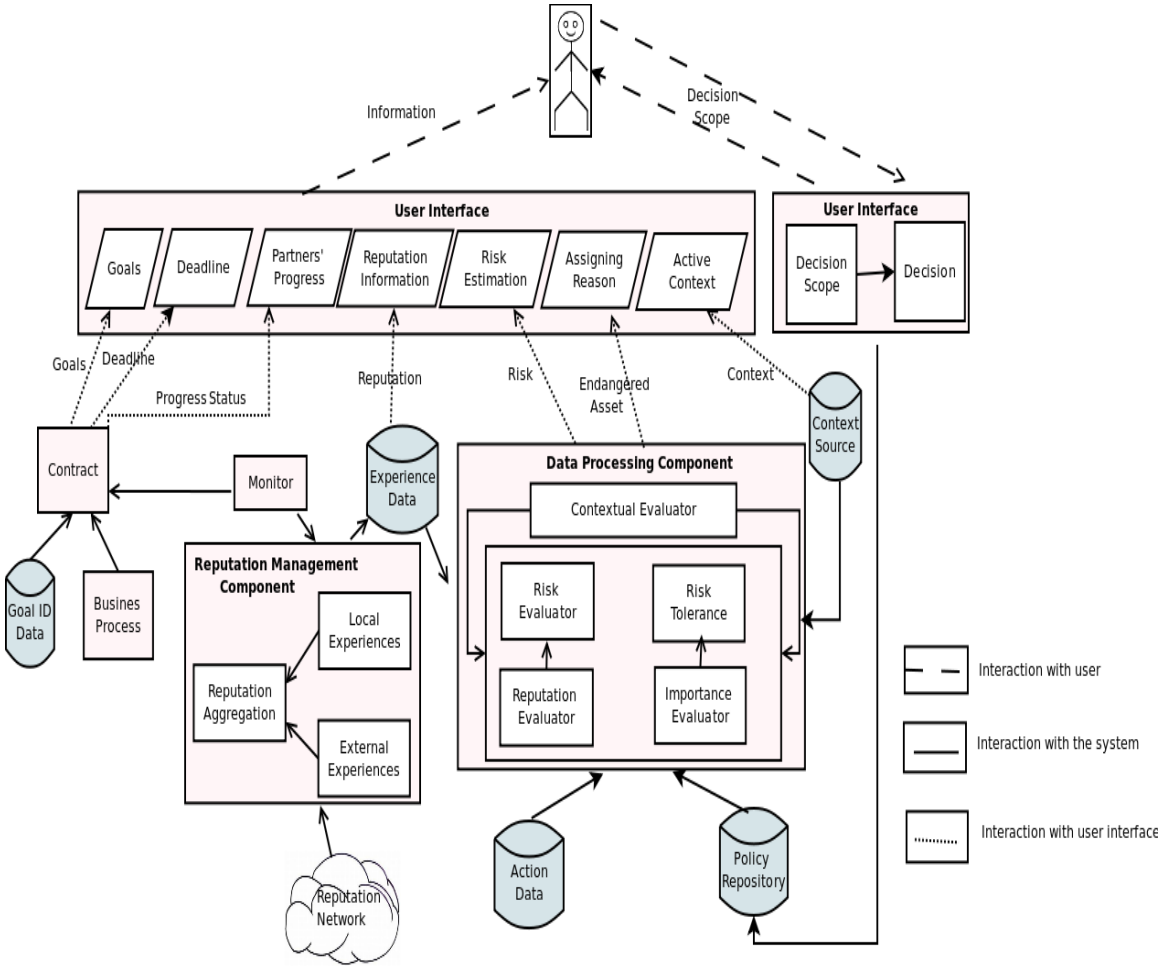

Figure 5.4: System Design of Trust Decision Expert Tool.

The **interaction within the system** visualizes the communication between different components of the Pilarcos middleware and its trust management system. As noted before, this interaction provides the information that needs to be shown on the user interface. The *data processing component* of Pilarcos trust management system takes input from action data, policy, experience data and context source repository for calculating the risk probabilities involved in the particular situation. The risk probabilities are calculated based on the reputation information and tolerance limits for the risks are based on the strategic importance of the action.

The *context evaluator* adjusts risk, reputation, tolerance limits and importance of the action based on the information provided by the context source repository. The data processing component provides information about risk

and endangered assets to the user interface of trust decision expert tool. The context source gives information about the active contexts, which act as recommender agents for human users while making the trust decisions regarding the collaboration.

The *reputation management component* of Pilarcos trust management system provides reputation information in the form of experiences for risk calculations to data processing component. Reputation management component merges the input from Pilarcos middleware monitors and third party reputation networks for producing merged reputation information. The experience data repository, which stores the merged reputation information, provides reputation information in the form of experiences to the user interface.

The *goal id data repository* and *business process* of Pilarcos middleware provide the goals for the collaboration, partner progress and deadline information to the user interface of trust decision expert tool through the means of contract.

The **interaction with the user interface** presents the transference of the outcomes of the interaction within the system to the user interface of the trust decision expert tool.

The **interaction with the user** involves providing the gathered information to the user for trust decision making. The main aim of this interaction to make the trust decisions regarding the collaboration.

The information presented on the user interface satisfies the basic information sources of the user for making trust decision regarding inter-enterprise collaboration in the online environment. The presented information first leads to trusting belief which later formulates into trusting attitude. The attitude to trust builds positive or negative expectations from the outcomes of the trusting behavior, which lead to the formulation of trusting intentions. The trusting intentions built as a result of the information presented on the user interface, lead to the actual trusting behavior. The trusting behavior in our case is to either accept or reject the action. If the user accepts the trust decision, then the user interface of the trust decision expert tool makes another interaction with the human user asking for the decision scope. The input provided by the human user completes the process. The results are stored in the policy repository of Pilarcos trust management system for future decisions.

In the next section different information views of the user interface of the trust decision expert tool are presented.

5.5 Information Views of Trust Decision Expert Tool

The user interface layer consists of different information views providing different functionality in the working of trust decision expert tool. The different information views of user interface are designed based on the pre-set design goals: presented information and usable interface. The usefulness of the presented information leads to confident trust decisions. On the other hand, usable interface deals with the presentation of the required information in such as way that it facilitates the human users in finding and perceiving the needed information in quick and easy manner for trust decision making.

5.5.1 Risk Information View

The risk information component of the trust decision expert tool shown in Figure 5.5 provides the risk information to the human users. The risk information is provided in the form of risk probabilities for all the four assets. Based on the design goals, there are two different views for viewing risk information - collaborative view and enterprise view. The collaborative view presents risk probabilities for the collaboration as a whole. On the other hand, enterprise view provides information about risk to the enterprise, who currently needs to make the trust decision regarding entering or continuing in the inter-enterprise collaboration.

The risk information view consists of four different graphs representing the risk probabilities for each high level asset class - monetary, reputation, satisfaction and control. The risk probabilities are presented on the scale of large negative effect, slight negative effect, no effect, slight positive effect and large positive effect. The outcomes scale represents the outcomes or effects that the collaboration has had previously. The risk probabilities are calculated by dividing the total number of experiences of one outcome by the grand total of all the experiences for one particular asset. The probability of each outcome for all the assets is calculated by dividing the total number of experiences for any outcome for a particular asset by the total number of experiences for all the outcomes of that asset. For example, if we want to calculate the probability of large negative outcome for monetary asset then it will be calculated by dividing the total number of experiences having large negative effect for the monetary during the past with total number of experiences for all the assets: large negative, slight negative, no change, slight positive and large positive - for the monetary asset.

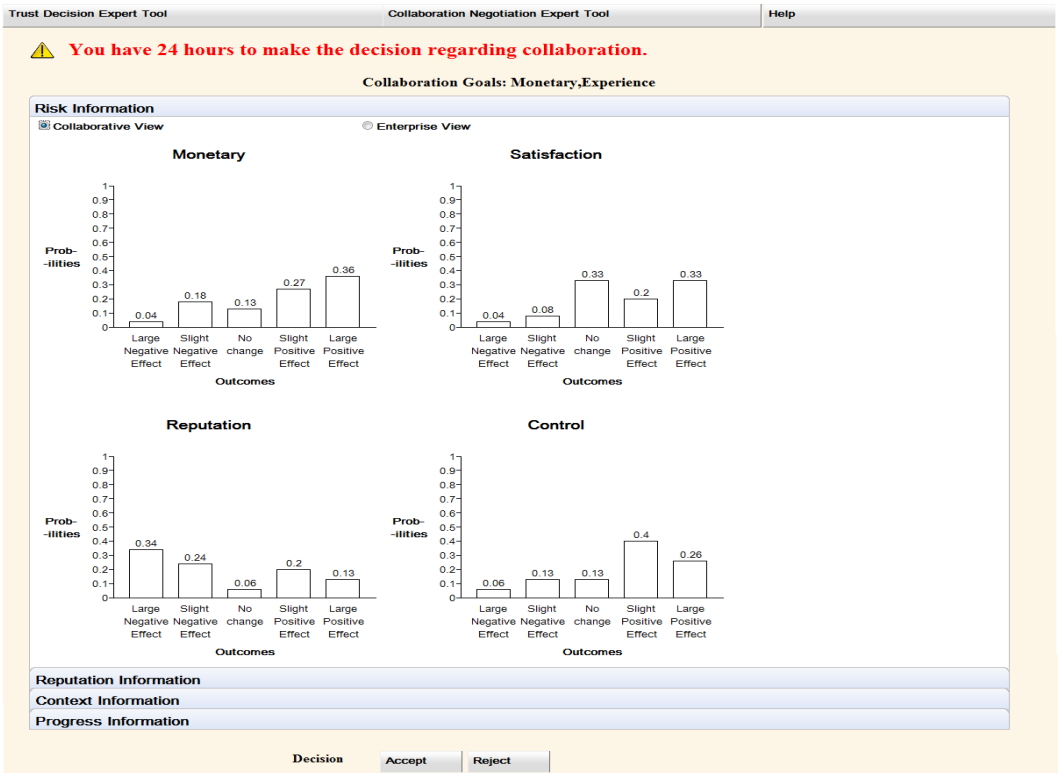

Figure 5.5: Risk Information View.

5.5.2 Reputation Information View

The reputation information view of the trust decision expert tool shown in Figure 5.6 presents reputation information about the past and present behavior of the target enterprises to human users. The reputation information is provided in the form of number of experiences for all the four assets in terms of previous outcomes of the collaboration. Similar to the case of risk information view, reputation information view also contains two different views for viewing reputation information - collaborative view and enterprise view.

Considering the design goals, the reputation information is presented in the graphical format containing number of experiences in terms of previous outcomes. The reputation information contains maximum of two graphs if the inter-enterprise collaboration has undergone reputation epoch changes, which denote major changes in behavior. In such a case, one graph presents the overall reputation status while the other gives the current status. The presentation of the information through two graphs enables the users to make easy comparison for trust decision making. The number of experiences constituting the reputation information is presented on the outcome scales similar

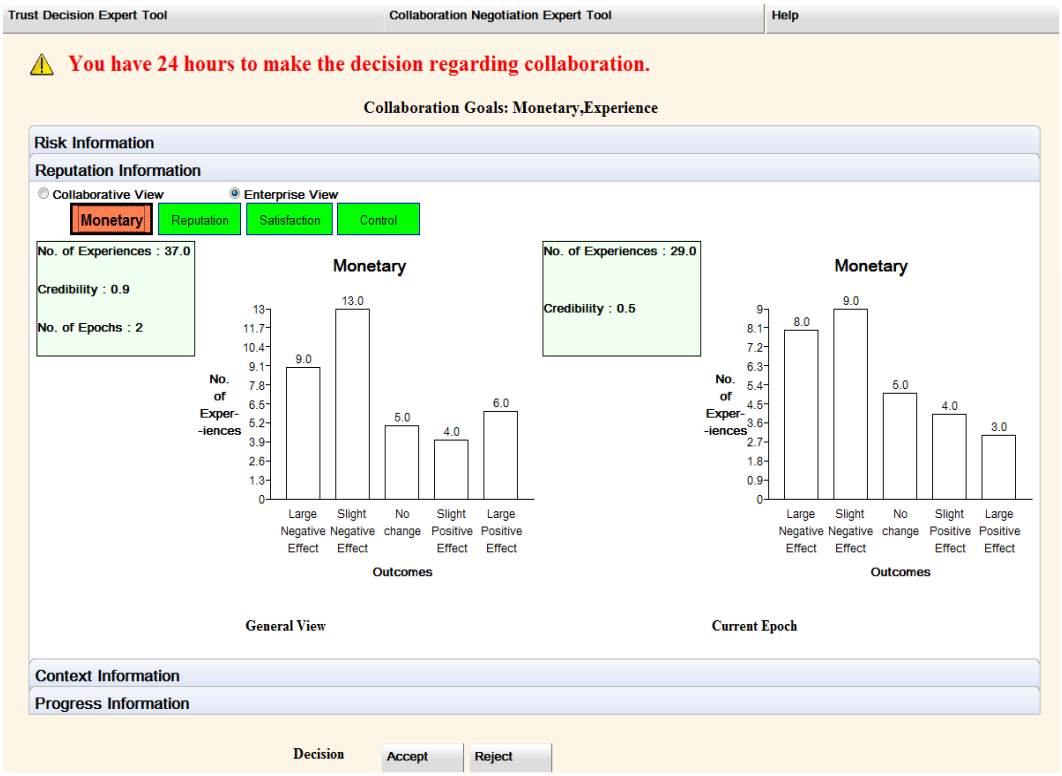

Figure 5.6: Reputation Information View.

to the scale used for presenting the risk information. The reputation information presents the reputation information for one asset at a time. Reputation for all the assets can be viewed using the button representing all the assets. The information about the endangered assets is provided using red and green color of the button representing the asset. The red color represents endangered assets whereas green color reflects safe assets.

The graphs presenting the reputation information also contain additional information such as total number of experiences, credibility and number of epochs. The additional information adds quality to the information presented for trust decision making. Credibility, which lies between 0 to 1, provides numerical information about trustworthiness of the sources providing reputation information. The number of epochs is another way of presenting the trustworthiness of the collaboration and the participating enterprises. New reputation epoch starts whenever current behavior differs greatly from the earlier behavior. The additional information promotes transparency by clearly presenting the background information which is used for the calculation of risk probabilities.

The graph visualizing general view of the reputation information contains all the additional information. On the other hand, current view graph contains only credibility information and number of experiences. Current view graph does not contain the number of reputation epochs as additional information. This is due to the reason that it presents the reputation information view of the current epoch and total number of epochs is already shown in the general view graph. Furthermore, the red and green colors also help the users to easily identify the endangered assets. The use of colors for information presentation also facilitate the users in quick and easy interpretation of the information.

5.5.3 Context Information View

The context information view of the trust decision expert tool shown in Figure 5.7 presents the contextual information for trust decision making. The contextual information acts as the recommendation agent facilitating confident trust decisions. For example, information about insurance can affect the trust decision when engaging in the collaboration endangers monetary asset. So, in this case information about having insurance serves to be the contextual information that positively effects trust decision making regarding inter-enterprise collaborations. The presented contextual information is specific for the enterprise, currently involved in the trust decision making about entering or continuing in the inter-enterprise collaboration.

Keeping the design goals in focus, the contextual information is presented in brief textual sentences. The brief textual sentences contain only the necessary piece of information required for trust decision making. It frees the human users from the burden of extracting the required information from the underlying formula contributing in the working of the context filters.

5.5.4 Progress Information View

The progress information view of the expert tool shown in Figure 5.8 presents the progress view corresponding the current business network epoch of the collaboration. The inter-enterprise collaboration also has business network epochs in addition to reputation epochs. The network epochs represents progress of the collaboration in terms of the milestones in the accomplishment of the objectives of the inter-enterprise collaboration. Each network epoch consists of number of tasks.

Based on the design guidelines, the progress information is presented in the graphical format. The progress information view graphically shows the

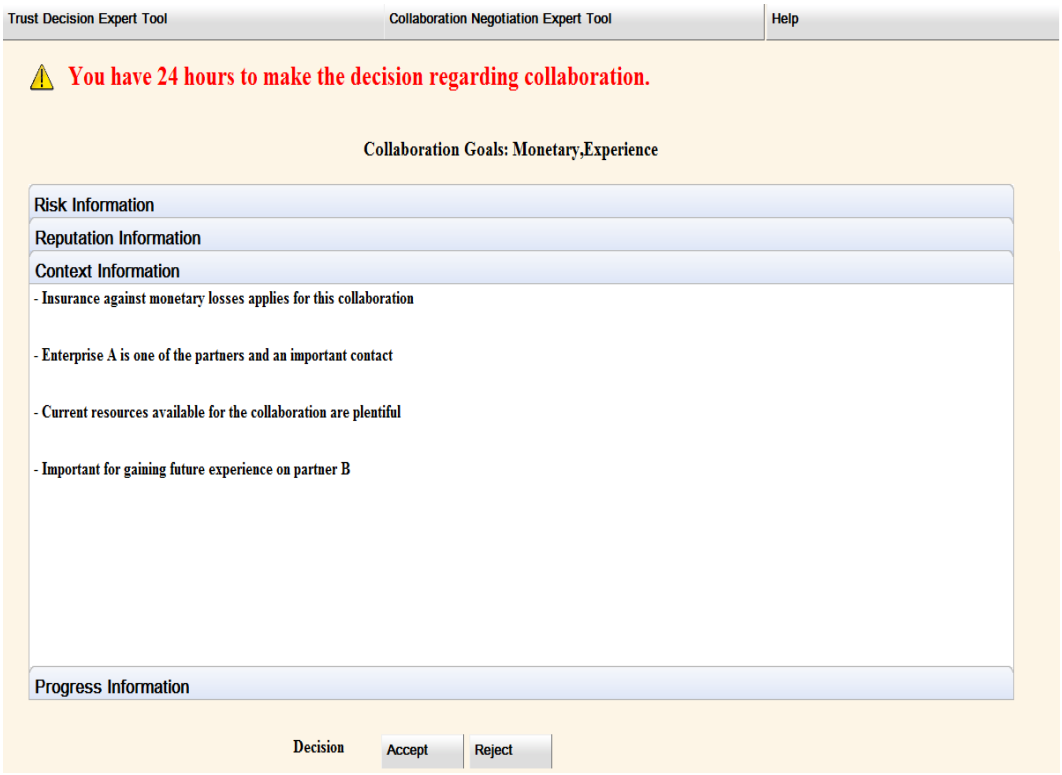

Figure 5.7: Context Information View.

status of all the participating enterprises in terms of task completion. It visualizes the number of tasks accomplished by each collaborating enterprise. The red and green colors are used for presenting the relative view of the progress of all the enterprises. The red color reflects slow progress. Slow progress means that the enterprise is behind the schedule as compared to other partner enterprises. Green color represents positive and on-time progress. The progress information view also contains the name of the business network epoch whose progress status is being presented.

5.5.5 Decision Scope Information View

The main objective of the decision scope view shown in Figure 5.9 is to semi-automate Pilarcos trust management system based on the human input. The Pilarcos trust management system is semi-automated by applying the made human trust decision to future trust decisions involving the same enterprise during the course of the collaboration. The application of the made human trust decision to the future decisions will reduce the frequency of human

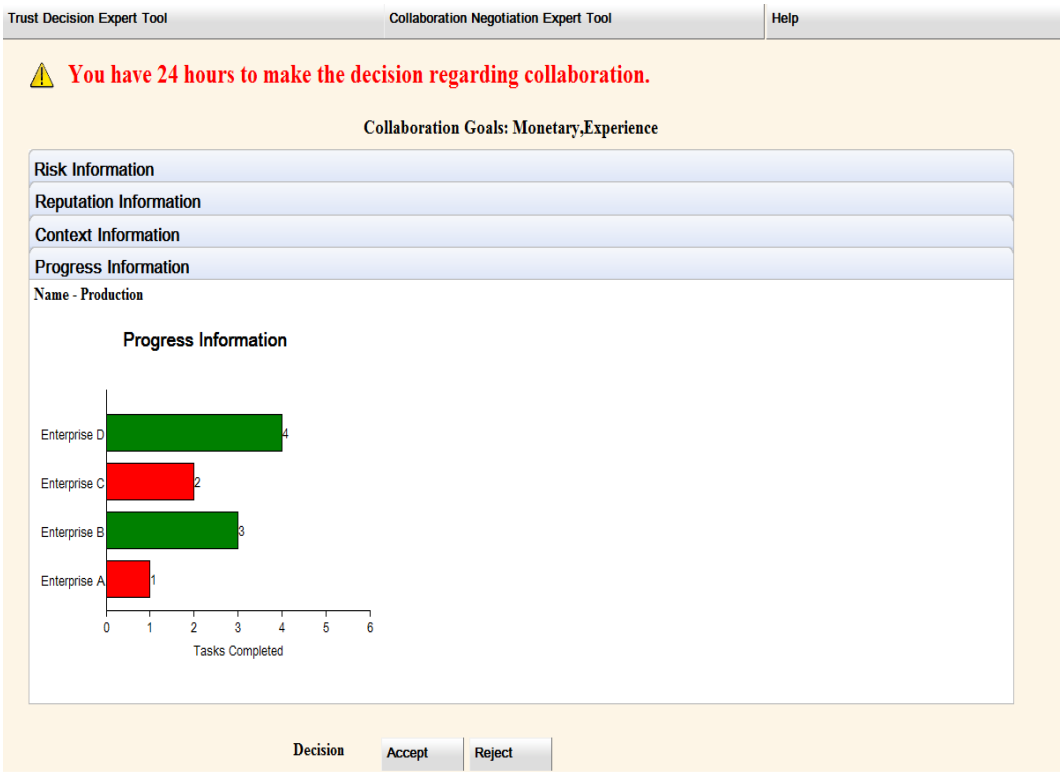

Figure 5.8: Progress Information View.

interventions needed in situations similar to the current one.

The decision scope window appears after the human user has made the trust decision regarding their participation in the inter-enterprise collaboration. This window appears both on acceptance and rejection. The decision scope view appears every time the human user makes a trust decision. It queries about the desire of the human user for applying the current decision in the future. If the user agrees than they are asked to define the scope for the decision by selecting the desired option from the presented options. The options presented to a user apply the decision for the whole contract or for some time period involving selecting the start and the end dates.

The decision transfered from the user interface layer to the Pilarcos trust management system is used for automating future deisions within the given scope. The decision scope information provided by the human user gives the time frame for decision applicability in future. The decision information stored in the context storage as a context rule is used by the Pilarcos trust management system whenever similar uncertain situation occurs and human intervention would be needed for trust decision making. Therefore, human

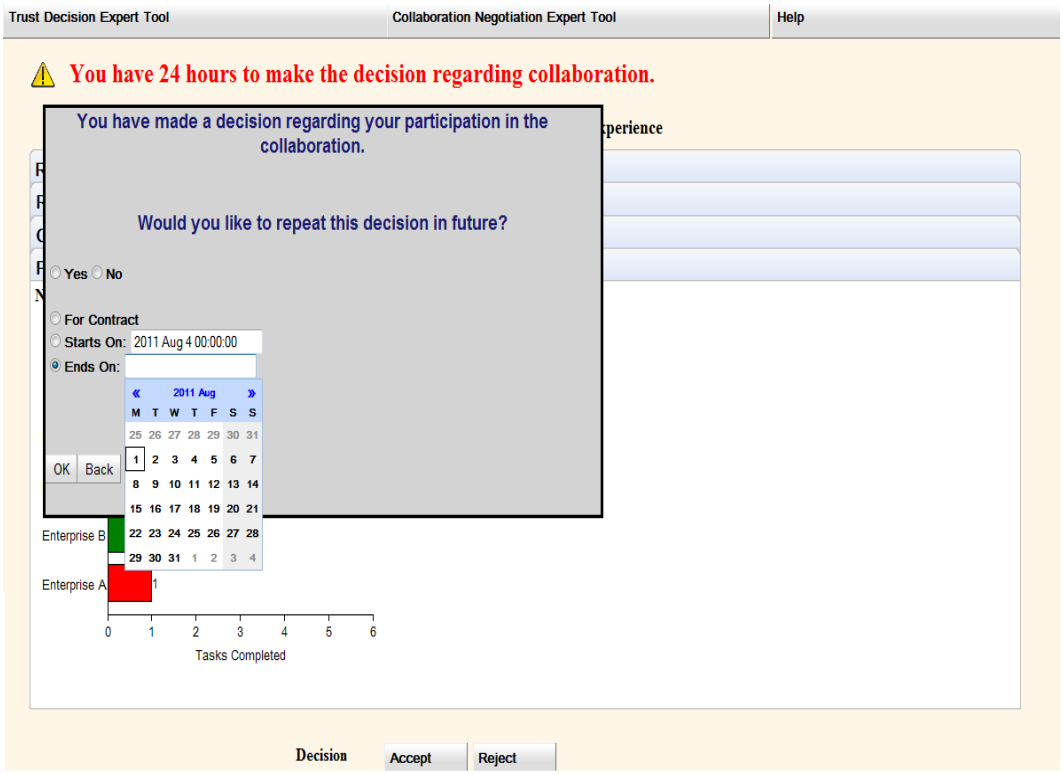

Figure 5.9: Decision Scope View.

user will be probed for trust decision making if required after checking the stored decision scope for similar uncertain situations. For example, if the human user selected the decision scope to be for the whole contract, then he/she will never be probed for trust decision making by the Pilarcos trust management system only for the given trustor. In this way, the decision information gathered through the means of decision scope view of the trust decision expert tool helps in automating trust decisions in Pilarcos.

5.5.6 Overview Information

The overview information of the trust decision expert tool presents the goals of the collaboration. The goals of the collaboration, specific to the enterprise, play a significant role in the human trust decision making process. In addition to goals, the user interface of the trust decision expert also presents the help window. The help window provides answers to the problems that might arise during the course of human trust decision making. The help window provides documentation of the expert tool. Apart from the above mentioned

information, trust decision expert tool also presents the deadline for making the trust decision regarding the collaboration.

All the information presented on the trust decision expert tool aids the process of human trust decision making. Information presentation formats and positioning of the information play crucial role in improving the performance and effort expectancy of human trust decision making. Most of the information required for trust decision making is presented in the graphical format such as risk, reputation and progress information. Graphs are a preferred way of information presentation of, for example, quick summary of vast amount of data, detecting trends over time, and comparing patterns of different variables for activity forecasting [16]. On the other hand, the use of small textual sentences for providing the information decreases the cognitive load on the human users for finding the required information out of the big chunk of information.

The next section discusses the implementation of the trust decision expert tool.

5.6 Implementation of Trust Decision Expert Tool

Trust decision expert tool is implemented using Java and Google Web Toolkit (GWT). Since the Pilarcos trust management system has already been implemented. The trust decision expert tool is currently a stand-alone prototype which is not really integrated with the existing Pilarcos trust management system. I have implemented the trust decision expert tool constituting user interface layer and transformation layer. The user interface of trust decision expert tool is developed using GWT. However, the trust decision expert tool sets up placeholders for extending the existing Pilarcos trust management system using both Java and GWT.

The user interface layer is implemented using the GWT designing service. The GWT designing service consists of different designing elements - such as GCharts, panels, flex tables, labels, text boxes, buttons, push buttons, radio buttons, date boxes and date pickers. All the GWT design elements provide support for organizing and presentation of the information required for trust decision making.

The graphs present in the risk information, reputation information and progress information view are implemented using GCharts. The trust decision expert tool makes use of flex tables and different panels - such as decorated stack panel, vertical panel, horizontal panel, and absolute panel.

The flex tables and panels are used for arranging the different pieces of information in the desired format. For example, vertical panels are used in all the information views for ordering the different information pieces in to follow one after the other or vertical order. Similarly, horizontal panels and absolute panels lead to arranging different bits of information in horizontal order.

The GWT design element called label is mainly used for the purpose of presenting a static piece of information to the human user. For example, labels are used for communicating the deadlines and goals of the inter-enterprise collaboration. Labels are also used for informing human users about the input required from them. For example, user interface of trust decision expert tool also uses labels for this purpose for informing users to make the decision by either clicking the accept or reject button.

Other GWT design elements - such as radio buttons, push buttons, buttons, text boxes, date boxes and date pickers â are used for getting input from the user for performing the desired action. For example, human users communicate their desire for viewing the graphs for a specific view by proving their input through clicking the radio buttons named “Collaborative View” or “Enterprise View” in risk information and reputation information view.

The transformation layer of the trust decision expert tool is implemented using Java and GWT data providing service. The GWT data providing service includes implementation two main components - interfaces and a service servlet. There are two different interfaces: service interface and asynchronous service interface. The service interface defines all the methods providing services to the client. On the other hand, asynchronous service interface defines asynchronous features of the services provided by server to client. It consists of a callback object for receiving data from the server side, to manage the asynchronous aspects of the service.

The second component of the data providing GWT service is servlet. The servlet, present on the server side, actually performs the intended task of receiving the required information from the Pilarcos trust management system and storing the decision scope information to it for future use. The transformation layer recieves the required data, for example experiences for all the outcomes of all the assets using the servlet. After receiving the required data, transformation layer transforms the experiences for the outcomes of the assets into probabilities. The interfaces of GWT data providing services provides the transformed data to the user interface of trust decision expert tool for the purpose of human decision making. However, in the case of decision scope, a transformation layer fetches the information from the user interface using GWT data providing interfaces. The fetched decision is stored on the server side using the servlet.

5.7 Summary

This chapter presents the design and implementation of the proposed trust decision expert tool. The design goals in addition to the information sources of the trust decision expert tool are presented. The chapter also covers the division of the gathered information sources into two different expert tools: trust decision expert tool and collaboration negotiation expert tool. The information required for trust decision making is presented on the user interface keeping the pre-set design goals in focus. The architecture, workflow and system design of the trust decision expert tool discuss its internal design and working. The different information views of the user interface of the trust decision expert tool are presented in terms of their need and satisfaction of the design goals. The details of the tool used for implementation of the trust decision expert tool are also elaborated towards the end of the chapter.

After the design and implementation of the proposed trust decision expert tool, the details of its usability evaluation are presented in the next chapter.

Chapter 6

Evaluating the Trust Decision Expert Tool

This chapter presents the methodology and procedure followed to evaluate the trust decision expert tool. The evaluation intends to evaluate trust decision expert tool on four dimensions including information sufficiency, general usability, user performance and quality. The evaluation is conducted at Collaborative and Interoperable Computing group at the University of Helsinki with five test participants. The chapter first presents the methodology of the evaluation in Section 6.1. The results of the evaluation are presented in Section 6.2. Finally, the chapter concludes with a summary in Section 6.3.

6.1 Methodology

This section presents the methodology used for conducting the evaluation of the trust decision expert tool. The section starts by presenting the purpose of the evaluation followed by the details about the test participants, procedure and equipments used for conducting the evaluation.

6.1.1 Purpose

The evaluation aims to evaluate the trust decision expert tool on four dimensions: sufficiency of the presented information, usability, user performance and quality. The sufficiency of presented information evaluates the presence of all information required by the human users for trust decision making in risky situation pertaining to joining and continuation of the inter-enterprise collaborations. Furthermore, this dimension also aims to identify the additional information required for trust decision making. The usability dimen-

sion evaluates the general usability of the user interface of the trust decision expert tool. It aims to determine ease of use, ease of finding the required information, clarity in information presentation and co-relation between the information presentation formats and the tasks to be performed. Furthermore, the impact of all these factors aims at ascertaining the learnability, memorability and perception about trust and security held by the human users for performing trust decisions with previously little known or unknown enterprises. The performance dimension evaluates the task completion rates including the rate of successful task completion, average time taken to complete the tasks and number of errors committed by the human users. The quality dimension of the evaluation measures the user's satisfaction and accuracy of the tasks performed by the users using the trust decision expert tool. Overall, the main goals of the evaluation is to determine if the presented information is clear and if some functionalities or information is missing from the current version of the trust decision expert tool.

6.1.2 Procedure

The basis for performing usability evaluation is "Think aloud" method given by Jakob Nielsen [33]. During the evaluation, I acted as the study moderator responsible for recording time taken for performing a particular task, errors made by test participants and documenting participants comments, suggestions and behavior. All the comments of the test participants are collected on a plain paper and later documented in this chapter. The evaluation is conducted in three stages: introduction, solving test tasks and debriefing.

Introduction: In the introduction phase, purpose of the study, ethical information, underlying study setup and different phases of the study. All test participants are clearly informed about the code of ethics for the evaluation and are asked to sign the permission form. The test participants are explained the procedure for performing the test tasks and recording their responses. After the presentation the test participants are presented the following test scenario.

"You are a running an enterprise named "Quick Service" which provides online logistic services within Europe. Your enterprise is involved in collaborating online with other enterprises through out the world. You are using Pilarcos middleware for managing your online collaborations. Usually, Pilarcos middleware makes automated decisions regarding your enterprise's participation in the online collaborations. But, now you have received an email, containing a link, asking you to make a decision regarding your continuation

in an ongoing collaboration."

The test scenario presents the realistic situation and test participants are instructed to imagine themselves in such a situation. Following this, the test participants are asked to write their expectations about the information that they would use or like to see in the trust decision expert tool for trust decision making. After writing the expectations, the test participants are asked to explore the trust decision tool for getting familiar with it.

Solving test tasks: After the introduction, test participants are asked to perform test tasks using the trust decision expert tool running on a laptop. The test participants are encouraged to think aloud while they are performing the test tasks. Considering the design of the user interface of trust decision expert tool, the main task addressing each information view is presented to the test participants one by one. The example of the test task is as follows:

"After reading the email, you already started thinking about the assets that might be endangered by further participating in the collaboration. You figure out money is the most important asset for your enterprise. You decide to find out the risks that the collaboration poses economically to your enterprise."

Each main task includes of three to four sub-tasks. The sub-tasks motivate the users to use the trust decision expert tool and a particular information view to find the asked information. The sub-tasks are given on a piece of paper where the participants can mark their answers to multiple choice question using a pen or a pencil. Presenting the tasks on a piece of paper reduce the influence of the test moderator during the test. The sub-tasks are handed out one at a time. So, there will be one task per page. This enables concluding the test at any time if the test participants desire. Furthermore, this will avoid making the test participant feel uncomfortable for not completing all the tasks. After finishing each task, the test participants are asked to fill in a short questionnaire capturing their experience of using a particular information view. Filling the questionnaire after each task concerning a particular information view helps in capturing real time data, which the test participants might forget while solving other tasks of the evaluation.

Debriefing: After completing all tasks, the test participants are asked to fill in a post task questionnaire. The post-task questionnaire aims to capture the overall experience and general impression of the test participants about using trust decision expert tool and its different functionalities. The post-task questionnaire consists of objective type questions gathering feedback using five point likert scale ranging from stronly agree to strongly disagree in addition to open ended questions. The example of questions constituting post task questionnaire are: *"The trust decision expert tool is easy to use." "I think trust decision expert tool presents all the information needed for*

decision making." " I think trust decision expert tool presents the information in the formats co-related with the task of decision making. " "In trust decision expert tool I liked" "In trust decision expert tool I think following information is missing"

All the three stages are performed sequentially one after the other. The copy of introduction, test tasks and debriefing questions are available on request.

6.1.3 Test Participants

I recruited five test participants working as researchers at the University of Helsinki and are familiar with Pilarcos trust management system beforehand. The test participants are contacted by email asking them to participate in the usability test. The email stated the purpose of the evaluation, study setup and duration of the study.

The researchers are recruited as test participants owing to their familiarity with the Pilarcos trust management system considering the nature of the target population. Moreover, the Pilarcos trust management system is still as a research prototype which is not commercially available to the outside world. Therefore, the target population familiar with the basic working approach of the Pilarcos trust management system, the researchers are recruited for conducting usability evaluations. Among the test participants, four are Finnish male and one Chinese female. The participants are aged 25 to 39 (Mean - 30.6 years, Standard Deviation - 5.8).

The evaluations are conducted in English. One participant is tested at a time and it took approximately one hour for one single evaluation session.

6.1.4 Equipment

The usability test is conducted on a laptop having Windows Vista operating system. The trust decision expert tool is run on the Mozilla Firefox browser. Apart from this, the test participants used a pen and a paper for giving responses. The test moderator also used a pen and a paper for taking the notes during the evaluation. The stopwatch is used for tracking the time for accomplishing each sub-task.

6.2 Results

This section presents the results of the evaluation of the trust decision expert tool from four different perspectives: sufficiency of the presented information,

usability, user performance and quality.

6.2.1 Sufficiency of the Presented Information

The sufficiency dimension aims at evaluating the sufficiency of the presented information to the human users for trust decision making in risky situations. The user interface of the trust decision expert tool presents the information regarding risk, reputation, context, collaboration progress status and credibility for trust decision making. The decision regarding showing the specific information on user interface of the trust decision expert tool is based on the literature review made in the domain of e-commerce and online environment. Therefore, it is important to evaluate if the gathered information requirements really matched the information needs of the user for trust decision making regarding joining and continuing the inter-enterprise collaboration.

The evaluations on five test participants show that three test participants (60%) agree that the trust decision expert tool presents the information required for trust decision making (Figure 6.2). However, other two test participants disagree on the statement. The evaluation results also show that 60% of the test participants are of the opinion that the trust decision expert tool satisfies to their expectations (Figure 6.1). The probable reason for disagreeing or not strongly agreeing with both these statements can be the absence of all the information required by the test participants. The test participants reported about the missing information while performing the sub-tasks and during the debriefing session. For example, the test participants found following information missing: monetary profits, collaboration alternatives, summary of the already presented information, decision history, ontological explanation of presented factors, possibility of using different calculation methods (i.e. simulating the effects of new policies) and proper business process representation.

6.2.2 Usability

The main objective of the usability dimension is to evaluate the ease of using the trust decision expert tool. Furthermore, it also aims to find if the test participants consider (i) the presented information easy to find, (ii) clearly presented and existence of correlation between the information presentation formats and the tasks to be performed. The trust decision expert tool should satisfy all these usability measures according to pre-defined goals behind its design. These goals are set based on the learning from the cognitive theories for designing user interfaces [56, 58, 59, 61] and usability design guidelines [33]. All these usability metrics can be considered as important parameters

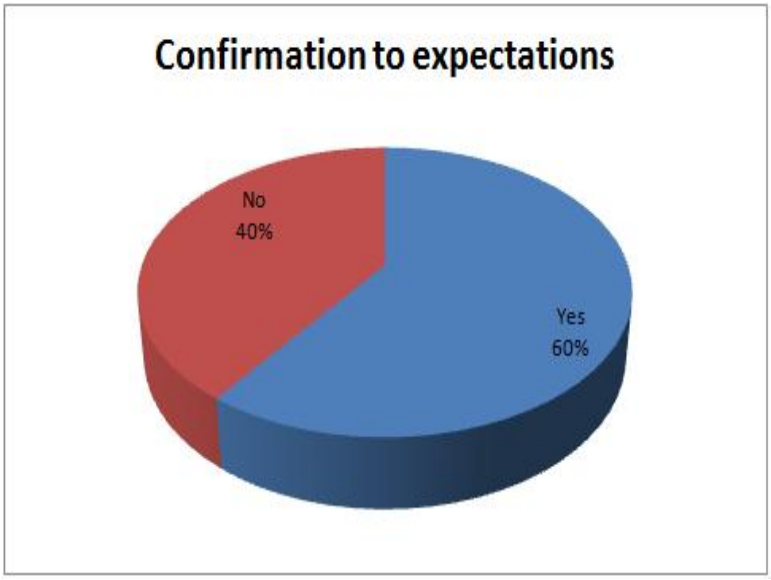

Figure 6.1: Result of the Confirmation of Expectations regarding the Information required for Trust Decision Making.

behind the success of the trust decision expert tool. Therefore, it is essential to evaluate these usability measures through the means of the evaluation.

Overall, three test participants agree that the trust decision expert tool is easy to use. On the other hand, two test participants hold neutral opinion on considering the trust decision expert tool as easy to use (Figure 6.2). The test participants hold almost similar opinion on all the individual information views constituting the trust decision expert tool (Figure 6.3). Three test participants agree and two disagree on the statement that the risk information view is easy to use. Regarding reputation information view, three participants are neutral while the other two disagree. The context and progress information view perform better in terms of ease of use. Two test participants strongly agree whereas three agree that the context information is easy to use. On the other hand, two participants strongly agree whereas out of remaining ones, two agree while one disagrees in context to ease of using progress information view. The probable reason for disagreeing or holding a neutral opinion is the missing ontological explanation of the presented factors. For example, the test participants are confused with the ontological meaning of the control asset. The test participants suggested using asset specific labeling for the graphs and explaining the ontological meaning of the presented factors for enhancing the clarity and ease of use of the trust decision expert tool.

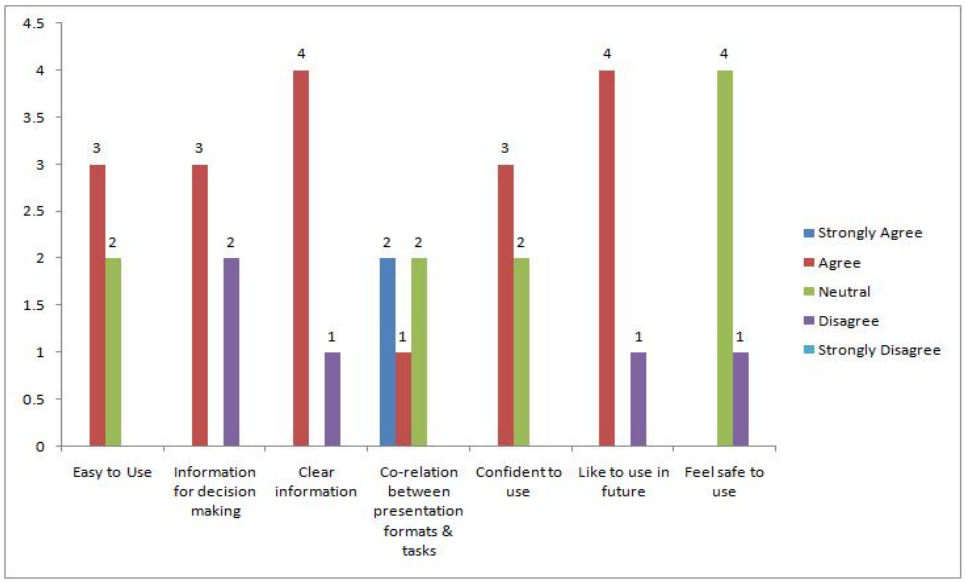

Figure 6.2: Results of the De-Briefing Phase.

In context to finding information easily, one test participant strongly agrees, three agree whereas fifth participant holds neutral in the case of risk information whereas three participants agree and two disagree in the case of reputation information view. The reputation information view presents a lot of information. Therefore, the possible reason for disagreeing can be absence of the summarized view of the presented information. In contrast, majority of the test participants (60%) have a neutral opinion while other 40% strongly agree that the information is easy to find in the case of context information view. The test participants have rated the progress information view somewhat similar to risk information view where four participants agree whereas one is neutral in context to ease of finding information.

According to the results of the debriefing phase, four test participants agree and only disagrees regarding clarity of the information presentation. On the other hand, test participants have a mixed opinion on clarity of the presented information for individual information views of the trust decision expert tool (Figure 6.3). Three test participants agree while two disagree in the case of risk information view whereas there are similar agrees but one neutral and one disagree in the case of reputation information view. Three test participants have neutral opinion while one of the remaining two agrees and other disagrees regarding clarity in the presentation formats in the context information view. The progress information view experienced mixed reactions regarding clarity of the information presentation formats.

The reaction of test participants for the progress information view is: one strongly agrees, two are neutral, one disagrees while one strongly disagree.

The probable reason for disagreeing can be the lack of provision of a summarized and concise view of the already presented information. Three of the test participants are of the view that there should be a summarized view presenting a comparative and analyzed view of the presented information. For example, the trust decision expert tool can present summarized information as small textual phrases such as: *"you have 63% probability of earning monetary benefits"*. One of the test participants suggested that the summarized view can also be based on the analysis made by the automated trust management system of the current data. Absence of concrete analysis of the presented information and missing ontological explanation of the presented factors is the main problem in the case of risk and reputation information view. However, presentation of the information in textual format in the form of small phrases consisting of relevant information is main reason behind disagreeing in the case of context information view. The test participants disagreeing with the information presentation formats of the progress information view desire to see proper presentation of the business process in terms of progress using tools such as Business Process Model and Notation (BPMN) or in the form of percentage of tasks completed.

Two test participant strongly agree whereas one agrees and other two are neutral in context to co-relation between information presentation formats and tasks to be performed. Overall, the users seems to be satisfied on this front. As previously mentioned, majority of the test participants are also satisfied regarding ease of using the trust decision expert tool. According to CFT and CLT, the existence of co-relation presentation formats and tasks to be performed is important metric for enhancing the performance of the human users. As previously mentioned, clarity of the information presentation and the co-relation between them reduces the cognitive load on the human users thereby enhancing their efficiency. UTAUT and TAM state that the ease of use and effort expectancy impact users' attitude towards acceptability of new technology.

6.2.3 User Performance

The objective of the user performance dimension is to evaluate the success rate of task completion, number of errors committed while performing the sub-tasks and time taken to perform the tasks by all the test participants. The user performance dimension aims at evaluating the human users and not the performance of the trust decision expert tool or the Pilarcos trust management system. The evaluation of the user performance dimension is

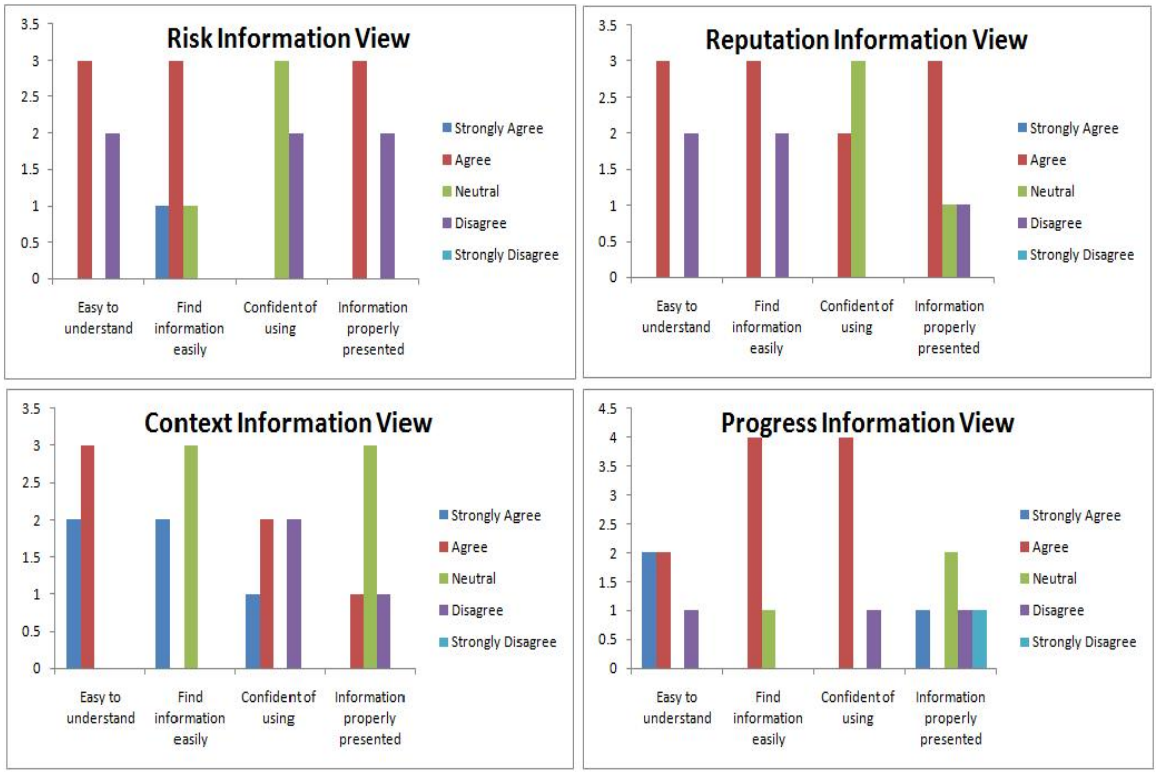

Figure 6.3: Results of the Perception Questionnaire.

significant for determining the success of the trust decision expert tool. The trust decision expert tool will be a failure if either the users are not able to perform tasks at all using it or in appreciable timings. Both these aspects play critical role towards the success and acceptability of the trust decision expert tool.

Based on the main tasks, there are in total 14 sub-tasks which motivated the test participants to find asked information using trust decision expert tool. The task completion rate is 100 percent. All the test participants completed all the tasks despite the accuracy of the provided answers. The only exception is when one test participant deliberately choose not to answer the asked information due to absence of the required information. The test participant provided the following reason: *"can't decide as the time and percentage of the tasks completed is needed to decide"*. Otherwise, all the sub-tasks are answered by all the test participants.

The successful task completion rate for two test participants is 100% whereas 93% for the other two participants and 78% for the fifth participant (Table 6.1). Only one test participant gave incorrect answer to three ques-

	Sub-Tasks													
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
1	OK	OK	OK	OK	OK	OK	OK	OK	X	OK	OK	X	OK	*
2	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
3	OK	OK	OK	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
4	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
5	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	X
Success	5	5	5	4	5	5	5	5	4	5	5	4	5	3
Success Rate	100%	100%	100%	80%	100%	100%	100%	100%	80%	100%	100%	80%	100%	60%

Table 6.1: Success Rate of the Performed Sub-Tasks. * = Test Participant deliberately did not answer the Sub-Task.

tions where one question is deliberately not answered as explained in the previous paragraph. Therefore, in general the error rate is 7%. Regarding error rate there is no unique point of committing the error. I suspect the main reason for committing the errors is lack of attentive focus while reading the sub-tasks. The main argument behind this statement is that the test participants have given correct answers for other similar sub-tasks.

	Sub-Tasks													
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
1	1:47	0:40	1:55	0:30	1:06	0:39	1:15	0:43	0:05	0:40	0:06	0:28	0:07	0:08
2	0:56	0:53	0:43	0:29	2:21	1:14	1.32	0:58	0:22	1:22	0:17	0:16	0:11	0:32
3	0:29	0:58	1:26	0:46	2:00	1:52	0:23	0:19	0:23	1:01	0:07	0:09	0:21	0:22
4	0:44	0:21	0:50	0:50	1:08	1:10	0:42	0:24	0:33	1:00	0:07	0:04	0:29	0:14
5	0:36	0:21	0:28	0:23	0:48	1:00	0:17	0:50	0:04	0:40	0:07	0:23	0:11	0:23
Mean	0:54	0:38	1:04	0:35	1:28	1:11	0:49	0:38	0:17	0:56	0:08	0:16	0:15	0:19

Table 6.2: Average Time taken for performing Sub-Tasks.

The average time taken to perform all the sub-tasks is 40 seconds. Table 6.2 shows the average time taken to complete the all the sub-tasks. The sub-tasks T1 to T4 are related to risk information view whereas T5, T6, T7, T8, T9 focus on the reputation information view.The sub-tasks from T10 to T12 involve finding information from the progress information view. Finally, sub-tasks T11 and T12 deal with context information view. In general, 60% of the test participants are able to perform 71% of sub-tasks in seconds whereas remaining participants perform 79% and 93% of the sub-tasks in seconds. The time taken by the test participants to complete the tasks is appreciable from the viewpoint that none of them have used this kind of trust decision expert tool previously. As evident from the Table 6.2, majority of the test participants have taken more time for finding information related to risk, reputation and progress information view. The following sub-tasks:

T1, T3, T5, T6 T7, T10 took one to three minutes for finding the required information. The probable reason for taking minutes can be novelty of the trust decision expert tool and the methodology of presenting the information in terms of collaborative and enterprise view against outcomes for all the four high level classes of assets. The test participants take time to get adapted to new technology and its ways [13]. Therefore, more time taken by text participants to accomplish certain sub-tasks as compared to others is justifiable considering the nature of human beings. Based on the provided reasoning, the trust decision expert tool displays efficieny in terms of user performance.

6.2.4 Quality

The quality dimension evaluates user satisfaction of the trust decision expert tool. The user satisfaction is mainly evaluated through ease of use, confidence, willingness to use and perception about safety. Evaluating user satisfaction is an important determinant of estimating the success of the trust decision expert tool.

As previously mentioned that majority of the test participants (3 out of 5) agree that the trust decision expert tool is easy to use. Similarly, three test participants are confident in using trust decision expert tool whereas two participants hold neutral view on it. Furthermore, four test participants agree and only one disagree on the statement regarding using the trust decision expert tool in future. In contrast, four test participants are neutral in perceiving the trust decision expert tool safe to use for decision making in risky situations. One of the test participant disagree on the statement that the trust decision expert tool is safe to use. The most probable reason for disagreeing to use the trust decision expert tool in future and neutrality regarding perception about safety can be insufficient information as mentioned previously.

The test participants liked and disliked certain aspects of the trust decision expert tool. The likes and dislikes regarding the trust decision expert tool are listed in the Table 6.3. In general, the test participants liked the way of presenting the information in the form of graphs and small textual phrases. The test participants are of the opinion that the used information formats bring ease, clarity and unambiguity in perceiving and comprehending the information for trust decision making. At the same time, the test participants also disliked certain aspects about the trust decision expert tool. The dislikes of the participants signify their need for having more clarity. Furthermore, the test participants also found some information missing that would enhance the clarity of the trust decision expert tool further.

Likes	Dislikes
Easy to read and understand graphs.	Presentation of progress information view in the form of number of tasks completed.
Easy and readable textual format for context information view.	Missing information.
Use of colors to signal endangered assets and progress of the enterprises.	Generic labeling of the graphs with respect to assets.
Easy to see information.	
Intuitive GUI.	
Unambiguous information presentation formats.	

Table 6.3: Likes and Dislikes regarding Trust Decision Expert Tool.

The test participants also provided some suggestions about the missing information. Table 6.4 presents the suggestions or recommendations for improving the existing version of the trust decision expert tool. It also presents the justification of introducing these changes in the current version of the trust decision expert tool. Furthermore, the priority of these suggestions is also presented in the Table 6.4. The priority of the suggestions is decided based on three factors. These three factors are: (i) effect of these changes in the working of the trust decision expert tool, (ii) support provided by Pilarcos and (iii) number of test participants supporting it. For example, having a summarized view of the presented information will have positive effect on the users using trust decision expert tool for trust decision making. The summary can be provided in two ways. First, it can be provided by simulating the effects of the presented information for example, merging the probabilities from no effect to major positive effect for all the assets. Second, the summary can also be provided based on the analysis of this information made by the Pilarcos trust management system for automated trust decision making. Provision of such a summary will certainly affect trust decision making positively. Furthermore, the Pilarcos trust management system can also provide support for it. In addition to it, three out of five test participants desire to have summary of the already presented information.

Suggestions	Participant Concern	Priority
Summary/Analysis of the presented information.	Test participants are concerned about analyzing the presented information. The summary can give them more confidence and enhance clarity.	High
Information about other collaboration alternatives.	Test participants are anxious about knowing other collaboration possibilities. This need will be addressed by the planned collaboration negotiation expert tool.	Low
Previous decision history.	Test participants are concerned about the previous decisions made automatically or manually on behalf of the enterprise. This will enhance clarity and confidence.	Medium
Ontological explanation of presented factors	Test participants are particularly concerned about the exact meaning of the presented information. This will enhance confidence, clarity and perception about security.	High
Simulating effects of different policies.	Test participants desire to analyze the effects of simulating different policies on the presented values. But, Pilarcos supports only one simulation at a time. Availability will enhance confidence, clarity and perception about safety.	Medium
Proper business process representation.	Test participants are concerned about current used format for presenting progress information. Informative format will promote clarity, confidence and safety perception.	High

Table 6.4: Suggestions, Participant Concern and Priority regarding Recommendations for Trust Decision Expert Tool.

6.3 Summary

This chapter presents the implementation and results of the evaluation of the trust decision expert tool with five users. The evaluation is conducted to gain feedback on four different dimensions: information sufficiency, general level of usability, user performance and quality. It is found that majority of the test participants (60%, 60%, 80% respectively) agree that the trust decision expert tool presents all the required information, is easy to use and presents the information clearly. On the other hand, 60% of the test participants are confident of using the trust decision expert tool whereas 80% would like to use it in future. But, majority of the test participants (80%) have neutral opinion in their perception about safety of using the trust decision expert tool. The possible main reason for such percentage values is missing information. The test participants also provided suggestions about missing information.Availability of the missing information can boost up the existing confidence levels and perception about safety of the human users in addition to enhancing the clarity of the trust decision expert tool.

The next chapter presents the discussion and insight of the overall research process followed for resolving the main research question of dealing with the human intervention in the case of inter-enterprise collaboration.

Chapter 7

Discussion

This chapter presents discussion on the overall research conducted for answering the research question behind the thesis. It discusses the research methodology, contributions of the research in addition to validity and reliability of the conducted research.

The main objective of the thesis is to resolve the open issue of handling human intervention for trust decision making in the domain of inter-enterprise collaborations. The thesis studies the main objective from the existing Pilarcos trust management system point of view. But, the findings of the thesis can be applied by other trust management systems in the domain of inter-enterprise collaborations as well. The main objective of the thesis is addressed through four different aspects:

- studying the process of human trust decision making in the online environment;
- analyzing information needs of the users for trust decision making in the domain of inter-enterprise collaborations;
- designing an appropriate way of presenting the information to the users;
- reducing the frequency of requests human interventions in the future.

Studying the process of human trust decision making is significant for designing the trust decision expert tool handling human intervention for trust decision making in risky situations. The existing literature on trust, trust development and decision making focusing on human perspective in the domain of B2C ecommerce, traditional organizational setup and online environment have been reviewed for understanding the overall process of human trust decision making. This research aspect is challenging because

the literature on trust is scattered due to involvement of different disciplines. Moreover, I did not come across research addressing the issues similar to the main objective of the thesis. Therefore, the information concerning B2C ecommerce gathered through the literature review has been mapped in the domain of inter-enterprise collaboration for assessing the expectations and requirements of the human users for trust decision making.

The gathered knowledge has been used to propose a trust relationship development model suitable for the domain of inter-enterprise collaboration. The different relevant elements of the trust relationship development model are used for designing the proposed trust decision expert tool. Moreover, the methodology followed for answering this research question is also useful for designing future trust management systems and improving the existing ones.

Analyzing the users' information needs is essential for designing and implementing the trust decision expert tool. Understanding the information needs provides insights into the requirements of humans for trust decision making in risky situations in addition to providing guidelines for deciding the content to be displayed on the trust decision expert tool. In this way, the gained insights help in prioritizing and arranging the information to be presented on the user interface for trust decision making.

The information needs for the trust decision expert tool are gathered in three phases. First, as mentioned before, the general information needs of human users for trust decision making are gathered. Second, the working of the three existing trust management systems (TrustCoM, ECOLEAD and Pilarcos) is studied for gaining knowledge on different factors used for automated trust decision making regarding inter-enterprise collaborations. Finally, considering the scope of the thesis, the analysis of the Pilarcos middleware and its trust management system is made for understanding the way different gathered information needs are supported by it. This has provided input for deciding what needs to be presented and how it should be presented on the user interface of the proposed trust decision expert tool.

As mentioned before, the first phase contributed towards the main goals by proposing the trust relationship development model for the domain of inter-enterprise collaboration. The second phase contributed through the results of the comparitive analysis of the proposed trust relationship development model and the working of three existing trust management systems against each other. The comparative evaluation helps in validating the findings of the literature review in addition to finding the extend to which the concerned trust management system satisfy the needs of the humans since the automated decisions are being made on their behalf. The comparative analysis showed that all the three systems differ in their approaches towards trust management and trust decision making. Considering the scope of the

thesis, the final phase provided the actual input for implementing and designing the trust decision expert tool.

Presentation of the required information in an appropriate way helps strengthen the perception about trust and security towards the use of implemented trust decision expert tool. The availability of the required information helps in promoting transparency and clarity in addition to providing confidence to the human user for trust decision making. This leads to confident and efficient trust decision making.

The presentation and positioning of the information impacts the user's attitude towards trust decision making. The knowledge regarding information presentation formats provides useful guidance for designing the user interface of trust decision expert tool. Nielsen's usability principles and different theories dealing with cognitive aspects of human users provided input for designing the user interface of trust decision expert tool.

Providing usable information and interface are the design goals behind the trust decision expert tool. These design goals are evaluated in terms of four dimensions: information sufficiency, usability, user performance and quality. In context to sufficiency of the information, the evaluation results show that majority of the test participants are satisfied. However, the test participants that disagree provide suggestions about missing information. For example: summary of the presented information, ontological explanation of presented factors and previous decision history. The other three dimensions assess the usability of the trust decision expert tool from three correlated points of view reflecting the second design goal. The results of the usability evaluation reveal that the majority of the test participants find the trust decision expert tool usable in terms of ease of use, clarity of presentation formats and correlation between the presentation formats and tasks to be performed. Similarly, majority of the test participants would like to use trust decision expert tool in future and are confident of using it. However, the probable reason for majority to have neutral opinion on perceiving the trust decision expert tool as safe is missing information. The availability of missing information can enhance trust, ease of use, confidence, and clarity in using trust decision expert tool.

Reducing the frequency of human intervention is important for retaining the efficiency in the establishment and functioning of the inter-enterprise collaborations. The trust decision expert tool makes an effort to improve the existing Pilarcos trust management system by reducing the frequency of the human interventions for trust decision making. As noted before, the trust decision expert tool reduces the human intervention in future by retrieving the information about scope of the decision made by the human users regarding the joining and continuing the collaboration. The human

users can set the scope of the decision applicable in similar situations in future either for the whole contract or for fixed number of days by choosing the starting and ending dates. The trust management system can save the decision scope and consider it whenever required for automated trust decision making for similar situations in future.

While reviewing the literature, I realized the findings from B2C e-commerce can not be applied directly to the domain of inter-enterprise collaborations due to existing weaknesses. For example, consideration and awareness of the objectives and perspectives of the collaboration is important for trust decision making regarding inter-enterprise collaborations while it has very little emphasis in B2C literature. This is because the collaborating enterprises might have different objectives such as: making money, gaining experience or reputation or attaining expertise, which might effect the perspectives towards trust decision making. Furthermore, I found it valuable to combine the perspectives of cyclic and staged models into a hybrid trust development model. The proposed trust relationship development model tries to fulfill all these aspects by correlating different independent concepts together related to human trust, trust development and trust decision making.

The comparative evaluation of three existing trust management models based on different trust metrics, architecture, focus areas and system purpose revealed that the proposed trust relationship development model matches with their working. The mapping of the proposed model with the process of automated trust decision making of the existing trust management systems shows that the model is usable in the domain of inter-enterprise collaboration. However, different trust management systems relate to the proposed trust relationship development model in their own way. The implementation and designing of the trust decision expert tool got input from: (i) analysis of the Pilarcos middleware, (ii) proposed trust relationship development model, (iii) usability principles and (iv) existing cognitive strategies governing the design of user interface. The implemened trust decision expert tool is evaluated using a user study to validate usability involving five test participants. The feedback provided by the evaluation is valuable for future development. However, the results can not be generalized yet because of the limited number of test participants. As this work on trust decision expert tool and human trust decision has not been done before regarding the domain of inter-enterprise collaborations, the results presented in this thesis act as a first step towards usable decision making tools for semi-automated collaboration management systems.

Chapter 8

Conclusions and Future Work

Trust decision making is a primary element of trust management in the domain of inter-enterprise collaborations. The existing trust management systems use automation for ensuring efficiency regarding the establishment and functioning of inter-enterprise collaborations. However, human intervention is still needed for trust decision making. Therefore, addressing human intervention for trust decision making is an important research question in the field of inter-enterprise collaborations. The existing trust management systems involve humans during their working and realize the importance of designing user interfaces and tools for resolving the problem for human intervention. For example, ECOLEAD and TrustCoM have portlets for interaction with the human user for trust decision making in their implemented prototypes. But, neither of them have reportedly made an effort to research on designing the user interfaces besides Pilarcos through the means of this thesis.

This thesis proposes the trust decision expert tool for handling human intervention regarding trust decision making specifically in the case of the Pilarcos trust management system. The development of the trust decision expert tool is based on an extended human trust relationship development model applicable in the domain of inter-enterprise collaborations proposed in this thesis. It is important to understand the needs and expectations of the human users based on the existing literature on trust and trust decision making in the online, e-commerce and organizational environment. Reviewing of the existing literature resulted in understanding the process followed by human users for trust decision making and trust development. The findings from the literature are adapted as required to satisfy the needs and requirements of the domain of inter-enterprise collaborations.

The thesis follows the methodology of understanding human preferences regarding trust decision making and the process of trust decision making followed by different trust management systems existing in the domain of

inter-enterprise collaborations for proposing the trust decision expert tool. Understanding human preferences behind trust decision making serves three purposes. It helps in: (i) understanding the phenomenon behind human trust decision making in context to inter-enterprise collaborations, (ii) developing future automated trust decision expert tools satisfying human needs and (iii) evaluating existing trust management systems for further improvements.

The three existing trust management systems; TrustCoM, ECOLEAD and Pilarcos; were also compared against gathered human preferences on trust decision making in addition to three other factors: focus areas, system purpose and architectural foundation. The comparative analysis of the three systems revealed that they all involve humans in their process of automated trust management for trust decision making. On the other hand, from the comparative analysis I found that Pilarcos supports certain attributes which differentiate it from other two discussed trust management systems. First, the definition of trust given by Pilarcos is most appropriate since it gives a holistic view and is easy to interpret as compared to definitions given by other systems. Second, Pilarcos follows a hybrid approach to trust development which covers the weaknesses I have found in both the cyclic and staged approaches to trust development. In other words, hybrid approach is required for the success of the inter-enterprise collaborations. Third, to the best of my knowledge, only Pilarcos is making an attempt to study the designing of the user interfaces and expert tools for the handling human intervention for trust decision making through the medium of this thesis work. Last, Pilarcos functions in the open service ecosystem which truly provides the possibilities of opportunistic partner selection as compared to other trust management systems.

The proposed trust decision expert tool is found to be acceptable in terms of the information presented for trust decision making by majority of the test participants. However, they emphasized the need for availability of additional information such as: alternatives for collaboration, possibility for viewing the brief analysis of the presented information, proper representation of business process, decision history and ontological explanation of the presented factors. The majority of the test participants are satisfied with the overall usability of the trust decision expert tool. However, the proposed trust decision expert tool can be further improved by incorporating the missing information. The missing information will improve the trust decision expert tool further not only in terms of information needs, but also its usability. Even though the evaluation provided valuable insights for further enhancing the existing version of the trust decision expert tool, the findings are not representative because it is conducted on only five users. Hence, the results are not generalisable. Despite this, they provide valuable feedback on the further

development of the tool and encouragement for other planned collboration negotiation expert tool.

8.1 Future Work

In the future, the proposed trust decision expert tool can be enhanced further on the basis of the changes suggested by the test participants during the evaluation of the current version of the trust decision expert tool. The current version of the expert tool focuses only on quick decision making with only accept and reject options. It does not provide the possibility of negotiating terms and conditions with other participating enterprises. The expert tool will be extended further to include negotiation and simulation support as well. The renewed expert tool will provide broader view of the collaboration and allow more extensive reconfiguration than simple yes/no decisions. All the information presented through the means of the collaboration negotiation expert tool have effect on the trust decision making regarding the collaboration. The trust decision expert tool was prioritized for this thesis work as it enabled quick decision making by providing required information having direct impact on the human users for trust decision making.

The systems supporting inter-enterprise collaborations are making automated decisions on the behalf of the human users. A method providing feedback on the quality of the automated decisions is important for these systems. The quality of decisions includes amount of acceptances and rejections, and what kind of decisions are either accepted or rejected. This kind of feedback promotes transparency and trust among human users. Assessment of quality of the automated decisions is absent in the current systems supporting inter-enterprise collaborations. Therefore, in future the method which can enable users to get feedback on the quality of the automated trust decisions should also be studied, as it will provide a method for self-evolution for service ecosystems.

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