Curtin Business School

Digital Ecosystems and Business Intelligence Institute

A Methodology for Maintaining Trust in Virtual Environments

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DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Signature: 

Date: 04/10/2011

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THESIS SUMMARY

The increasing interest in carrying out business in virtual environments has resulted in much research and discussion of trust establishment between the entities involved. Researchers over the years have acknowledged that the success of any transaction or interaction via the virtual medium is determined by the trust level between trusting agent and trusted agent. Numerous publications have attempted to address the various challenges of assigning a trust level and building trust in an interacting party. However, the building and allocating a value of trust is neither easy nor quick. It involves high cost and effort. Hence, the ensuing research challenge is how to maintain the trust that has been established and assigned. Due to the dynamic nature of trust, the trust evolution, and the fragility of trust in virtual environments, one of the most pressing challenges facing the research community is how trust can be maintained over time. This thesis is an effort in that direction. Specifically, the objective of this thesis is to propose a methodology for trust maintenance in virtual environments which we term 'Trust Maintenance Methodology' (TMM). The methodology comprises five frameworks that can be used to achieve the objective of trust maintenance.

In order to achieve the aforesaid objective, this thesis proposes a: (a) Framework for third party agent selection, (b) Framework for Formalization and Negotiation of service requirements, (c) Framework for Proactive Continuous Performance Monitoring, (d) Framework for Incentive Mechanism, and (e) Framework for Trust Re-calibration.

The framework for third party agent selection is used for choosing and selecting a neutral agent who will supervise the interaction between two parties. This is the first step of our methodology. The neutral agent is involved throughout the course of the interaction between two parties and takes a proactive-corrective role in continuous performance monitoring. Once both parties have chosen a neutral agent, they carry out a formalization and negotiation process of their service requirements using our proposed framework. This is in order to create an SLA which will guide the interaction between two parties. The framework for proactive continuous performance monitoring then can be used to evaluate the performance of both parties in delivering their service based on the SLA. If a performance gap occurs during the course of transaction, the third party agent will take action to help both parties close the performance gap in a timely manner. A key salient feature of our continuous performance monitoring is that it is proactive-corrective. Additionally, we design a framework for providing an incentive during the course of interaction to motivate both parties to perform as closely as possible to the terms of the mutual agreement or SLA. By the end of the interaction time space, both parties will be able to re-assess or re-calibrate their trust level using our proposed framework for trust re-calibration.

Finally, in order to validate our proposed methodology, we engineered a multi-agent system to simulate the validity of the TMM. Numerous case studies are presented to elucidate the workings of our proposed methodology. Moreover, we run several experiments under various testing conditions including boundary conditions. The

results of experiments show that our methodology is effective in assisting the parties to maintain their trust level in virtual environments.

To my parents: Fatchan Hasbi and Ruchiyati

To my dear husband, Miftakhul Huda Tohir and my lovely daughters:

Fannisa Balqis Huda, Nisrina Adiba Huda and Arsyania Iftikhar Huda

To my brothers: Fahrudin Hasbi and Baharudin Hasbi

To all my family

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LIST OF PUBLICATIONS

Refereed Journal Articles

1. Fachrunnisa, O. and F. K. Hussain (2011). "A Methodology for Maintaining Trust in Industrial Digital Ecosystems". IEEE Transactions in Industrial Electronics. DOI: 10.1109/TIE.2011.2173890

2. Fachrunnisa, O. and F. K. Hussain. "A Framework for Service Formalization and Negotiation for Trust Maintenance". Multiagent and Grid Systems - an International Journal. Accepted with minor revisions on 26th April 2011.

3. Fachrunnisa, O. and F. K. Hussain. "A Methodology for Modelling Temporal Nature of Trust in Trust Maintenance for Digital Enterprise". International Journal of Computer Systems Science & Engineering. To appear in May 2012.

4. Fachrunnisa, O. and F.K. Hussain. "A Methodology for Creating Sustainable Virtual Multimedia Communities". Multimedia Tools and Applications: an International Journal, Accepted with minor revisions on 26th August 2011.

Refereed Conference Proceedings

1. Fachrunnisa, O., F. K. Hussain, et al. (2009). "*Current Research Trends and Future Research Directions for Trust Maintenance in Virtual Environmments*", International Conference on Information Integration and Web-based Application & Services (iiWAS 2009), 14 - 16 Desember 2009. Kuala Lumpur, Malaysia, ACM**:** 718-724 (**Awarded Best Paper**).

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3. Fachrunnisa, O., F.K. Hussain (2010). *"A Framework for Creating A Sustainable Community in Virtual Environments",* International Conference on Information Integration and Web-based Application & Services (iiWAS 2010), 8 - 11 November 2010, Paris, France, ACM: 735 – 742.

4. Fachrunnisa, O. (2011). "*A Performance-Driven Incentive-Based Approach for Successful Service Delivery*". 5th IEEE International Conference on Digital Ecosystems and Technologies (IEEE DEST 2011), 31 May -3 June 2011, Daejeon, Korea, IEEE: 324-329.

Chapter 1 - **Introduction**

1.1 Introduction

In this chapter, we present an overview of the role and importance of trust maintenance in virtual environments in general, and business environments in particular. In Section 1.2, we discuss the importance of trust maintenance in virtual environments. Section 1.3 explains the pressing issues related to the research of trust maintenance in virtual environments. Section 1.4 presents the objectives of this thesis. Section 1.5 discusses the scope of the thesis and outlines clearly what lies within the scope and what lies outside it.

Section 1.6 presents the importance or significance of this thesis. Section 1.7 provides a very brief introduction to each of the remaining ten chapters of this thesis. Finally, Section 1.8 concludes this chapter and sets the scene for the second chapter.

1.2 The Importance of Trust and its Maintenance in Virtual Environments

The shifting of economic activities from the physical environment to the digital environment has been acknowledged as bringing many benefits. Some specific advantages of conducting business in virtual environments include an increase in productivity, adaptability, flexibility, agility and strategic competitiveness in providing and delivering product/service (Sieber and Griese 1998; Grabowski, Ayyalasomayajula et al. 2007; Wietrzyk and Takizawa 2003). Virtuality or virtualness is defined as 'the ability of the business entities to consistently obtain and coordinate critical competencies through its design of value-adding business process and governance mechanisms involving external and internal constituency to deliver differential, superior value in the marketplace' (Venkatraman and Henderson 1998). Moreover, business in virtual environments can be defined as the delivery of work, products and services using the advantage of Information and Communication Technology (ICT). Voss (2003) defines 'service in a virtual environment (e-Service) as the delivery of service using new media such as the Web'. In virtual business, physical location is not important since network technology and the Internet is used to link members or companies across the world. It allows them to share information, resources and costs that enable them to compete on a global scale. This type of business provides many advantages over traditional methods of business, including the ability to bridge time and space, and offer better utilization of distributed resources without physical relocation.

However, the characteristics of virtual and physical relationships from a business perspective differ in several aspects. Interaction in virtual environments is characterized by anonymity, uncertainty, lack of familiarity, lack of face-to-face meeting etc. Kanawattanachai et al. (Kanawattanachai and Yoo 2002) assert that trust is one of the fundamental factors that drive the success and failure of virtual business relationships. This is because trust functions like the glue that holds and links agents together in virtual environments as they operate remotely from each other. For instance, unlike the customers in a traditional business setting, e-business customers may have no opportunity to touch the product or see the service before they decide to purchase. Their purchase decision is based on their trust that the product and/or service that they will receive will be the same as what they see on the computer screen or a virtual medium. Selling and buying online can occur only if buyer and seller have a high level of trust in each other. Furthermore, (Chang, Dillon et al. 2006) state 'in a virtual environment, a trust relationship is established between two parties who normally have never met or may never meet and where communication takes place through a virtual interaction medium'. Chang, Dillon et al (2006) also argue that trust makes one able to express opinions about products or services that they received from interactions in virtual environments. Hence, business in virtual environments may offer the best points of operation within a trust-based culture, in that it enables meaningful interactions between geographically dispersed parties, which was not possible prior to the birth of the Internet.

Moreover, trust between entities in a networked economy is vital due to the expansion of service exchange (e-service) in virtual environments (Giannoutakis and Petrou 2007; Debenham 2009; Ping, Durresi et al. 2011). The new paradigm of interaction of business entities in virtual environments is built not only on transactions, but on establishing, sustaining and improving relationships with existing or potential stakeholders (Jones, Wilikens et al. 2000; Ion, Danzi et al. 2008). Stakeholders are comprised of participatory, enabling and supervisory members. Participatory stakeholders could be business partners, customers, individual/end customers, and suppliers. Technology is an enabling stakeholder that supports the means of communication, while a supervisory stakeholder is a third party agent who regulates transactions or provides advice in some way (Jones, Wilikens et al. 2000; Ion, Danzi et al. 2008). Hence, trust is always seen as something which strengthens a relationship. A successful relationship depends on the strength of the trust and commitment of the trusting agent and the trusted agent to deliver service according to the terms of a mutual agreement.

The establishment of an adequate level of trust in any interaction in virtual environments is neither simple nor quick, but is a lengthy and ongoing process. Therefore, once a sufficient level of trust has been established, it is a challenging effort to maintain it so that the relationship can be sustained. Both parties (trusting agent and trusted agent) need to take appropriate steps to ensure that a successful relationship that has already taken resources (such as time, effort etc) will be sustained over time if that relationship is valuable to both of them. If both parties do not take the steps necessary to maintain this trust level, then it may result in a diminished trust level, or even distrust. Once distrust exists in a relationship, it cannot be rebuilt in a short time (Currall and Epstein 2003; Babar, Verner et al. 2007). Therefore, constant effort is required from both parties in order to maintain the trust level. This is a research issue yet to be addressed in the existing literature. Although the literature indicates that much work has been conducted on the issue of building trust (Hussain, Chang et al. 2007; Jøsang, Ismail et al. 2007), there is no methodological framework for maintaining trust.

However, in the field of trust modelling, most of the research focus is on trust determination and trust prediction. By ‘trust modelling’, we mean a process to assign the value of trust from trusting agent to trusted agent. A formal definition of trust modelling is presented in Chapter 3. Trust determination is concerned with determining the trust condition or trust level after an agent has carried out an interaction with another agent (Raza, Hussain et al. 2010). It can be with subjective or objective information (Sawamura, Aikebaier et al. 2010; Sawamura, Barolli et al. 2010). On the other hand, trust prediction is the process of making use of the current trust value or trust condition or the previous trust values of an entity to reliably predict its trust value at a future point in time (Raza, Hussain et al. 2010). For example, the Service Level Agreement (SLA) between service provider and service requester is agreed upon and signed during the current time slot, but the service delivery will occur at a future point in time. Therefore, a service requester may need to predict the level of trust in this service provider for the future point in time when the service will be delivered. Additionally, those two key researches have been acknowledged as providing an important step in trust management; however, the next important step is how to maintain the existing or the current value after it has been determined. By ‘trust management’ we mean a set of activities to manage the existence of trust in a relationship. A formal definition of trust management is presented in Chapter 3.

Further, determination of trust value is neither a simple nor an easy task. An agent needs to assess all criteria and consider the service context before assigning a trust value to a trusted entity (Sawamura, Aikebaier et al. 2010). Therefore, once an agent holds or is assigned a trust value by another agent, it needs to maintain this trust, or preferably increase it after several further interactions, particularly if the relationship is beneficial to the agents.

Moreover, it has also been widely argued that trust is dynamic rather than static (Chang, Dillon et al. 2006). By ‘dynamic’ we mean that the value of the trust that is assigned to an agent may change dynamically due to a change in the performance or behaviour of the trusted agent. On the other hand, trust essentially has evolutionary phases in both physical and virtual environments (Currall and Epstein 2003; Xiao and Wei 2008). For instance, (Currall and Epstein 2003) divide the trust evolution pattern into three phases: developing, maintaining and destroying. The manner in which trust develops and is maintained has been recognized as a critical factor in certain relationships (Hexmoor, Wilson et al. 2006). (Javernpaa, Knoll et al. 1998) also argue that a significant and critical issue when carrying out business in virtual environments is the development and maintenance of trust among parties. The first step in the initial business relationship is the development and establishment of trust. However, once trust has been developed and established, the next logical step is to maintain the trust level. This is particularly true if the relationship is valuable to either the trusting agent or trusted agent or both. The building of trust is difficult and costly; however, it can be destroyed quickly with a simple misbehaviour that disrupts the component of trust. Distrust or negative trust is a part of trust dynamism that should be avoided at all times in business relationships. One can start an initial relationship with distrust or negative trust. With the passage of time, both parties harbour the hope that distrust may lead to positive trust. Once positive trust has been established, it needs to be maintained. If, however, both trusting parties do not take the initiative to maintain trust, the trust level decreases to distrust or reaches a negative level. A concerted effort is then required to convert negative trust to positive trust. Hence, the maintaining of trust is a critical element in the trust management process (Xiao and Wei 2008). In order to maintain such relationships in virtual environments, a demanding and significant effort is required to avoid decreasing the level of trust to distrust. Therefore, the trust maintenance stage needs significant attention from scholars to foster the sustainability of a networked economy.

Additionally, research in the trust field has been carried out by several researchers across a wide range of disciplines. Due to the unique nature of trust in the virtual environment, the important need to understand how it develops and is maintained provides an opportunity for researchers to discuss the mechanics of trust (i.e., how it is produced and maintained) in such a context (Connolly 2008; Aikebaier, Barolli et al. 2009). Connolly also states that research on the dynamic nature of trust, particularly in a virtual (technology-mediated) environment, is limited. However, the theory and application of trust in virtual environments is increasingly attracting interest from many disciplines. Some studies also suggest the need for research on how to maintain the trust level in virtual relationships (Javernpaa, Knoll et al. 1998; Chang, Dillon et al. 2006; Abuelmaatti and Rezgui 2008). Therefore, in this thesis, we aim to provide and validate a methodology for maintaining trust in virtual environments.

1.3 The Pressing Issues of Research of Trust Maintenance in Virtual Environments

As was discussed in the previous sections, in order to be successful in a long-term interaction in virtual environments, it is essential to maintain trust either vertically, laterally, internally or externally (Handy 1995; Ishaya and Mundy 2004; Nakayama, Binotto et al. 2006; Kenichi Watanabe, Enokido et al. 2009). This means that business entities in virtual environments have to deal with the process of trust among the entities that are part of their virtual network. For example, members of a virtual team must maintain their trust level in their leaders, their peers, their subordinates (internally) as well as with their customers or suppliers or other teams which are their external business partners. Business entities need to examine ways to build trust with their internal and external parties, as well as maintain it. This is because ‘trust is not static and automatic; it involves risk calculation and requires a long time and high cost to build’ (Ariss, Nykodym et al. 2002). Building trust is a challenging activity for every business relationship and it is therefore very fragile. Currall and Epstein (2003) suggest that business entities must think in a systematic way about what they can do to cultivate and maintain trust with the various entities in their industry and company.

Hence, in order to support the establishment of a trusted environment in a Digital Economy, a proven and common framework or methodology would be of great assistance in maintaining a sufficient level of trust in the interaction between service provider and service requester. Such a methodology would guide the behaviour of both interacting parties, with a view to sustain if not increase the level of trust between them. The existing literature provides numerous discussions on how to build trust. However, there is scant research on trust maintenance in the existing body of literature. In addition, the following pressing issues arise in the literature regarding trust maintenance:

1. Most of the existing literature focuses on the trust building phase, with the vast majority of works presenting a single practice or policy for building trust. There is no component or architecture for maintaining trust. Some researchers noted that this is a pressing research issue that needs to be addressed (Jones, Wilikens et al. 2000; Chang, Dillon et al. 2006). Our research is concerned with trust maintenance. In this thesis, we present the design of a methodology for trust maintenance in virtual environments. The common goal of both parties (the trusting agent and the trusted agent) is therefore to sustain an adequate level of trust in their relationship.
2. There are some good practices / principles and policies proposed in the literature that can be used to maintain trust. However, most of them consider only single factors or single activities to maintain trust. Whereas, there is no practical and complete solution to maintain trust which may rely on several important factors or events. Additionally, these proposed good practices/principles/policies to maintain trust lack empirical proof.
3. There is a lot of confusion in the existing literature between the terms ‘trust building’ and ‘trust maintenance’. There is no clear distinction made between them. Additionally, there is no clear explanation of when the relationship can be categorized as being in the stage of building trust, maintaining trust or where trust starts to decline.

1.4 **Objectives of the Thesis**

The previous sections outline the role of trust in virtual environments and the importance of trust maintenance once trust has been determined and established. This thesis attempts to address the pivotal need for trust maintenance by proposing a methodology to maintain trust. The objectives of this thesis are summarized as follows:

1. To propose definitions of: trust evolution, trust building, trust maintenance and trust decline in the context of trust evolution pattern.
2. To develop a comprehensive methodology by which a trusting agent can maintain the level of trust in a trusted agent. In order to address this second primary objective, it is broken down into the following sub-objectives:
    a. To develop a framework for third party agent selection
    b. To develop a framework by which the trusting agent and trusted agent can articulate and formalize their service requirements.
    c. To develop a framework whereby the third party agent can monitor the performance progress of both trusting agent and trusted agent. We also develop a resolution strategy in case the service is not delivered as planned.
    d. To develop a framework that can be used to motivate the agent to perform as much as possible according to the terms of the mutual agreement.
    e. To develop a framework in which both trusting agent and trusted agent re-calibrate the trust value by the end of the interaction.
3. Validation of the proposed methodology for trust maintenance.

Therefore this research does not focus on ways to determine trust value or to build trust in the new entities, but on how the trusted agent can preserve or even exceed the existing level of trust of the trusting agent beyond the minimum threshold of trust in order to successfully carry out a transaction in a virtual environment during the trust maintenance phase.

We use the terms 'trust maintenance methodology (TMM)' or 'methodology for maintaining trust' synonymously to refer to the preservation of the existing trust level condition or to increasing it to a higher level. Throughout the text of this thesis we use the acronym TMM to represent Trust Maintenance Methodology and use it throughout consistently. In the following chapters, we consider trust between two independent actors in service environments, namely trusting agent and trusted agent. The trusting agent is a service provider offering a business service to another agent in a virtual environment and the trusted agent is either a business partner or an individual customer requesting access to the trusting agent's services, as represented by an identifiable agent in the network.

1.5 **Scope of the Thesis**

This thesis presents a methodology that will enable a trusting agent to maintain its trust level in a trusted agent after trust has been determined and established. The scope of this thesis can be specified as follows:

1. This thesis is concerned with the behaviour of trust which is '*offer related'* not '*person related'*. (Coulter and Coulter 2002) argued that there are two areas that influence the relationship between trusted agent and trusting agent, '*person related*' (e.g. empathy, politeness and consumer/service representative similarity) and '*offer related'* (e.g. customization, competence, reliability and promptness). As this thesis deals with business relationships that transpire in virtual environments, '*person related'* is unobservable and hence is outside the scope of this thesis. Therefore, we are concerned with '*offer related'* only. (Coulter and Coulter 2002) also argued that the effect of '*offer related'* characteristics on trust became greater as the length of the relationship increased. In a mature relationship, the trusting agent becomes more and more aware of and tied to a particular service provider over time; therefore, the service provider (trusted agent) needs to be extremely competent in delivering service as mutually agreed.
2. In this thesis, we are more concerned with the notion of '*soft trust'* rather than '*hard trust'*. Hard trust factors represent information derived from security mechanisms such as identity keys, credentials and certificates, whereas '*soft trust*' encompasses information that is inferred from experience and observation of others. Therefore, the establishment of identity trust falls outside the scope of this thesis.
3. This thesis focuses on maintaining trust in virtual e-business environments. Other environments such as physical settings etc do not fall within the scope of this thesis.
4. This thesis is concerned with interactions which are medium to long-term relationships. The interaction between trusting agent and trusted agent is bounded by a contractual agreement. Therefore, the short-term transactional focus and non-contractual interaction is not within the scope of this thesis.

1.6 **Significance of the Thesis**

To the best of our knowledge, at the time of writing, this thesis is the first and only one of its kind to present a methodology for maintaining trust in virtual environments. Specifically, the significance of this thesis arises from the following:

1. This thesis defines the concepts of trust evolution, trust building, trust maintenance and trust decline (in the context of trust evolution pattern) along with the specific characteristics and features of trust and relationships in each phase of the trust evolution. To the best of our knowledge, these concepts and the distinction between them for virtual environments have not previously been defined and presented.

2. This thesis proposes a methodology for maintaining trust in virtual environments. By proposing a methodology for maintaining trust between trusting agent and trusted agent, the significance of this thesis also arises from the following:
   a. This thesis proposes a framework for selecting a third party agent in virtual environments. The availability of a third party as a neutral agent is significant in the interaction between trusting agent and trusted agent. This third party agent will help both trusting agent and trusted agent to monitor the performance of '*soft trust*' in their interaction. To the best of our knowledge, the third party agent discussed in the literature is more concerned with the third party agent's ability to support the availability of '*hard trust'* rather than '*soft trust'*.
   b. This thesis proposes a framework for the formalization and negotiation of service requirements. This framework will guide the trusting agent and trusted agent to construct a Service Level Agreement (SLA) for their interaction. To the best of our knowledge, the existing literature does not consider any pre-activities such as the formalization of service requirements prior to negotiating the service criteria. Moreover, in some cases, as the interaction will be carried out during the trust maintenance phase, the service criteria being formalized and negotiated may be derived from several previous transactions. There is no discussion in the existing literature on how to construct an SLA for interaction during the trust maintenance phase.
   c. This thesis proposes a framework for proactive continuous monitoring. With this framework, the trusting agent and trusted agent can keep track of their performance progress during their interaction in the trust maintenance stage. To the best of our knowledge, such a framework for proactive continuous monitoring has not been proposed in the literature. The literature tends to be more concerned with conducting a performance assessment at the end of the interaction, and nothing is done during the course of the interaction regarding the monitoring and performance assessment. Proactive continuous monitoring would provide a platform for timely resolution of discrepancies between agreed performance and actual performance, before they inflate to unmanageable levels.
   d. This thesis proposes a framework for providing an incentive during the course of the interaction. We designed a mechanism for giving an incentive that is done together with proactive continuous performance monitoring to further motivate the interacting parties to deliver according to the terms of the SLA. The existing literature review suggested and designed an incentive mechanism whereby the incentive is given by the end of the interaction. To the best of our knowledge, no framework to date has been proposed for an incentive mechanism that encourages the successful delivery of service during the trust maintenance phase.
   e. This thesis proposes a framework for trust re-calibration. The trust re-calibration is, unlike in the existing literature, conducted during the trust maintenance phase. This re-calibration considers the value of intermediate trust which is an intermediate performance assessment as a result of proactive continuous monitoring. Hence, our framework for trust re-calibration is unique since it also takes into account the dynamic

behaviour of an agent during the interaction. To the best of our knowledge, such trust re-calibration or trust re-calculation which is specifically intended for activities in the trust maintenance phase has not been discussed in the literature.

3. This thesis validates the proposed methodology for maintaining trust in virtual environments by conducting several experimental simulations.

1.7 **Plan of the Thesis**

In this thesis, we provide a complete methodology for trust maintenance in virtual environments. In order to achieve its objectives, this thesis is organised into eleven chapters. In this section, we give a brief summary of each chapter:

Chapter 2: Chapter 2 provides an extensive review of the existing approaches to trust maintenance in the current literature. It broadly classifies these into approaches for trust maintenance in virtual environments and non-virtual environments. The problems arising from the current literature with regard to trust maintenance are identified in this chapter. Additionally, based on the comprehensive survey of literature, we identify the problems that we intend to address in this thesis. The aim of this chapter is to illustrate that the problems that we intend to address via this thesis have not been previously addressed and resolved in the literature.

Chapter 3: Chapter 3 formally defines each of the problems that we intend to address in this thesis. Furthermore, here we present definitions of several terminologies that will be used to define the problems addressed in this thesis. Additionally, we discuss the research methodologies and research approaches used in this thesis.

Chapter 4: Chapter 4 presents an overview of the solution to each of the issues identified in Chapter 3. Chapter 4 also provides pointers to the chapters containing the detailed solutions for the identified research issues. Moreover, this chapter presents the conceptual definitions of trust evolution, the phases of trust evolution (building trust, maintain trust and declining trust) and the associated trust and relationship characteristic of each phase.

Chapter 5: Chapter 5 presents the framework for third party agent selection, whereby the trusting agent and trusted agent can select a third party agent for their interaction during the trust maintenance phase. This third party agent can be chosen in one of two ways: by using a mutual trusted friend or by hiring a paid professional third party agent. The detailed algorithmic framework and design of these approaches is presented in this chapter.

Chapter 6: Chapter 6 presents the framework for the formalization and negotiation of service requirements. The proposed framework enables the trusting agent and trusted agent to articulate their service requirements, formalize them using a structured mechanism, and determine the prioritization of service criteria. This chapter also presents a framework that can be used by both trusting agent and trusted agent to negotiate and address any conflict. Finally, in this chapter, we use a case study to illustrate how the service requirements being negotiated can translate into the construction of SLA.

Chapter 7: Chapter 7 presents the framework for proactive continuous performance monitoring. The proposed framework enables a third party agent to carry out proactive continuous monitoring during a transaction between trusting agent and trusted agent. This chapter also presents mechanism by which lapses in performance during the course of the interaction can be addressed. Additionally, in this chapter we present the framework for an incentive mechanism which is an additional activity during the proactive continuous performance monitoring. This framework, coupled with the framework for proactive continuous monitoring, facilitates the success of service delivery in an interaction during the trust maintenance phase. We present three approaches to providing an incentive that can be used for different circumstances and interaction requirements. The algorithmic framework and design of the framework are presented in this chapter.

Chapter 8: Chapter 8 presents the framework for trust re-calibration. The proposed framework allows both parties to re-assign or re-calibrate their final trust level after an interaction. This chapter also presents three different approaches that can be used for final trust calculation. We illustrate how the final trust calculation model can be used for an interaction which employs our methodology.

Chapter 9: Chapter 9 presents the prototypes that we engineered in order to validate the proposed methodology to maintain trust in virtual environments. The validation of the proposed methodology is carried out by measuring the effectiveness of our methodology in maintaining trust between trusting agent and trusted agent. We have 7 (seven) broad objectives to measure the validity of our proposed methodology. We divided each objective into several sub-objectives. In this chapter 9, the 3 (three) broad objectives taken to validate the methodology are as follows: (a) a comparison transactions which use our methodology with those transactions which do not use our methodology, (b) a comparison between initial trust value and final trust value by the end of the interaction, and (c) a comparison of transactions which use our methodology with an incentive mechanism with those without the incentive mechanism. Additionally, we investigate and evaluate when the behaviour of an agent is dynamic or static. In chapter 9, we also present and discuss the results obtained from the engineered prototypes.

Chapter 10: Chapter 10 also presents the prototypes similar to Chapter 9. In this chapter, the 4 (four) remaining objectives to validate our proposed methodology are presented. The primary measurement is of the effectiveness of having third party agents that supervise the interaction between members in the community and in terms of creating and maintaining the sustainability of communities in virtual environments. In this chapter, the 4 (four) broad objectives of validating the methodology are to ascertain: (a) the accuracy of third party agent's information, (b) the ability to identify all non-compliant agents in a community, (c) maximizing social welfare of the community and (d) measuring sustainability index. The results obtained from the prototypes are presented and discussed in this chapter.

Chapter 11: Chapter 11 concludes the thesis by giving a summary of the results of our work, along with the potential directions for future work. The structure of all chapters and the relationship between chapters is shown in Figure 1.1 below.

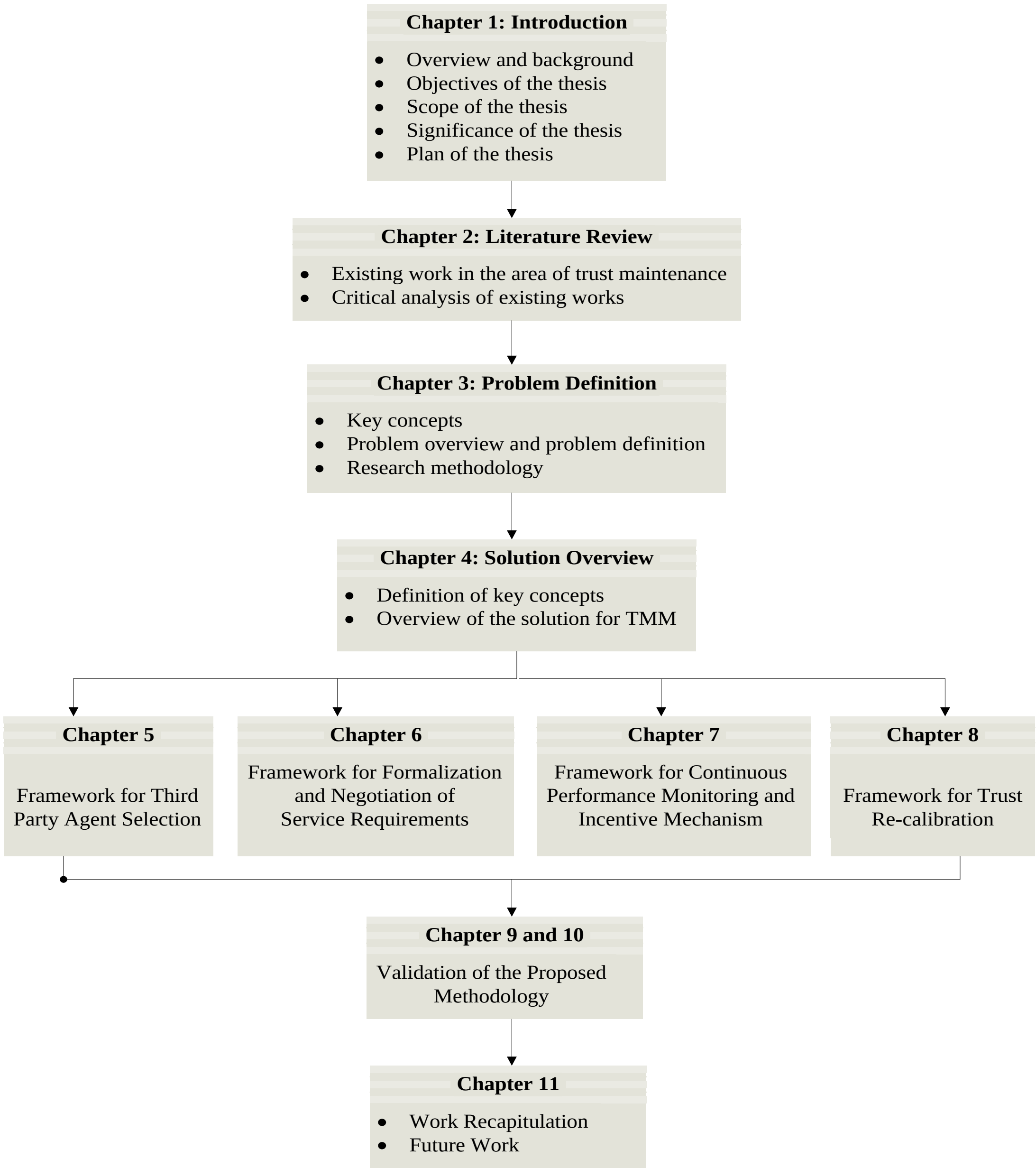

Figure 1.1: Relationship between the chapters of this thesis

1.8 **Conclusion**

In this chapter, we provided an introduction to the importance of trust in a virtual environment and the importance of trust maintenance once trust has been determined and built. We then presented several research issues related to trust maintenance in a virtual environment. Specifically, it was pointed out that there is a pivotal need to make an effort to maintain trust; however, to the best of our knowledge, in the literature no complete methodology has been proposed for maintaining trust. The existing research focuses mainly on how to build trust between entities. In terms of trust modelling and trust management, the literature is mainly concerned with how to determine the value of trust or to make a trust decision regarding the trusted agent.

Additionally, we discussed the dynamic nature and the fragility of trust in virtual environments and the need for any trust maintenance mechanism to consider these. The objectives of undertaking this study were subsequently stated and discussed, followed by a description of the scope and significance of this thesis in enabling a trusting agent to maintain the trust value toward the trusted agent. Finally, the plan of this thesis was presented.

In the next chapter, we present an overview of the existing literature on trust evolution and trust maintenance for both the virtual environment and non-virtual environments. The objective is to ensure that the problems that we intend to address through this thesis have not been addressed previously.

1.9 **References**

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Chapter 2 - **Literature Review**

2.1 **Introduction**

In this chapter, we present an overview of approaches to trust and relationship evolution, and strategies presented in the literature to maintain trust relationships in both virtual and non-virtual environments. In Section 2.2, we examine the views on trust evolution in an interaction presented in the current literature. For discussion and evaluation purposes, we divided the existing literature into two broad classes based on the pattern of trust evolution. The two different views are:

a. Continuous increasing: this view takes into account that trust level in a relationship between trusting agent and trusted agent will follow a certain phase of development or increase depending upon the level of knowledge about the trusting behaviour of the interacting agent. We present these arguments in Section 2.2.1.
b. Non-linear increment: this view takes into consideration that trust level will follow a life cycle pattern similar to the biological pattern of life. It starts from birth, progresses to maturity and then to dissipation. We present these approaches in Section 2.2.2.

In Section 2.3, we present a collection of strategic approaches to maintain trust as proposed in the existing literature. These approaches can be categorized into three different classes for discussion and evaluation purposes as follows:

a. Variance-based / Factors-based Approach.
   The main characteristic feature of this approach is that it provides one or more factors that influence the preservation of trust in an interaction. Moreover, literature falls into this category if the authors provide an explanation for behaviour or social phenomena in terms of the relationship between dependent and independent variables that influence the movement of trust level condition from a certain level to a higher level.

b. Process-based / Stage-based Approach.
   The existing literature on models or methods to maintain trust falls into this category if the approach provides sequential events, activities and mechanisms in order to maintain trust over time.
c. Hybrid Approach
   The existing literature on trust maintenance is grouped under this category if the approach takes into account the combination of variance-based and process-based approaches. Typically, such approaches identify variables in conjunction with processes that can impact on maintaining trust.

In Section 2.6, we present a comprehensive review of all the existing approaches in the literature. Finally, Section 2.7 concludes the chapter.

In the literature review presented in this chapter, we refer to the terms ‘building’ 'maintaining', 'developing' and 'nurturing' used by the respective researchers in presenting their proposal. Moreover, we use the terms, ‘interaction’, ‘relationship’ and ‘transaction’ interchangeably as do the researchers in explaining their works.

2.2 **The Evolution of Trust and Relationship**

In this section, we present and subsequently discuss all the proposed views of trust evolution presented in the literature. The manner in which trust develops and is managed has been recognized as a critical factor in human relationships (Hexmoor, Wilson et al. 2006). In relationships, trust will evolve and change over time as knowledge and information about other parties’ trustworthiness also evolves in those relationships (Chang, Dillon et al. 2006; Hussain 2006). Several studies have described this evolution pattern. Trust evolution is the process by which the trust level condition in such relationships may evolve or change depending upon several factors, either intrinsic or extrinsic (Chang, Dillon et al. 2006). The existing literature presents several different views on the pattern of this trust evolution. The discussion in this section is divided into two parts. Section 2.2.1 presents the existing views of trust evolution as a continuous increasing process and Section 2.2.2 presents the existing literature which view trust evolution in non-linear increment.

2.2.1 **Continuous Increasing**

The continuous increasing views of trust are closely intertwined with the relationship development processes (Lewicki, McAllister et al. 1998). It argues that the level of trust in such a relationship will develop with the passage of time. Hence, the trust level will increase with the increasing length of the relationship. The central tenet of this approach is that trust is an increasing function of time. As the time of the relationship increases, the level of trust also increases.

Corritore et al. (Corritorea, Krachera et al. 2003) propose the developmental stages of trust level in a relationship. They divided the levels at which trust develops as follows:

a. Rudimentary level.
   The rudimentary level is the initial stage of a relationship where risk is relatively small because there is not much at stake (e.g. much money, very personal information) and in which there is a recognized system of rewards and punishments (e.g. Verisign trust seal)
b. Intermediate level
   The intermediate level is a situation where knowledge can be used to predict behaviour and thus assign trust. It is usually reached after several satisfactory interactions between trusting agent and trusted agent.
c. Most developed level
   This is the deepest level of trust. At this level, a trustor expects that his or her interest will be respected by the trustee and that he/she has no more need to calculate the level of risk.

Clemmensemen et al. (Clemmensen, Khryashcheva et al. 2008) also argue that trust development in a virtual team is composed of three stages: predisposition to trust, trust formation and trust maintenance. Predisposition to trust exists in the initial relationship which is formed on the basis of cultural similarity (country, upbringing, etc.), and the personal and psychological characteristics of team members. The second stage, trust formation, happens when trusting parties become formal members of a group. In an initial meeting of the group, they share resources in order to finish the task. The establishment of trust is dependent on the willingness of team members to share information and any other resources to achieve the team's task. Trusting agents will form or assign a trust value to the trusted agent based on the trusted agent's competence and ability to share resources and to finish tasks. The final stage of trust development in a virtual team is trust maintenance. The trust maintenance stage is entered when the importance of a task is increased. Hence, once trust has been firmly established in the second stage (trust formation), members of the virtual team start to maintain trust with attention given to the high quality of information about trust dimensions (willingness, competence and ability).

Gwebu et al. (Gwebu, Wang et al. 2007) explained the continuous increasing stage of trust development in a virtual organization setting. The process of trust evolution in a relationship comprises three stages: calculative-based trust (CBT), knowledge-based trust (KBT) and institutional-based trust (IBT). Calculative-based trust is the trust that is initially established in the early stage of a relationship. In this stage, an agent decides to trust the other agent based on its calculation of the amount of punishment or reward that it might receive if s/he trusts the other party. Therefore, both trusting agent and trusted agent obtain information and calculate any potential gain or loss that may ensue from the relationship in order to make a trust decision. A clear reward system will guide behaviour and build the reputation of trusting parties, thereby enabling them to move to the second stage of trust, KBT. In the KBT stage, the trusting agent and trusted agent have sufficient knowledge about each other's reputation and trust level. In this phase, trusting parties carefully choose partners with whom to interact. It involves high levels of interactive communication to confirm the knowledge about the other party's trustworthiness. Both trusting agent and trusted agent tend to depend on the behavioural predictability of the parties involved in order to make rational judgments. Therefore, KBT is an extension of the trust building exercise (Gwebu, Wang et al. 2007). The last stage is institution-based trust (IBT). In this stage, both trusting agent and trusted agent have a mutual understanding and acknowledge each other's desires, needs and intentions. Other studies have also developed a similar approach to describe trust development based on CBT, KBT and IBT (Lewicki, McAllister et al. 1998; Hernandez 2010).

McKnight and Chervany (McKnight and Chervany 2001) stated that there are two stages in the trust building process in e-commerce: the exploratory stage and the commitment stage. The exploratory stage occurs in the initial stage of a relationship when parties have limited knowledge of each other. In a typical e-commerce transaction, parties do not know each other from any previous interaction. It follows the form of an initial trust model. After several interactions between the involved parties, expectations are either met or unmet. If desired actions are reciprocated, trust can be expected to move to the commitment stage. In this stage, both parties have a high commitment to continue their relationship as the trust level is higher than in the exploratory stage.

Zhang and Zhang (Zhang and Zhang 2005) also divided the trust relationship into two stages, initial stage and committed stage. The model also accommodates the dynamics of trust so that initial trust may turn into robust trust after long-term interaction. The experience during the robust trust or committed stage may result in either distrust or higher trust. The authors then present several factors that contribute to the initial trust and robust trust. The factors are derived from the characteristics of the online environment which considers the trusting agent, trusted agent, system trust belief, interaction factors and external environment factors. They concluded that different factors influence the assignment of initial trust and robust trust. A similar argument has also been proposed by Kim and Tadisina (Kim and Tadisina 2003) who present a model of trust development for E-businesses. They divided the development of trust into two stages: initial stage and committed stage. The initial stage is the stage of the initial relationship when the trusting agent has an initial trust that is determined by those factors impacting on initial trust. Once the initial trust has been established, then it moves into robust trust. Robust trust occurs in a committed relationship during the committed stage.

Javernpaa et al. (Javernpaa and Leidner 1999) described the development of trust in global virtual teams. As members of virtual teams rarely meet face-to-face, the developed trust is known as 'swift trust' (Meyerson, Weick et al. 1996; Javernpaa, Knoll et al. 1998; Javernpaa and Leidner 1999). However, in global virtual teams, trust develops in two steps: initial development and mature trust. Initial development corresponds to building an initial trust. Effective communication and the sharing of personal information help to build trust in initial task completion. It serves as an initial trust level between members in a virtual team. In order to show how trust levels can change during an interaction, they correlate this trust developmental view with the Group (Team) Life. They divided the group life into two stages, early stage and later stage. In the early stage, effective communication (such as social communication and communication of enthusiasm) will establish the initial trust and in the later stage, advanced communication behaviour (such as predictable communication, substantial and time responses) will help to maintain the trust level. If members of virtual teams successfully interact with technology-mediated communication, mature trust is formed. In their research, Javernpaa et al. (Javernpaa and Leidner 1999) raised appropriate questions: from where is trust imported to the global virtual team and how is trust maintained in a relationship via electronic communication? Hence, this is a challenging research area that addresses the question of how to maintain trust in virtual environments.

Jones and George (Jones and George 1998) see the development of trust in a relationship as a development path from conditional trust to unconditional trust (the development may also deteriorate backwards to distrust). In the first stage of a relationship, both parties develop their trust based on initial knowledge and information about each other. Conditional trust may be enough for an exchange relationship to function at a certain level, but it still needs to be monitored. In this stage, the relationship is characterised by distance, and trust is conditional during a testing period. Even minor signals of distrust may freeze the interest and deter any attempt to develop the relationship. If trust deteriorates enough, a party will no longer accept the other's role and distrust emerges. If the parties are able to reach the level of unconditional trust, they may then be able to concentrate fully on the task at hand. Unconditional trust enables both parties that are involved in a business relationship to achieve the task. Furthermore, the best level for establishing a relationship is the unconditional trust level. It will create a positive effect and friendship, which results in a good performance outcome from the relationship.

2.2.2 **Non-linear Increment**

A non-linear increment pattern of trust evolution has been derived from the view of a biological evolution pattern. All the biological things in the world will follow a pattern of birth, growth, maturity and disappearance (Bateson 1988). The trust level condition in a relationship also follows this pattern and the longevity of a certain phase will depend upon the effort made by both trusting agent and trusted agent.

Currall and Epstein (2003) divide the trust evolution pattern into three life cycle phases: developing, maintaining and destroying. In the early stage of the relationship, the trust level starts from a baseline of either trust or distrust. However, as the relationship progresses, if trust-building actions are taken, the level of trust grows until it begins to level off during the maintenance stage. It may either increase or decrease (relative to the initial trust level). The direction of the movement of trust value (increase / decrease) and the amount of increase / decrease during the maintenance stage depends on the capability and willingness of the other interacting party. Currall and Epstein (2003) argued that during the maintenance stage, the level of trust stays constant with some minor variations. If, however, the trust is negatively affected, then the level of trust drops quickly into the lower level or may turn to distrust.

Deelmann and Loos (2002) present a pattern of trust cycle for SMEs in E-business. The trust cycle depends on the manner in which a customer establishes trust in SMEs when conducting E-business. It is argued that trust goes through three phases: trust building, transaction and evaluation. In an initial interaction, the trusting agent builds trust in the trusted agent. Once trust is established, it goes to the transaction phase. After n^{th} transaction or several repeated transactions, the trusting agent will evaluate the trustworthiness level. Once the trusting agent is satisfied with the trusted agent, it will increase customer loyalty which leads to another transaction(s). After each transaction, the trusting agent will then evaluate its experience and satisfaction with the interacting party. If the situation is not satisfying, then it leads to less trust and decreased customer loyalty. On the contrary, if customers are satisfied with their experiences, their trust level in the SME increases. Thus, it follows a circle depending on the level of satisfaction experienced.

Wagealla, Carbone et al. (2003) argued that trust follows the life cycle pattern in a relationship. The model of the life cycle starts with how trust is formed, how trust evolves over time due to available information and how trust can be exploited. Therefore, there are three aspects to the dynamic nature of trust during the trust life cycle: trust formation, evolution and exploitation. Trust formation involves collecting evidence about trust components that might be actively formed in initial trust in initial stage of interaction. Trust evolution refers to the process of changing one's estimation of trust based on gathered trust information from interactions. The last aspect, trust attraction or exploitation, represents the effect of a new piece of evidence on the current trust value. The new evidence (either from observations or recommendations) has some influence on the trusting agent's opinion, in the sense that it 'attracts' his/her opinion towards it. It may result in the level of trust either decreasing or increasing.

2.3 Integrative Review of Trust and Relationship's Evolution

This section builds on the critical evaluation of existing views of trust evolution carried out in the previous section. It works towards an integrative view to find out the main issues presented in the literature. As a general note, basically trust has a pattern of evolution whereby the level of trust may change over the time of the relationship. This also accommodates the view that trust is dynamic by nature (Kanawattanachai and Yoo 2002; Chang, Dillon et al. 2006; Winch and Joyce 2006; Kuo and Yu 2009). Based on discussion in the previous section, it can be concluded that in every trust-based interaction, trust has an evolution, characterized by a certain pattern and features at each stage. The movement from one phase to another phase depends on the efforts of both interacting partners.

Moreover, a trust-based relationship always involves at least two interacting agents, the trusted agent and the trusting agent. From the relationship perspective, a long-term strategic relationship is based on shared interests, mutual trust, ethics, cooperation, quality of alternatives, satisfaction, dependence, commitment, and other bonds that enable the relationship to continue (Giller and Matear 2001; Zineldin 2002; Laaksonen, Pajunen et al. 2008; Aikebaier, Enokido et al. 2011). An adequate level of trust is an essential condition for all subsequent transactions to be successful (Das and Teng 1998; Chen and Lin 2004; Wilson, Straus et al. 2006). Therefore, it is imperative to follow the evolution of trust at every stage of the relationship's evolution in order to create, sustain and maintain an ongoing relationship. It has been argued that trust is dynamic rather than static (Kanawattanachai and Yoo 2002; Six 2005; Chang, Dillon et al. 2006; Kuo and Yu 2009). Since most authors consider that there are phases of trust such as building, stabilizing and declining, they tend to view trust as being dynamic but focus on specific phases when developing conceptual frameworks. Some are interested in trust at the beginning of a relationship (the trust formation), others at the end of the interaction (trust termination), but very few are concerned with examining trust in an ongoing and stable interaction.

However, as trust is always integral to any relationship, the vast majority of the existing literature on trust evolution does not provide any characteristic features for each phase of trust evolution. Moreover, no clear definition of trust evolution itself has ever been provided. The main shortcomings of the above approaches relate to the modelling and defining of trust evolution. The literature on trust evolution is rarely focused on changes to the trust level within a business interaction. None of the existing literature focuses on trust evolution within the life-span of a trust-based relationship. Researchers have pointed out that the evolution of trust has three different broad phases: building, maintaining and declining. However, current literature does not present a formal definition and characteristics of the three broad phases of trust evolution.

2.4 **Strategic Approaches to Maintain Trust in Virtual Environments**

In this section, we present and subsequently discuss all the strategies presented in the existing body of literature to maintain trust for relationships in virtual environments. This thesis is concerned with the phase that follows the initial trust building in trust evolution, with a focus on existing work regarding trust maintenance or whenever trust has already been established in an interaction. The discussion in this section is divided into two parts. Section 2.4.1 presents and subsequently discusses the existing approaches to maintain trust with a variance-based approach and Section 2.4.2, presents and subsequently discusses the existing approaches to maintaining trust using a process-based approach, and Section 2.4.3 presents and subsequently discusses the existing approaches to maintaining trust with a hybrid approach.

2.4.1 **Variance-based (Factor-based) Approach**

We describe the variance-based (factor-based) approach as a research that explains phenomena in terms of the relationship among dependent and independent variables. A variance-based approach is characterized as follows: more of X and more of Y produces more of Z. Variance theories attempt to predict different levels of outcome variables as a function of some input variables (Markus and Robey 1988); (Mohr 1982); (Sabherwal and Robey 1995). They attempt to explain the variance in outcomes often as a mathematical function.

Variance theories typically use the standard box and line diagram to illustrate the relationship between variables. Most laboratory experiments are used to test variance theories because they are the most straightforward to operationalize and measure. The variance-based or factor-based approach is well suited to answering ‘what’ questions, such as: what are the variables or factors that are considered best to maintain trust in a relationship? In this section, we examine the existing literature that proposes several variables or factors to maintain trust relationships in virtual environments.

Balasubramanian et al. (2003) argue that institutional safeguards such as trading regulations and formal statements about service criteria have a significant impact on trust formation. In virtual environments, a good repead experience will help the trusting agent to perceive service attributes in virtual environments such as reliability of information and efficiency of transaction execution. Reliability of information can be found in trading regulations or business contracts. Moreover, the efficient execution of a transaction can be seen as an actualization of its regulations statement. Hence, the agreed regulations that govern business interactions between trusting agent and trusted agent will help to maintain their trust level. Balasubramanian et al. (2003) suggested that customers rely strongly on the trust that leads to security provided by regulatory policies in online business transactions.

However, this proposed model has the following shortcomings:

a. This approach suggested the availability of agreed regulation to govern business interactions. With the agreed regulation, both parties will rely on this to execute the transaction. However, they do not explain in detail how both interacting parties access this agreed regulation. As they have suggested only one single factor or practice to influence the trust level, it is not a complete methodology.
b. The authors used the terms 'trust building' and 'trust maintaining' synonymously, making no distinction between them It is also not clear whether the factors will work well in the initial relationship or mature relationship. Hence, it does not make clear whether they propose a factor for trust building or trust maintenance.
c. Finally, they have not proven empirically the validity of their proposed factor for maintaining trust.

Xiao and Wei (2008) offer several principles for trust construction and maintenance in a virtual team member relationship. The first principle is repeated communication. Communication of trustworthiness is acknowledged as an important element of restoring and maintaining trust in every relationship. It is described as 'an interactive process that affects, monitors, and guides members' actions and attitudes in their interactions with one another'. Via communication, trusting behaviour will be gathered as a means of assigning or deciding the trust level condition. The second principle focuses on the cognitive dimension of trust. In trust relationships in virtual environments, the cognitive dimension is easier to observe than the affective dimension. The third principle for maintaining the trust level is to keep promises regarding task delivery. Task-oriented information and delivery of service tasks should be managed in order to restore the trusting agent's confidence and in turn to maintain trust. Conversely, trust can be destroyed when the other party provides distorted information to mislead the other agent, or creates a discrepancy between promise and delivery.

In this work, Xiao and Wei (2008) propose three different factors that can be used to construct and maintain trust in the relationship between members in a virtual team. Intensive communication, concern with the cognitive dimension only rather than with the affective and timely delivery of the finished task, are the main factors in maintaining trust. However, the main drawback is that these three factors seem to be independent of each other. There is no link or sequential order in the process of achieving trust maintenance by applying these three factors. Therefore, it is not a complete methodology for maintaining trust. The second shortcoming is that the authors used the terms ‘construction’ and ‘maintenance’ without clearly defining these terms or making a clear distinction between them. It seems that construction is similar to forming an initial trust, while maintenance is the next phase. However, the authors do not differentiate between these terms. Additionally, the authors do not explain in which phase these two activities can be categorized in trust evolution. Moreover, they do not validate their proposed principles; hence, empirical research to show how the principles work is the next research challenge.

Iacono and Weisband (1997) provide a theoretical and descriptive explanation of how to produce and maintain trust as a foundation for cooperative and interdependent work in virtual team. They suggested that the forming of good communication habits (e.g., checking and responding to email as demanded by task) is important in building active communication and consistent interaction in virtual environments. It becomes a foundation for cooperative and interdependent work in virtual teams. The ability to attend to requests from a distance while simultaneously handling local work demands is an effective way to produce and maintain trust.

In their work, Iacono and Weisband (1997) are merely concerned with the importance of effective communication to produce and maintain trust in virtual collaboration. However, this is a single means of maintaining the communication between virtual agents which in turn maintains the availability of trust in an interaction. There should be other factors to maintain trust in virtual environments, which the authors do not address. Additionally, the authors do not provide details of how this communication should be conducted in order to maintain trust. Similar to (Balasubramanian, Konana et al. 2003; Xiao and Wei 2008), the authors also use the terms ‘produce’ and ‘maintain’ without differentiation. If we consider trust as an evolutionary process, the phase where trust is produced may be different from the phase where trust is maintained. As the authors propose only a single factor, they do not provide a complete methodology for maintaining trust. The last shortcoming is that their work lacks validation and implementation. They propose only a theoretical framework, so validation and empirical research is the next challenge which the authors need to address.

Hung et al. (2004) propose an integrated model that can be used for trust formation and maintenance in both traditional organizational settings and temporary virtual teams. The model is based on the dual process theories of cognition, Elaboration Likelihood Model and the Heuristic-Systematic Model. They proposed that trust is formed through different routes at different stages. Moreover, their model incorporated the dynamic nature of trust and relationship in virtual teams. It proposed that to effectively manage trust, one needs to identify the stages of the relationship and emphasize their bases of trust formation. At the initial stages of a relationship or within the short life span of virtual team collaboration, trust is mainly determined by peripheral and situational factors. To enhance presumptive trust, managerial emphasis should be placed on providing individuals with strong and clear peripheral cues such as well-defined roles, rules, increased reputational capital and illusion of control. In the middle stages of a relationship, the cognitive dimension of trust plays a critical role in determining one's level of trustworthiness in terms of trust. Thus, the interacting parties' ability, integrity, and benevolence should be emphasized. In the later stages of a work relationship, the emotional dimension of trust is critical for maintaining a trusting relationship. In this case, managers should strengthen the emotional bonds to support habit-enacted trust. Hence, their model integrates the different forms of trust and focuses on the dynamic shifts of trust over time. They offer managerial strategies for managing trust as follows:

a. Pay attention to peripheral cues (third party information, dispositional trust, rule, category, and role) as individuals have limited prior interaction.
b. Activate team support mechanisms such as team building exercises to reduce negative biases and stereotypical attributions by providing chances for individuals to build relationships and accumulate personal knowledge of each other.
c. Create well-established rules and patterns of using various communications to increase the level of control.

The shortcomings of their proposed work can be summarised as follows:

a. The authors are concerned with the importance of well-established rules and patterns in conducting communication and collaboration in virtual environments. However, they do not provide a detailed explanation of the elements or criteria that should be communicated to achieve the agreed goal.
b. Although the authors incorporate the dynamic nature of trust and recognize that different actions are needed for different stages of the relationship's life, the managerial strategies that they offer seem to be similar for both building and maintaining trust. They argue that the strategies can be implemented during both the initial relationship and the mature relationship stages. However, from the perspective of trust and relationship evolution, we need different strategies for each phase of the relationship.
c. They use the terms 'formation', 'maintenance' and 'enhance' synonymously. They do not provide clear definitions to differentiate between these terms. Hence, it is not clear with which phase they are actually concerned.
d. The proposed approach for maintaining trust is applicable to virtual teams or virtual organizations, where the participants know each other on a face-to-face basis. Their method cannot be used for maintaining trust in virtual business, where the transacting parties may not necessarily have met each other previously.
e. The last shortcoming is they do not propose a complete methodology since they propose three different unrelated factors or variables to manage trust in a virtual environment.

Pavlou (2002) and Pavlou and Geven (2004) presented three IT-enabled institutional mechanisms to engender buyer trust in the B2C E-marketplace. The rules for implementing this mechanism are: providing feedback, third party escrow service and credit card guarantees. By conducting a survey-based online questionnaire in a community of online auction sellers, it shows that a feedback mechanism and third party escrow service influence the transaction behaviour of buyers. Pavlou (2002) described feedback as an opportunity to react quickly to signals that are sent out by others. It means that since the third party agent reveals that one of the trusting parties has misbehaved, they can quickly detect and determine what should be done next to reach a goal satisfactorily with a balanced solution between them. A content analysis and evaluation by an independent expert supports the existence of trust for business relationships in virtual environments. Therefore, the availability of this third party agent is significant in a trust maintenance effort. It also confirms that perceived monitoring by a third party agent as a part of institutional trust can engender trust between buyers and sellers in an online B2B relationship. Perceived monitoring is defined as 'the extent to which buyer organizations believe that the third-party monitoring mechanism assures that all transactions in the marketplace are performed as expected' (Pavlou 2002). This research focuses primarily on the role of the third party agent in providing feedback and the importance of control and monitoring in a trust-based interaction. However, this research has several shortcomings as follows:

a. They use the term 'engender' without providing a clear definition of what engenders trust and the characteristic features of a relationship in which trust has to be engendered.
b. The research focuses only on a single factor which is an IT-based institutional mechanism by discussing the role of third party assurance and feedback mechanism. Hence, it does not provide a complete methodology.
c. Although this research regards the role of a third party and a feedback mechanism for control and monitoring, they do not discuss in detail the role of the third party agent in maintaining trust.
d. The authors do not validate their proposed framework empirically. Hence, the validity of their proposed framework is unclear.

Kong and Hung (2006) propose an integrated model for online trust, and identify the fundamental drivers of the online trust attitude formation process by adopting the dual cognitive processing notions of the Elaboration Likelihood Model of persuasion. They attempt to identify the fundamental drivers of information processes that lead to customers' trust decisions. They identified two fundamental drivers that aid customers in their trust decision-making process: motivation and ability to process relevant information. The model provides a basis for understanding the relationships between initial and repeat trust. Although their model separates initial and repeat trust, they do not propose any differentiating mechanism to distinguish between initial trust and repeat trust. They propose only fundamental drivers that lead to trust decisions. Therefore, it does not provide a methodology for maintaining trust in existing customers.

Yee (2007) conducted a thorough literature survey on trust management for e-commerce. Based on the analysis of his literature survey, he proposes seven methods for building and maintaining trust in internet e-commerce. The seven methods which are known as approaches in one form or another are as follows:

a. Branding.
   It proposed that the trustworthiness of the brand will be automatically transferred to the product or service in the eyes of the consumer. The consumer will also believe that the product or service is trustworthy.
b. Seal of approval (including privacy seals)
   The appearance of a recognized and trusted party in an e-commerce Web site is to show that they are trustworthy. However, existing research provides some controversy as to whether consumers are aware of these seals and whether they really work as expected. Additional research is still needed to examine this factor.
c. Trustable user interface
   One of the most important factors that influence the trust decisions in customer e-commerce is a well-designed visual interface which is determined by such factors as design, predictable performance, visual interpretation, fulfilling customer expectations and showing technical competence.
d. Trustable sub-providers
   Sub-providers are the secondary providers that a primary provider uses to supply one or more components of its service such as payment for the service.
e. Reputation
   The reputation of an e-commerce service provider directly determines whether a consumer will trust the provider's service. The higher the reputation of the provider, the higher the level of trust the consumer will have in the service.
f. Insurance
   Providing insurance to build trust means that insurance policies are in place for the market space, to encourage buyer trust and seller trust.
g. Economic incentives
   The use of economic incentives to build trust in e-commerce refers to incentives to purchase such as reduced pricing, more products for the same price, or offer of free delivery.

These seven methods seem to provide a comprehensive approach to building and maintaining trust in e-commerce. It accommodates all factors that need to be understood and implemented to gain customer trust in carrying out transactions over the Internet. It ranges from the technological aspects to the social relationship itself and third party involvement. However, as each of the methods is separate from the others, we cannot regard it is a methodology. They also do not show in detail how each method can be implemented. Additionally, the authors mentioned that this method is for information purposes rather than for recommendation. Future research is still needed to explore and validate the methods. Similar to other authors in the literature (Hung, Dennis et al. 2004, Kong and Hung 2006), they use the terms 'trust building' and 'trust maintenance' synonymously to refer to the process of trust formation. Moreover, the authors do not validate their proposed method empirically.

Zhang and Wang (2006) propose a computational model on which the E-commerce system can be developed, whereby the trust level will be introduced and assessed based on users' attitudes, opinions and motivations. The model has two purposes: to assess the trust level of existing E-commerce systems and to suggest to the E-retailers ways to improve the trust level. They proposed a new trust building model and e-commerce system which is based on the model. The model is based on the assumption that trust level in a relationship is influenced by several factors such as:

a. Direct Experience which could be from customers, from current context and from another trust party.
b. System Guarantees which includes hardware update, new technology introduced, software update and system upgrade.
c. Digital Credentials from government, business partners or from community.
d. Certificates from a third party agent or evaluation scale
e. Evaluation/ Recommendation which could be from customer evaluations, recommendations, testimonials or complaints.

The authors developed an ERC^2G model based on the above factors. This model is a mathematical trust model that assigns different weights to each of the information sources according to their trustworthiness effect. The authors acknowledged that due to the dynamic nature of trust, the trust level is dynamically measured in this model. At the beginning, an initial trust level is generated by the model based on e-retailer's offline reputations, prior certificates, credentials and system guarantees. Based on the initial trust level, any positive support from the five major trust information sources will make the current trust level either increase or drop, depending on the value of this information. It suggests that the establishment of trust is of necessity a complex process that needs to involve more information sources in order to maintain trust levels. However, this model has several shortcomings as follows:

a. They only provide several factors that can be used to maintain trust level without any detailed explanations of how to use those factors to maintain the trust level. Therefore, it does not provide a methodology for maintaining trust.
b. They have not yet validated their model empirically. This validation should be on their next agenda.

Gao and Wu (2010) proposes a cognitive model of trust in e-commerce based on consumer research and the trust literature. They argue that three cognitive perceptions which are perceived informativeness, perceived entertainment and perceived irritation of online shopping, coupled with trust propensity, contribute to a customer's general trust in e-commerce and intention to use e-commerce. Gao and Wu conducted a field study in China to validate their research model. It reveals that online marketers should pay more attention to those variables (perceived informativeness, perceived entertainment and perceived irritation of online shopping) in order to nurture consumer's trust in e-commerce. Perceived informativeness is defined as a customer's perception of web vendor's benevolence, integrity, competence and predictability. For example, complete contact information and a return policy add to credibility and also perceived integrity. FAQs and available feedback mechanisms show that the online merchant is concerned about its customers' opinions and this enhances perceived benevolence.

The second perception, perceived entertainment, is defined as an entertaining shopping experience that can enhance the trusting beliefs of a consumer in the trustworthiness of e-commerce. For example, a video or animation to demonstrate the product increases the perceived entertainment. It not only shows the vendor's goodwill in keeping its visitors entertained, but also demonstrates its confidence in its product design and delivery. The third perception, perceived irritation, is customers' perceptions that need to be considered so as to nurture customer trust. Online marketers need to control perceived irritation that has a negative impact on trust in e-commerce. For example, online vendors sometimes employ tactics such as pop-up ads and animated banners that annoy visitors. Visitors' feelings of confusion, distraction and messiness of online shopping sites may contribute to perceived irritation. Therefore, it needs to be controlled. Moreover, trust propensity is a personal trait that influences the formation of trust in e-commerce together with those three perceived factors. However, this approach has limitations as follows:

a. This research delivers only several factors that influence consumers' trust. However, the authors have not identified factors that can be used to maintain trust. Therefore, it is not a complete methodology for maintaining trust.
b. They use the terms 'building' and 'nurturing' synonymously when they actually mean 'building trust'.
c. The authors do not describe a relationship or trust level condition that requires a nurturing of trust.
d. The applicability of this model is limited to a particular country or geographical region. It cannot be generalized to be applicable to another country.

Li et al. (2011) developed a holistic framework for trust which can be used to analyse the establishment and maintenance of trust in online transactions. The framework systematically illustrates the links between actors, transactional attributes and context, and the level of perceived trustworthiness by the actors in a transaction. It identifies the key attributes of a transaction and the context in which it is embedded, and maps out six types of trust antecedents that can be used to assess the trustworthiness of the transaction by different actors. The key attributes are:

a. Third party certificates; it considers these as an attestation of the attributes of a seller from a third party
b. Reputation systems; it describes these as aggregated feedback based on opinions of buyers
c. Tips and recommendation; the availability of advice, suggestions, guidance to increase knowledge of buyers
d. Dispute services: the availability of services provided by commercial organizations to facilitate resolution of disputes between partners
e. Privacy policy: the availability of policy on providing sensitive personal data
f. Security policy: the availability of policy on exchanging information and payments

g. Web site design: quality of graphical design, overall structure due to navigation, presentation of sellers, and products/service information.
h. Communication with buyers; Communication through mail, telephone, and online forms
i. Payment services: payment administration and escrow credits, money-back guarantees.

They conclude that a party in an online transaction will perceive the other transactional party, the transactional attributes and its contexts to form trust antecedents in trust level calculation. If the trust level is sufficiently high enough, the transaction may go ahead. If not, one or both parties may abandon the transaction. Therefore, they argued that in order to establish and maintain trust in online transactions, the service provider needs to consider these key attributes.

The main shortcomings of their proposed framework are:

a. This framework gives an understanding to enable trust in general and in online transactions in particular. Although the authors argue that their framework can be used to maintain trust, they do not differentiate between establishing and maintaining trust. Additionally, they do not provide a specific relationship characteristic according to which the trust level has to be established and maintained.
b. The framework is theoretical in nature and the authors provide three challenges to validate and refine the framework.
c. The framework provides the key attributes of an online transaction and the embedded context. Since the framework only provides key factors, it is not a complete methodology to maintain trust.
d. They use the terms ‘building trust’ and ‘maintaining trust’ synonymously when actually referring to ‘building trust’.

2.4.2 **Process-based (Stage-based) Approach**

We define the process-based research approach as research that is concerned with understanding how things evolve over time and why they evolve over time in a particular way. Process data consists of anecdotal evidence: who did, what, and when. Hence, events, activities, and choices are ordered over time. This research approach provides explanations for phenomena in terms of the sequence of events leading to an outcome. Temporal ordering and probabilistic interaction between entities are important here. Understanding patterns in events is thus the key to developing a ‘process’ theory.

Process theories attempt to explain how a process operates and how different events induce variables to change states, and often include time-oriented explanations (Markus n Robey, 1988; Mohr, 1982; Sabherwal n Robey, 1995). At the extreme, process theories can be explained with process flow diagrams or state transition diagrams. In this section, we present several approaches in the existing literature that can be categorized under process-based research.

Javernpaa and Leidner (1999) propose a model of communication behaviour for facilitating and maintaining trust in global virtual teams. Facilitating trust occurs in the initial relationship stage and maintaining trust occurs later in the life of the relationship between members of a virtual team. The models of communication behaviours differ for building and maintaining trust. In trust building, the trusted agent needs to share social information (such as personal interest, email address, mobile number, country of origin, etc) and verbalize the desire to work collaboratively. On the other hand, the trusting agent needs to cope with technical uncertainty that may be faced in initial contact and present high initiatives (e.g., volunteering to complete tasks) to work in a trusted situation. Furthermore, in the trust maintenance phase, the trusted agent must be in predictable communication, which means guaranteed availability to reply to a task communication from the trusting agent. This is in order to provide a substantive and timely response to communication with the trusting agent. Moreover, in the trust maintenance phase, this model suggests that the trusting agent and trusted agent should move from a procedural orientation to a task orientation. Procedural orientation may include frequency of checking e-mail, and how messages will be exchanged during the trust building stage. Once this rule has been well established, it will be possible to make a successful transition from social orientation to task orientation.

Their process framework has several shortcomings as follows:

a. Although this research has considered the evolution of trust by dividing the relationship into two stages, facilitating and maintaining, they do not provide a clear definition, defining characteristics, or the distinguishing parameters of certain relationship characteristics for both of these stages.
b. The proposed framework at each phase of trust evolution contains only a single practice to manage trust, effective communication in virtual environment. Therefore, we cannot consider their framework as a complete methodology for maintaining trust.
c. The other shortcoming is that the framework is theoretical in nature and thus subject to empirical challenge.
d. The authors used the term 'facilitating' and 'maintaining' synonymously when actually referring to 'building' trust.

Greenberg et al. (2007) propose actions or steps to develop and sustain trust in virtual teams. The actions should be performed by both managers and team leaders. They argued that a virtual team has its own life cycle and each stage of the life cycle has different strategic requirements. Hence, both managers and team leaders have to perform different actions to help members develop and sustain trust through to the project's successful completion. (Greenberg, Greenberg et al. 2007) divide the virtual team process into five stages: (a) establishing the team; (b) team inception; (c) task organizing; (d) transition; (e) accomplishing the service.

During the first stage, members' recruitment, training and clear reward structure is needed to build dispositional trust. In the second stage, the introduction of team members and team building exercises are actions intended to swiftly build and sustain trust. In the third stage, evaluation of member participation and action to encourage participation of member to communicate in virtual environments is needed to change the form of trust from ability- and integrity-based to benevolence- and integrity-based. Furthermore, in the fourth stage, transition, leaders and managers must always be available to support and guide members and shift their focus from procedures to task/service accomplishment. In the last stage, the type of trust is based more on benevolence and integrity. Team leaders and managers need to encourage supportive communication among members in order to successfully deliver the service.

The main drawbacks of their proposed framework are as follows:

a. This approach proposes a sequence of actions by which manager and team leader assist the development of trust during team life cycle. It will facilitate how team members accomplishing the service as requested. However, this approach has not yet been validated.
b. The authors propose a conceptual framework for a leader and team member relationship but the applicability of their propose work to another domain remains questionable.
c. They do not propose any measurement to show the involvement of trust in the degree of service accomplishment.
d. They use the terms ‘develop trust’ and ‘sustain trust’ synonymously when actually referring to ‘building trust’.

Ishaya and Mundy (2004) propose a mechanism for trust development in a virtual community. The process mechanism includes calculative, competence, predictive, intentionality and transference. In the first process, virtual community members need to define and agree on the interaction rules such as reward and punishment. Once virtual members have a set of interaction rules, in the second step, they communicate extensively to obtain information about status, level of experience and others experience members. The objective of this step is to acquire information about other members’ reputation. The third step, predictive, is the process of frequently interacting in regard to task-based issues. Once all members are aware of the expertise of others, they will initiate an interaction or transaction based on their expert interest. The next step is intentionality. In this step, virtual community members become more engaged and they get to know each other closely. It is characterised by a high amount of social dialogue, tenure relationship and sharing of team goals. The last process is transference where both parties have established basic communications and individual propensity, and have information about others. This mechanism shows that in trust building, there is a linear progression whereby the trusting agent moves from the first to the second process and so on. The trust level will increase from one step to the next. In this mechanism, by the end of the process, trust will be established between trusting agent and trusted agent.

The shortcomings of their work can be summarised as follows:

a. The authors present several different factors for each stage of trust evolution. They also state the need to pay attention to the movement of the trust level from one step to the next step during the course of the relationship. Hence, in each stage, there are different factors to manage the condition level of trust. However, their approach does not clearly provide a mechanism for maintaining the trust level once it moves from the lower level to the higher level.

b. Even though the authors did acknowledge that a mechanism is required to maintain trust at every stage, they do not propose or discuss in detail the means by which such a mechanism can be implemented. For example, in the initial stage, interacting parties should have an agreement about the interaction rules. However, they do not explain how both trusting agent and trusted agent can reach this agreement. Therefore, it is not a complete methodology for maintaining trust in virtual environments.
c. Finally, the framework is theoretical in nature. It has not been empirically validated.

Kim and Tadisina (2003) present a model of trust development for E-businesses. They divided the development of trust into two stages: initial stage and committed stage. Initial stage is a stage that occurs during the initial relationship. In the initial relationship, the trusting agent will have an initial trust that will be impacted on by factors during that first encounter. Once the initial trust has been established, it moves into robust trust. Robust trust is present in a committed relationship during the committed stage. The factors that impact on robust trust are different from those of initial trust. Moreover, in 2005, the authors validated factors impacting on initial trust in e-business in their further empirical study (Kim and Tadisina 2005). The results provided evidence that the quality of a website has the largest effect on customers' beliefs that an e-business had competence and goodwill. Other predictors like company profile and supporting organizations, had less impact. The authors suggested that these results should be used with caution since they were based on data gathered under limited conditions. However, they have not yet discussed the second stage which is the committed stage.

The shortcomings of their approach are as follows:

a. Although this study has separated initial trust and robust trust, and also differentiated between initial relationship and committed relationship, the main concern of their research is develop a measurement of initial trust which can be classified as building trust.
b. They do not present any mechanism or model for trust management in the committed stage. Therefore, it does not provide a complete methodology for maintaining trust.
c. Since the authors acknowledged that the data that they used for validation were gathered under limited conditions, the generalization of their framework to another condition is limited.

2.4.3 **Hybrid Approach**

We define the hybrid research approach as research that is based on a combination of process-based and variance-based methods. To a certain extent, the work contains several factors which are structured as ordered actions to achieve certain goals (Fidock and Carroll 2009). In this section, we present several approaches in the existing literature that use the hybrid approach in their proposals.

Wang et al. (2011) built a formal model that considers probability and uncertainty as two dimensions of the dynamic nature of trust. It proposes a mechanism by which an agent can update the amount of trust it places in other agents on an ongoing basis. The authors view trust maintenance as the process of updating trust values. They posit that if an agent already has a certain trust value in the other agent, this trust value needs to be maintained by updating the information or current evidence about the trusted agent's behaviour. It could be done by asking referrals to provide the evidence on their past or current interaction. Therefore, they termed it as 'trust in history'.

Their approach deals with how to incorporate new evidence in maintaining a trust rating. The simulation results show that their proposed approach: (a) provides accurate estimates of the trustworthiness of agents that change behaviour frequently due to the dynamic nature of trust; and (b) captures the dynamic behaviour of the agents. For example, agent A has a trust value toward agent B in a level of '5'. In one point in time, B informs to A about B's trust value toward C as '4'. In such time, A has an interaction with C and then A updates his trust value toward C. Based on this direct observation and referral information from B, A will update his trust value toward 'B' based on this information and evidence. If referral information is equal to direct observation, the evidence is increased. However, if information from referrals does not equate to direct observation, conflict is increased. Trust would be maintained if evidence increased and conflict decreased.

This approach concludes with a trust maintenance methodology since the authors propose a certain ordered action to update the trust value. They argue that once a trusting agent holds a trust value toward a trusted agent, this needs to be maintained by updating information. However, their use of the term 'trust maintenance' is not expressed or derived from trust evolution but rather from the process of updating trust values from previous interaction or information. Moreover, the updated information needs to be gathered from the other agent. If no agent is able to provide new evidence or new information, then the trusting agent cannot update or maintain the trust value.

Gwebu et al. (2007) propose a process-based framework that captures the manner in which trust develops in the virtual organization setting. The framework explains that the hierarchy of trust can be divided into three stages: calculative-based trust, knowledge-based trust and institutional-based trust. This conceptual framework contains events, activities and mechanisms for each stage. Calculative-based trust is a form of trust that is established in the initial relationship. Calculative-based trust is built by establishing a clear and effective reward system, establishing an effective reputation management system, ensuring a credible punishment and sanction system, and developing well-defined relational contracts. A clear reward system will guide behaviour and build the reputation of trusting parties. Based on this reputation information, the trusting agent will develop trust in the trusted agent. In the second stage, knowledge-based trust is the stage in which the trusting agent and trusted agent have a sufficient knowledge of each other's trust level and reputation. In this phase, trusting parties carefully choose partners with which to interact successfully. It involves high levels of interactive communication to confirm the knowledge about the other party's trustworthiness. Trusting agent and trusted agent tend to depend on the behavioural predictability of the involved parties in order to make rational judgments. Therefore, knowledge-based trust is an extension of the trust building exercise. The last stage is institutional-based trust (IBT). In this stage, both trusting agent and trusted agent have a mutual understanding and appreciate each other's desires, wants and intentions. The events that can encourage the existence of IBT are (a) mutual goal setting (b) creating joint activities to produce product/service, and (c) creating a shared value and ideology.

The shortcomings of this work can be explained as follows:

a. They have divided trust into three hierarchy levels and provide several interaction characteristics for each level. However, they do not clearly distinguish between the building and maintaining stages.
b. The authors also propose different events and actions at each stage. Those events and actions are continuous activities from one phase to the next phase. However, they do not propose a complete methodology for maintaining trust as they do not make a clear distinction between building trust and maintaining trust.
c. Their framework is theoretical in nature and thus subject to empirical challenges.

Zhang and Zhang (2005) propose an integrated model for the establishment of online trust that incorporates both the stage approach and factors approach. Their model is based on several theories: Social Exchange Theory, Expectation-Confirmation Theory, Theory of Reasoned Action, Theory of Planned Behaviour, and Technological Acceptance Management. The model is concerned with trust at different stages. The trust relationship is divided into two stages namely, initial stage and committed stage. The model also accommodates the dynamicity of trust, meaning that initial trust may turn into robust trust after long-term interactions. The experience during the robust trust or committed stage may result in either distrust or higher trust. The authors then present several factors that contribute to the initial trust and robust trust. The factors are derived from the characteristics of the online environment which include the trusting agent, trusted agent, system trust belief, interaction factors and external environment factors. They concluded that in order to gain initial trust and robust trust, different factors would be involved. Although this research recognized the different stages of trust and the contributing factors, they do not mention how to maintain robust trust. Additionally, as there is no mention of the way to implement the contributing factors, they do not provide a methodology for maintaining robust trust. Moreover, they do not validate their proposed model empirically.

Winch and Joyce (2006) propose a model that incorporates the dynamic nature of trust, arguing the possibility that trust can be lost after being well established. This model is designed to prevent loss of customer trust in B2C E-commerce. Once the customer makes a decision to proceed with the transaction, this means that s/he has initial trust in the vendor. However, during the next stage of the transaction, customers may have experience regarding perceived risk in carrying out a virtual transaction. This level of trust could change – it may either increase or decrease depending on personal experience, extrapolation and hypothesized problems. The company then needs strategic management actions to keep or maintain this customer trust based on the three risk determinants. Details of their proposed strategy are as follows:

a. Personal experiences
   Personal experiences are a function of the number of experiences and perceived quality of outcome that customers feel they experienced. The accumulation of experience will create the quality of experiences in carrying out e-transactions. If the customer has been satisfied with past experiences, then trust may increase. Repeated positive experiences with online transactions will increase the trust level.

b. Extrapolated problem
   A change in trust level from extrapolation is driven by the customer's understanding of technology and their development of a suitable knowledge level of technology. Thus, in order to reduce perceived risk based on this problem, the provider should provide an information infrastructure to increase the customer's knowledge about e-transactions.

c. Hypothesized problem
   A hypothesised problem occurs if a customer perceives risk associated with the transactions and individual companies that they are dealing with. It will be moderated by the actual risks or quantifiable risks. Educational programs which aim to reduce perceived risk in e-transactions, perceived risks in company, quantifiable risks related to transaction and quantifiable risks related to company, are needed to overcome this problem.

The authors inferred that with those strategies, the service provider should be able to change the customer's perception of risk. It can be considered as providing a policy for risk minimization. However, their work has the following limitations:

a. Their proposed strategy is intended to provide complete actions for building and maintaining trust. However, this work proposes only a conceptual strategy without detailed explanation of how to educate customer to decrease the perceived risk in carrying out e-transactions. Therefore, it does not present a methodology for maintaining trust.
b. The authors do not describe in detail the particular relationship characteristics at each stage of the trust relationship (building and maintaining stage).
c. They do not validate their proposed conceptual strategy.
d. The authors used the terms 'building trust' and 'maintaining trust' synonymously when actually referring to 'building trust'.

2.5 **Strategic Approaches to Maintain Trust in Non-Virtual Environments**

In this section, we present and subsequently discuss all the strategies for maintaining trust that have been discussed in the existing literature for relationships in non-virtual environments. These relate to inter-organizational and intra-organization relationships.

Babar, Verner et al. (2007) have identified variables that influence the establishment and maintenance of trust. By investigating the relationship between a client and vendor in the context of outsourcing global software development, they argue that initial trust is very important. However, they contend that what is most important is that a vendor needs to maintain the trust in ongoing relationships. Business entities should pay more attention to activities that maintain trust. Once distrust exists in a business relationship, it cannot be rebuilt in a short time. Therefore, constant effort is needed to maintain the trust level in any form of business relationship. They maintain that several factors play a vital role in maintaining a trust relationship. These factors are: effective communication, cultural understanding, provision of capabilities, contract conformance, quality and timely delivery, development processes, managing expectations, personal relationships and performance of staff. They note that contract conformance which includes quality and timely delivery plays a significant role in maintaining a trust relationship. With a contract conformance, both parties can confirm whether or not they will obey all clauses in the agreement. It will help to gain the trust of clients. Contract conformance is defined as an agreement between two parties about how they will create a virtual collaboration in software outsourcing.

The main drawbacks of their work are:

a. Although they have differentiated between establishment and maintenance, between initial trust and ongoing trust, they do not provide a clear definition of these two terms. Additionally, they do not describe the characteristics of each stage of the relationship.
b. The factors that they proposed for maintaining trust seem to be independent of each other. There is no concurrent activity between these factors. Moreover, the authors do not clarify any dependencies between these factors. Therefore, it is not a complete methodology.
c. Their proposed model is limited in application to global software development outsourcing; thus, it cannot be applied or generalized to virtual environments. Therefore, the generalization of their model to another relationship context has not been demonstrated.
d. They use the terms ‘trust establishment’ and ‘trust maintenance’ synonymously when referring to ‘trust building’.

Sako (1998) proposed three sets of approaches to maintain trust in a bilateral relationship between supplier and customer. The three sets of approaches are as follows:

a. Favourable and adversarial effects of legalistic remedies.
   Legal procedures such as formalizing contracts and rules are used to attempt to restore trust. These procedures may be used as substitutes for interpersonal trust which may not be available in organizations due to the absence of a history of face-to-face contact.
b. History of long term trading and rational calculation

The availability of historical duration and experience of a relationship is a significant in building trustworthiness in business relationships. Furthermore, to those who place importance on a rational calculative basis for creating cooperation, what matters more than the record of long-term trading, is the expectation of long-term commitment into the future.

c. Gift exchange and Credible Commitments.
   One mechanism for creating informal commitment is for the company to provide technical assistance to a customer. To the extent that the company demonstrates knowledge and skills by providing technical assistance, it enhances the customers' trust in the competence of the company.

Finally, the author argues that trust between trading partners may vary not only with the attributes of bilateral transactions, but also with the trading environment in which they operate. This environment includes:

a. Societal culture, politics, regulation, professionalization and national institutions.
b. Industrial environment, the financial system, the national legal tradition and system, the systems of industrial relations and skill formation.

The shortcomings of this work are:

a. The author proposed best practices that can be implemented in an organization to enhance trust. However, she does not provide a detailed explanation or concrete mechanism for adhering to the legalities in a contract relationship. Moreover, she does not discuss a framework for how to calculate the value of trustworthiness based on the information from history of trading. Therefore, it is not a methodology for maintaining trust.
b. Although the author presents empirical research evidence demonstrating how these three approaches can enhance trust, this applies only to suppliers of automotive parts in USA, Europe and Japan. Hence, we cannot make the generalization that this technique would be applicable to other countries and other types of business/firm relationships and to virtual environments.
c. The author uses the term 'creation and maintenance' of trust when proposing the three approaches. Then, in the discussion about survey findings, Sako (1998) says that this approach was found to 'enhance' trust. She uses the terms 'creation', 'maintenance' and 'enhance' synonymously. She has devised this approach to create, maintain and enhance trust between firms. However, each of these terms has a different meaning and activity associated with it.

Ariño, de la Torre et al. (2001) discuss the dynamic nature of relationships from the perspective of economic exchange in inter-organizational relationships. A long-term interaction can be seen as a relational exchange and therefore they argued that Relational Quality is one of the basic requirements for maintaining trust. The level of relational quality will affect the willingness of the parties to rely on trust in their everyday transactions.

The authors then propose four elements to achieve high levels of relational quality or high levels of trust in long-term joint venture relationships:

a. Initial conditions
   The initial conditions surrounding the exchange determine the degree of trustworthiness granted the parties and derived from the partners; inherent characteristics, the institutional context within which the alliance exists, their respective reputations for fair dealing, and any direct prior experience they may have given to each other.

b. Negotiation process
   Partners approach negotiation processes with a set of expectations for the standards of behaviour the other party will hold to, and hope that it will abide by those standards. These standards emerge from initial conditions that may not be anchored in the reality of any direct experience. The parties will turn sense-making processes into assessments of reputations and other person-based trust.

c. Partner interactions
   In the course of defining the terms of an alliance, managers are required to make decisions regarding the degree of vulnerability, uncertainty and risk they are willing to accept. Their willingness to rely on trust and their expectations regarding the partner's behaviour under diverse circumstances play a critical role in managing these issues, and these expectations will be subjected to continuous review following the negotiation process. It is the level of initial relational quality that will define how the partners interact and adjust their willingness to rely on trust as the alliance progresses.

d. External events
   External events or behaviour outside the context of the alliance can also have an impact on the quality of the partners' relationship. These events can be considered as belonging to one of three types: (a) Systemic: environmental changes that affect all parties simultaneously and indiscriminately; (b) Corporate: wherein one of the partners is involved in matters that affects its reputation for fair dealing in other circumstances or with other partners, and (c) Individual: where one or more persons directly involved in partner-interface participate in actions outside the partnership that influence either their own or their firm's reputation for fair dealing.

However, their proposed work has several shortcomings as follows:

1. This study considers only those elements necessary to maintain a high level of trust between organizations. These elements constitute a process to create a high quality of organizational relationship. Starting with discussion about how to observe initial conditions among parties, the negotiation process and then partner interaction. However, there is no detailed discussion of how to observe initial trust, how to negotiate and how to conduct the interaction in an appropriate manner. Therefore, it does not provide a methodology for maintaining the trust level condition.
2. These four elements for creating a high level of relational quality apply only to the management of trust in corporate alliances. Therefore, these elements

or requirements cannot be applied to other types of interactions including those in virtual environments.

3. This article is based on conceptualization only. The authors do not provide any empirical evidence to support their concept. Therefore, in order to prove that those elements are a basic requirement for high levels of relational quality, a validation of these proposed elements is needed.
4. The authors use the terms ‘creating trust’ and ‘building trust’ synonymously without clearly defining each of these. They also do not provide the relationship characteristics of these two phases.

Lamsa and Pucetaite (2006) argue that trust among employees is not inherent, but senior management can nurture it with the help of appropriate and context sensitive managerial practices. They take into account the procedural approach to explain why management should develop organizational trust especially where there is low work morale among employees. The procedural approach to trust development suggests that cognition-based as well as emerging affect-based organizational trust can be developed by managerial practices to initiate fellow partnership in a socio-cultural context where the general level of work morale is low. They define a ‘fellow partnership’ as the relationship between management and employees. Fellow partners do not need to fight for their interests, or go to the barricades, but aim for consensual agreement through rational and empathetic dialogue. Fellow partners have both explicit and tacit knowledge about each other, can predict each other’s actions in a certain situation and plan future activities relying on the congruence of the partner’s value.

The stages of the procedural approach to the development of organizational trust and the key managerial practices appropriate for advancing trust at each stage are the following:

	Stages process	Condition and Actions
1.	The relationship of opposing parties	Employees know that they are continuously controlled and monitored, and punishment is inevitable if they do not obey organizational rules and norms
	Key managerial practice to move to 2nd stage is making a strategic choice: consistent, fair and reliable rewards	
2.	Calculators	For the management, this means that there must be a knowledge about the employees’ values and preferences so that adequate rewarding practices can be created and necessary practices for trust building can be constructed
	To move to 3rd stage: Enabling prediction through regular and open organizational communication	

3.	Acquaintances	Management and employees learn to know each other and can predict one another's actions to a reasonable extent
	To move to 4th stage: Empowering employees' participation	
4.	Moral acquaintances	When standards for behaviour in a firm are clearly defined, reasoned and known to employees as well as influenced by them.
	To move to 5th stage; Enhancing organizational dialogue and searching for value congruence in organization	
5.	Fellow partners	Management proceed to build trust by showing care and consideration of the employees' interests

In general, the authors argue that trust building is an ongoing process that must be initiated, maintained and continuously authenticated. However, this proposed work has several shortcomings as follows:

a. Their approach is theoretical in nature. They do not validate their proposed framework. Therefore, their contribution and the developed model of a procedural approach require empirical investigation.
b. Although they recognize the developmental stages of trust in an interaction between employees intra-organization, and suggest actions that should be taken by senior management to move the trust level from the previous stage to the next stage, they do not discuss in detail how to translate these elements into concurrent activities. Therefore, their work does not provide a complete methodology for maintaining trust.
c. Their approach is applicable to a situation where both parties physically meet in a physical environment; hence, outward physical signs of trustworthiness information are easy to collect. Therefore, it is a challenge to apply their framework to virtual environment.
d. They used the terms 'building trust' and 'maintaining trust' synonymously which on closer examination refers to 'building trust'.

Pucetaite and Lamsa (2008) argue that the development of trust in organizations can be stimulated by raising the level of work ethic with organizational practice. They explain that work ethics are moral principles, norms and rules that guide a person's behaviour in the work place. Moreover, work ethics play a role as principles, particularly compliance with quality standards, self-discipline and commitment to professional norms and the job itself. Furthermore, they conclude that these features can be expected to contribute to workplace trustworthiness due to a lower risk of negative work attitude and deviant behaviour. Hence, Pucetaite and Lamsa (2008) assume that when the work ethic in a given society is low, organizational trust will also be lower, and in this case of high work ethic, organizational trust will also be higher. Accordingly, the idea of enhancing the work ethic and consequently developing organizational trust through management practices is of particular interest to societies.

An outcome from Lamsa and Pucetaite’s work is based on Human Resource Management practices. This view is also held by Gillespie and Mann (2004). According to Gillespie and Mann (2004), transformational leadership and shared value may build trust in a leader. Common values are believed to guide behaviour. Sharing common values helps team members to predict how a leader will act in the future, and gives them the assurance that the leader is unlikely to act contrary to the shared values. Moreover, a common vision aligns leaders and team members’ actions and focuses them on the achievement of shared goals. Goal-directed values motivate behaviour and help team members to predict the leaders’ future behaviour. By engaging in these leadership practices, the leader is both placed in a position of vulnerability and demonstrates trust in team members. These practices require the leader to openly communicate his/her ideas, vision and values, and delegate power and responsibility to team members. The trust that the leader conveys to team members through these actions, encourages the reciprocation of trust by team members.

Similar to Gillespie and Mann (2004), Connell, Ferres et al. (2003) also proved that managers can influence trust in their relationships with subordinates with the adoption of a transformational leadership orientation, by ensuring that procedural justice emerges and that employees are supported at every organizational level. The principle variables used in this study have repeatedly been established as having important consequences for organizational effectiveness. As such, these results reinforce the importance of creating and maintaining trust within manager-subordinate relationships while holding significant implications for both managers and human resource professionals. Specifically, these results suggest that organizations should adopt approaches that engender perceived organizational support and procedural justice between the various constituents, policies and procedures of their organization in addition to focusing attention on relationships at various levels and leadership orientation.

In addition, Six and Sorge (2008) explored the organizational policies which have been deliberately devised and are successful in encouraging trusting and trustworthy behaviour. Also, attention is paid especially to human resource management practices (selection, initiation, socialization, training, career management) and organizational policies (handling of interdependencies, attribution of roles, sanctioning of behaviour, organization of workflow and teams). Furthermore, they argue that interpersonal trust building is an interactive process in which individuals learn or unlearn to establish and maintain trustworthiness, under given organizational (contextual and structural) settings, and subject to policies directly or indirectly, positively or negatively sanctioning the building of interpersonal trust. Therefore, they argue that stable intentions for behaviour can be stimulated by durable policies, structures and contextual settings.

However, the works by several authors (Connell, Ferres et al. 2003; Gillespie and Mann 2004; Lamsa and Pucetaite 2006; Pucetaite and Lamsa 2008; Six and Sorge 2008) as discussed above offer only some organizational practices, policies and procedures or conditions to create, build, engender and maintain leader-subordinate trusting relationships. They also use 'create', 'build', 'engender' and 'maintain' trustworthiness synonymously. Therefore, it does not provide a complete methodology for maintaining organizational trust.

Moreover, similar to the shortcomings of other research, they use the terms 'creating', 'building' and 'maintaining' synonymously and do not make a distinction between them. All of the above work identifies factors for building and some of them identify factors to maintain trust (Sako 1998; Ariño, de la Torre et al. 2001; Babar, Verner et al. 2007). None of them provides a methodology for maintaining trust. As mentioned previously, the primary thrust of the work presented above is on building or in some cases maintaining organizational trust (Sako 1998; Ariño, de la Torre et al. 2001; Babar, Verner et al. 2007). The applicability of this work to maintaining trust in virtual business environments has not been investigated by researchers.

Velez, Sanchez et al. (2008) assert that MCSs (Management Control Systems) will be effective only in the early stage of relationships. However, by using a longitudinal case study, Velez, Sanchez et al. (2008) provide evidence that MCSs can build trust, even when trust is well-established. Action controls (e.g., electronic integration and norms) improved the amount and quality of information available. Result controls also enhanced members' mutual knowledge through the participation they developed. Therefore, MCSs create a frame where information about competence and ability is transferred, and in turn builds competence-based trust Sako (1992). Moreover, Sako (1992) states that MCSs presented the same information and evidence with a wider objectivity that knowledge transfer enhanced trustee abilities and competences. Some practices such as surveying the satisfaction level of the trusting agent and sustainable communication demonstrate the competence of the trusted agent in providing service. It also shows the ability to complement the needs of the trusting agent and indicates areas for improvement.

Additionally, Das and Teng (1998) argue that the basic roles of trust, control, and confidence level are important in any type of business alliance based on trust. Das and Teng (1998) offer four key techniques for trust building in alliances which are: evaluation of risk taking, equity preservation, effective communication and inter-firms adaptation. Moreover, similar with (Sako 1998; Velez, Sanchez et al. 2008), Das and Teng (1998) also argue that a control mechanism is important for trust building in strategic alliance. There are three specific control mechanisms that are relevant to strategic alliances: goal setting, structural specification and organizational blending. Goal setting improves control because business parties have agreed to this goal. With this goal commitment, they will use a structural specification to perform and deliver a task. Hence, an organizational blending that involves the two business parties seems reliable. Trust and control have a similar effect on the success of business alliances.

On the other hand, Long and Sitkin (2006) examine the ways to balance interpersonal trust-building and control-based efforts in order to maintain trust. They focus their explanations on task controls, which range from formal mechanisms (written contracts, monetary incentives and surveillance), to informal mechanisms (values, norms and beliefs) for building trust. The trusting agent can use those mechanisms to direct the trusted agent toward the efficient and effective completion of tasks. There are various points in the production process where the trusting agent alters its control applications to direct the trusted agent task: firstly, input controls, which are material production resources. Secondly, process controls**,** by controlling trusted agent performance to ensure that they employ prescribed task production methods and thirdly, output controls by measuring the outputs of trusted agent produce against established metrics to ensure that prescribed performance standards are met. Therefore, based on these arguments, both trusting parties should combine trust building and task control activities that are appropriate for the task and relational contexts they encounter, thereby helping to ensure that goals are accomplished and that positive trust level in relationships are developed and maintained. This approach uses the control theory to build and maintain trust. In process controls and output controls, both parties will control each other's performance to ensure that they perform as prescribed in the task description.

All the above works by (Das and Teng 1998; Long and Sitkin 2006; Velez, Sanchez et al. 2008) are mainly concerned with the factors of balancing trust and control mechanisms for building and maintaining trust. However, their works have several shortcomings as follows:

a. They use the terms 'building' and 'maintaining' trust synonymously without provide a clear distinction between these terms. Moreover, on closer examination, both of these two terms actually refer to 'building' trust.
b. They present the main factor for building and maintaining trust which is control monitoring, without providing a detailed explanation of a mechanism for this control monitoring. Therefore, they do not provide a complete methodology for maintaining trust.
c. Their work focuses on the relationship between organizations in non-virtual environments. Therefore, the applicability of their framework to the virtual environments is unclear.
d. Most of their proposed model is based on theoretical concept. They do not empirically validate their proposed model.

2.6 Integrative Review of Approaches to Maintain Trust in Virtual Environments and Non-Virtual Environments

In this section, we establish a critical evaluation of existing approaches to trust maintenance which were discussed in the previous section. We carry out an integrative critical review to determine the main issues that need to be addressed in this thesis. As a general conclusion, no work to date has proposed a complete methodology for maintaining trust in virtual environments. The existing literature provides several factors, variables, practices, events and actions to maintain trust with little or no empirical proof that these can actually maintain trust. Some of the literature proposed similar factors or variables or even best organizational practices.

The most common factors or variables or practices that have been suggested in the literature to maintain trust are as follows:

a. Effective communication between trusting agent and trusted agent to derive trustworthiness information
b. Common business understanding
c. Neutral party support
d. Control and monitoring
e. Service / Relationship Quality
f. Website Quality
g. Company Reputation
h. Security, privacy and familiarity

The meta-literature analysis in Table 2.1 below summarizes the existing literature on approaches for trust maintenance. Table 2.1 also presents whether the existing literature addresses the following questions:

Q1: Do they make a distinction between the terms ‘building trust’ and ‘maintaining trust’?
Q2: Do they propose a methodology to maintain trust?
Q3: Do they validate their proposed model / framework?

No	References	Critical Evaluations										
		Factors/Variables/Practices								Questions		
		a	b	c	d	e	f	g	h	Q1	Q2	Q3
1.	(Balasubramanian, Konana et al. 2003)		v	v						no	no	no
2.	(Xiao and Wei 2008)	v				v				no	no	no
3.	(Iacono and Weisband 1997)	v								no	no	no
4.	(Hung, Dennis et al. 2004)		v	v						no	no	no
5.	(Pavlou 2002; Pavlou and Geven 2004)			v	v					no	no	yes
6.	(Kong and Hung 2006)					v	v			no	no	yes
7.	(Yee 2007)			v						no	no	no
8.	(Zhang and ZhenWang 2006)			v						no	no	no
9.	(Gao and Wu 2010)	v								no	no	yes
10.	Li et al. (2011)	v		v			v	v	v	no	no	no
11.	(Javernpaa and Leidner 1999)	v		v						no	no	no
12.	(Greenberg, Greenberg et al. 2007)	v	v	v		v				no	no	no
13.	(Ishaya and Mundy 2004)	v	v							no	no	no
14.	(Kim and Tadisina 2003; Kim, Yum et al. 2005; Kim and Kim 2009)						v	v		no	no	yes
15.	(Zhang and Zhang 2005)			v			v	v	v	no	no	no
16.	(Gwebu, Wang et al. 2007)	v	v					v		no	no	no
17.	(Winch and Joyce 2006)					v	v			no	no	no
18.	(Babar, Verner et al. 2007)	v	v			v				no	no	yes
19.	(Sako 1998)	v			v					no	no	no
20.	(Ariño, de la Torre et al. 2001)					v				no	no	no
21.	(Lamsa and Pucetaite 2006)	v	v			v				no	no	no

22.	(Pucetaite and Lamsa 2008)	v								no	no	no
23.	(Gillespie and Mann 2004)	v	v							no	no	no
24.	(Six and Sorge 2008)	v								no	no	no
25.	(Long and Sitkin 2006)				v					no	yes	no
26.	(Das and Teng 1998)				v					no	no	no
27.	(Kusari, Cohen et al. 2005)				v					no	no	no
28.	(Kartseva, Gordijn et al. 2006)				v					no	no	no
29.	(Kabadayi and Ryu 2007)				v					no	no	no
30.	(Velez, Sanchez et al. 2008)				v					no	no	yes
31.	(Vlaar, Bosch et al. 2007)				v					no	no	no
Total		15	8	9	9	7	5	4	2			
		a	b	c	d	e	f	g	h			

Table 2.1: Critical review of the existing literature on trust maintenance

Based on the summary of critical reviews in Table 2.1 above, we conclude that several authors have proposed a model or framework for trust maintenance by defining factors/variables/actions/mechanisms. However, the existing literature treats factors/variables/mechanisms in isolation and fails to present a methodology for maintaining trust. The methodology for maintaining trust should comprise factors/variables/mechanisms to maintain trust. In some cases, they provide a detailed clarification of events and actions, although most of them propose only a single event and action. Therefore, the major shortcomings of the existing literature can be summarised as follow:

a. None of them proposes a complete methodology to maintain trust.
b. Although they propose or identify a single important factor to maintain trust, they do not provide a detailed explanation of how to convert this factor into real action to maintain trust.
c. They use the terms ‘building’, ‘developing’, ‘maintaining’, ‘nurturing’, ‘enhance’, ‘foster’ synonymously without any further effort to define these terms more precisely. They do not make any distinction between them. Based on the trust evolution theory, there should be several different factors for building and maintaining trust. Since they are different, a strategy or model to address this also should be different.
d. Most of them are theoretical in nature and do not provide empirical evidence or validation.
e. Some of them focus on a limited geographical setting and hence do not provide a generic method which can be applied broadly across domains and situations.

In this thesis, we intend to provide a complete methodology comprising factors, variables, practices, events and actions to maintain trust. Our methodology comprises frameworks to maintain trust as follows: (a) the selection of a neutral agent; (b) the importance of a common business understanding; (c) the role of control and monitoring, (d) reward and incentive for successful of service delivery and (e) a mechanism for trust re-calibration. In the next section, we summarise and subsequently discuss the associated problems in the existing literature related to each framework.

2.6.1 **The Involvement of Neutral Party as Independent Agent**

In the previous discussion, it has been argued by (Javernpaa and Leidner 1999; Papadopoulou 2001; Balasubramanian, Konana et al. 2003; Zhang and Zhang 2005; Zhang and ZhenWang 2006; Greenberg, Greenberg et al. 2007; Papadopoulou 2007) that the involvement of a third party agent as a neutral agent in such interaction can be used to preserve the existing level of trust. This is because the third party agent is a neutral and independent agent. As also suggested by Kasper-Fuehrer and Ashkanasy (2004), virtual environments are environments described as a network in which there is no formal and hierarchical authority between parties. Hence, it needs a network broker or third party agent to mediate between agents as the complexity of the relationship increases. In order to gain maximum benefit from the relationship, for trust maintenance purposes in virtual environments, both parties (trusting agent and trusted agent) need a third party agent as neutral party. This broker has a role as an independent and unbiased agent to monitor the trust relationship between virtual agents. The role of this agent is to advocate or mediate or judge and resolve conflicts or disagreements during the interaction. Moreover, in virtual worlds, rules of life are governed by contract. In virtual environments, the trusting agent designs a contract with each trusted agent. This contract or mutually agreed to behaviour establishes the rules of interaction between trusting agent and trusted agent. The role of the third party is to protect both parties if either intends to exploit the relationship. However, there is no literature that discusses in detail who the third party agent should be and how to select this third party agent from a virtual environment.

As was discussed in the previous section, Balasubramanian, Konana et al. (2003) suggest that customers rely strongly on the availability of other institutions to generate trust and security in conducting business with online service providers. Their research on online investing suggests that investors feel secure if there is a third party institution such as the SEC (Security and Exchange Commission) that is involved in their business relationship with an online service provider. This SEC has a role as a safeguard institution that protects both parties from malicious practices between them. Customers' secure feeling leads to trust perceptions toward the service provider (trusted agent). However, this kind of third party is derived from hard trust perspective which represents information derived from security mechanisms such as identity keys, credentials and certificates.

Javernpaa et al. (1999), Greenberg, Greenberg et al. (2007) also propose the role of a neutral party to develop and maintain the trusting relationship between trusting agent and trusted agent. An intermediary is an agent who acts as a link between trusting agent and trusted agent in order to try to bring about an agreement or reconciliation. Although business entities may never or rarely meet in person, they have an interest in relating to their partners virtually because it is beneficial to both of them. The main objective of this neutral agent is to establish trust for maintenance purposes in the relationship between two parties. This neutral agent is called 'an arbitrator agent'. The primary role of this agent is to act as an intermediary between the trusting parties. They are independent and provide their service either for free or for a fee depending on the volume of business transaction, the duration of relationships and the level of trust that has been already established between both parties. This intermediary role involves conflict resolution and ensuring the satisfaction of both trusting agent and trusted agent.

Basically, negotiation between both parties without the involvement of a third party is a better option when any conflict or disputes of contract arise during the relationship. However, even if the parties are willing to negotiate for purposes of conflict resolution, it may take a long time, even several days, to overcome their differences and arrive at a mutually satisfactory and practical solution. Moreover, it is a solution that is more likely to actually work because they reached it themselves. It may not be perfect, but it was not forced upon them by someone else who has not experienced the situation. However, due to the time limit to finish work in virtual environments and relationship constraints, mediation should be considered as an option. It may not be successful in every case; however, it is a real solution. The essence of mediation is compromise. It also does not mean that both parties lack faith in their case. The purpose of this mediation is for the trusting parties to be willing to work in a more economical, successful or satisfying manner. It also means that the parties wishing to use mediation want to maintain control of the outcome.

A successful mediation by the third party agent is one that resolves the conflict in a way that is acceptable to all the trusting parties. This does not mean that one or the other of the parties gets everything that it wants. On the contrary, the result is usually that neither party gets everything that it desires. But, this third party agent makes a decision as to what it can accept and live with, and what the trusting agent and trusted agent can give up or do without. Therefore, both parties decide how the matter will be resolved, and they should agree with the third party agent who will help them work with the other side to resolve it.

However, the existing literature which proposes the involvement of a third party agent, primarily discusses the involvement of a third party agent from the perspective of hard trust such as that proposed by (Zhang and ZhenWang 2006; Yee 2007). In this thesis, we propose the involvement of a third party agent in an interaction between trusting agent and trusted agent to maintain their trust level. We also propose mechanisms for third party agent selection and for the resolution of any conflict that arises. In Chapter 4, we present an overview of the problem solutions.

2.6.2 The Availability of Common Business Understanding

As pointed out by several researchers (Babar, Verner et al. 2007; Gwebu, Wang et al. 2007; Khalfan, McDermott et al. 2007), a well-defined relational contract is one of the most important factors in building and maintaining trust in virtual environments. Babar et al. (2007) noted that contract conformance which includes quality and timely delivery plays a significant role in maintaining trust relationships. With a contract conformance, both parties (trusting agent and trusted agent) can confirm whether or not they have abided by all clauses in the business agreement. A contract additionally serves the purpose of benchmarking the performance. Moreover, Khalfan, McDermott et al. (2007) also argue that contract and agreement are the foundation for a trusting business relationship. These contracts may be either formal or informal. A formal contract may include some agreement between parties regarding mutually agreed behaviour, profit sharing, responsibilities and obligations.

In addition, trust in virtual environments may increase as a result of repeated service experiences (experience base). It means that the trusting agent (e.g. customer) will have a high level of trust in the trusted agent (service providers) after a certain number of interactions. This is because the trusting agent does not have a set of pre-consumption expectations of service quality in online environments (Zeithaml, Parasuraman et al. 2000). Perceptions of service providers' competence (operational competence) as a part of trust dimensions are mostly pertinent when trust is formed through repeated interactions (McKnight and Chervany 2006). In contrast, in traditional environments, a trusting agent usually engenders trust by observing a service provider's competence and ability to deliver a requested service (observation base). Therefore, Balasubramanian, Konana et al. (2003) argue that agreed regulations that govern business interactions between trusting agent and trusted agent will help to maintain their trust level.

Moreover, Saphiro (1987) stated that the need to produce institutional structures that administer business activities is higher when there is a minimal personal relationship between trusting agent and trusted agent. In the trust field, situational normality and structural assurance are bases form of institution-based trust (McKnight and Chervany 2006). Situational normality is defined as the proper ordering of cognitive cues. Hence, we argue that a formal contract which contains cognitive signals between trusting agent and trusted agent is an expression of ordered activities that should be met in business activities. It is also a structural assurance that enhances trading security in virtual environments. Therefore, when security is perceived by trusting agents to be high, they may assign high levels of trust in the trusted agent, though they are in the limited number of personal relationship. It can be concluded that a formal agreement is an institutional structure that should be established in order to facilitate trust maintenance. Balasubramanian, Konana et al. (2003) suggest that customers rely strongly on the trust that leads to security provided by regulatory bodies in online business transactions.

Therefore, by designing and agreeing to contracts, agreements and regulations, business parties may implicitly set their service standards for trust maintenance in a business relationship. There are some reasons why a legal common business understanding such as Service Level Agreement (SLA) is important in the online environments. First, the virtual nature of interactions can increase discrepancies in information. Hence, regulatory guidelines may help parties to maintain acceptable levels of performance during their relationship. Second, trusting agent and trusted agent may implement business procedures that protect both parties from any deleterious effects of the high volume of trade in business and high market instability.

For this reason, a formal agreement is essential in an interaction as a foundation for trust maintenance. In order to establish an agreement regarding a business contract, negotiation between, and the participation of, both parties is an important step. Pruitt (1983) stated that negotiation is a process in which negotiator parties interact and communicate to discuss how to distribute and redistribute work resources and commitment. Moreover, Bichler (2003) described negotiation as an iterative decision-making process between two or more agents (parties or their representatives). The parties exchange information, starting with detailed offers, counter offers and arguments, deal with interdependent tasks, and search for an agreement which is a decision resulting from cooperation and conciliation (Aikebaier, Enokido et al. 2009; Aikebaier, Barolli et al. 2011).

As discussed in the previous section, several researchers argued that a common business understanding is important in the virtual context. In a virtual interaction, the specifications of common business understanding need to be communicated clearly between both parties to achieve a mutual agreement. The task specifications can be achieved by negotiating relational contracts that guide the formation, operation, and dissolution of the virtual business relationship. It is, therefore, conducive to maintaining the level of trust. However, none of the existing literature provides a detailed explanation of the means by which this negotiation in terms of a common business understanding can be carried out.

Hence, it is incumbent upon the trusting agent and trusted agent to develop their own (formal or informal) guidelines for their relationship in virtual environments. Such agreements may include clarification of members' tasks and responsibilities, agreement on service criteria, deadline for service delivery, rewards and punishment. In this sense, clear guidelines, spelled out in an early stage of the partnership, serve to minimise misperceptions and to foster the establishment and maintenance of trust (Handy 1995; Kusari, Cohen et al. 2005). However, based on the thorough review conducted and documented in this thesis, none of these works proposes a mechanism by which both trusting agent and trusted agent can reach this agreement contract. Such a specification of the set of agreed business activities is extremely important in virtual environments (in particular), as it would:

a. Enable both the interacting parties to determine or discover the business requirements of the interacting partner.
b. Enable each interacting party to make a judgment about whether the service capabilities being offered by its interacting partner would be sufficient for its business requirements from the interaction.
c. Provide clear criteria according to which the assessment process would be carried out.

In addition, we have conducted a thorough survey of the existing literature on the negotiation process used to reach an SLA. For example, Da-Yin and Chung-Liang (2005) proposed an autonomous negotiation to reach SLA with guaranteed Quality of Services in Service Negotiation Protocols. The protocol of Service Negotiation is as follows: (a) a service provider formulates a constrained resource allocation for a service requester; (b) if the service provider can meet the requirements of the service consumer, contracting between both parties then follows; (c) if the service consumer is not satisfied with the requirements, the consumer can change his/her requirements and negotiate with the service provider for a further three times; and (d) after three attempts at re-negotiation, if there is still no solution to meet the requirements, a service consumers may seek alternatives. Although Da-Yin and Chung-Liang (2005) proposed a service negotiation process, the primary shortcoming is that there is no framework for formulating the service requirements. Moreover, only one party (service provider) formulates a constrained resource allocation. In addition, the SLA that they reached is not for trust maintenance purposes and the iterative negotiation between service consumers and service provider is limited to three times only.

Yan et al. (2007) proposed an autonomous negotiation process for service composition provision. This autonomous negotiation aims to reach an agreement on service quality between service requester and multiple providers who offer various services in the composition. The negotiation process which could be agent-based or Web-based is as follows: (a) both parties reserve their values; (b) request an initial call for a proposal; (c) conduct an iterated negotiation between both parties; (d) both parties may select the best overall deal; (e) return to best deal (f) check overall QoS (g) confirm / amended reserve values, and (h) accept / reject proposal. Once the proposal satisfies the overall QoS, then the parties reach an agreement. The negotiation process of this work considers a similarity value between the service provider and the service consumer. However, they do not propose a framework to articulate and formulate the value of service requirements that they will exchange. Moreover, the agreement that they reach is not for trust maintenance purposes.

Huang et al. (2010) suggested a four-phase negotiation process between buyer and seller in e-commerce. They proposed a multiple-attributes negotiation model for B2C e-commerce which will facilitate automated negotiation of agreement in buying and selling. The four phases of negotiation are: (a) information collection, (b) search, (c) negotiate the requirements, and (d) evaluate the service requirements. The SLA negotiation process in this work includes information collection about service requirements and both parties are involved in the process to negotiate the requirements. However, the requirements are collected without any pre-defined service requirement formalization. In addition, the SLA between buyer and seller is not for trust maintenance purposes.

On the other hand, Abedin, Kuo-Ming et al. (2009) also proposed a framework for agenda-based negotiation between service provider and service consumer to reach an SLA in such e-commerce transactions. The process of negotiation to reach the SLA is as follows:

a. Both parties (service provider and service consumer) collect opinions about QoS
b. Enter the process for ordering requirement preferences
c. Provide individual priority order in different formats
d. Uniform representation based on fuzzy preference relations
a. Meet to determine preference ordering relations
b. Rank the preference issue
c. Start to negotiate based on agenda that is clearly stated in the previous step.
d. Either accept or reject the SLA

This negotiation process takes into account the collection of opinions about QoS from both parties so as to acquire a better knowledge about their respective service requirements. However, there is no framework for articulating and formalizing their service requirements.

Watanabe et al. (2010) proposed a requirement negotiation process for the design of cooperative service engineering. Firstly, both parties need to state their own service parameters. If there are any disparities regarding these parameters, the parties enter into a service requirement negotiation process. The process of service requirement negotiation is as follows: (a) specify contradicting requirement; (b) prioritize contradicting requirements to negotiate first; and (c) adjust the contradicting requirements. In this work, both parties have a chance to state their own service requirements. However, there is no framework for formalizing the service requirements. Moreover, the purpose of the negotiation is not to reach an SLA, but to engineer a cooperative service between both parties.

Based on the survey above, we conclude that no literature proposes any mechanism for concluding the 'specification of set of agreed business activities' for trust maintenance. Apart from the importance of agreeing to an SLA, from the trust maintenance perspective, the following properties are unique:

a. Since the level of trust between the interacting parties is high, one of the interacting parties (or possibly both) may be willing to negotiate, consider or agree to the business requirements of the interacting party.
b. Given the special nature of relationship in trust maintenance, the parties may need to go through repeated or iterative negotiation on service criteria, before agreement is reached.
c. Each interacting party would need to clearly determine and subsequently articulate what are its business requirements from the interacting party.

In the existing literature, it is clear that there is no framework or methodology for agreeing on an SLA for trust maintenance, that takes into consideration the above requirements. Although the existing literature (Lau 2006; Yan, Kowalcyk et al. 2007; Zulkernine, Martin et al. 2009) provides many discussions on creating the SLA between service provider and service requester, none of them discusses any pre-activities such as service formalization and service negotiation to reach an SLA. From the trust maintenance perspective, one may consider the SLA as a draft of the capability and willingness to meet standards requirements that both Easy Phones and Angela have agreed to. It also contains any strategies and tactics that they agree upon in order to conclude the service task. Therefore, service formalization and service negotiation are important steps in determining the SLA.

However, in the existing literature, there is no framework with which an agent can formalize its service requirements. The formalization of service requirements would enable each interacting party to clearly determine and articulate its particular requirements. Furthermore, this would enable each interacting party to discover what the other interacting agent wants. We propose service formalization as a step or a process of articulating the business requirements of both the interacting parties. Once the service formalization has occurred, then the interacting parties can negotiate the service requirements between themselves. Each interacting party should know the service criteria that they want in their interaction. In the existing literature, there is no mechanism by which either of the interacting parties can formalize their service requirements. Hence, the interacting parties are not in a position to discover the service requirements of their interacting partner. Therefore, there is the need for a structured model and method whereby the service provider's and service requester's requirements can be ascertained.

Moreover, in the existing body of works, there is only a limited discussion of a negotiation process by which both trusting parties can discuss their service requirements. Most of the literature considers negotiation as a process to satisfy or meet service requirements from the service requesters' perspective only. However, for trust maintenance purposes, an agreement on service requirements should consider the requirements of both parties and it may need to be negotiated iteratively on certain service criteria. However, the existing literature does not propose such a mechanism for service negotiation in trust maintenance. Therefore, in this research, we propose a framework by which an SLA between two interacting parties can be reached, based on service formalization and service negotiation. These two mechanisms, service formalization and service negotiation, will enable the trusting agent and trusted agent to reach an agreement. An agreement on service requirements from both parties is necessary in trust maintenance due to some basic assumptions. *Firstly,* both parties see a value, either monetary or non-monetary, in their relationship. *Secondly,* both parties are vulnerable in a reciprocal action to maintain or preserve this value. *Thirdly,* they engage in a joint effort to reach their common goal in such a business relationship. In Chapter 4, we present a solution overview for the formalization and negotiation of service requirements in a relationship for the purpose of trust maintenance.

2.6.3 **Performance Monitoring and Control Mechanism**

Performance monitoring is described as a set of activities undertaken to ensure and maximize the possibility of the actual behaviour of both trusting parties in a virtual transaction being in line with accepted agreements or contracts (Fachrunnisa and Hussain 2011).

As was discussed in the previous section, one of the several factors that can be used for the trust maintenance effort is the role of a control and monitoring mechanism. In the existing body of literature, several authors such as (Jagers, Jansen et al. 1998; Langfield-Smith and Smith 2003; Kusari, Cohen et al. 2005; Sitkin and George 2005; Kartseva, Gordijn et al. 2006; Long and Sitkin 2006; Kabadayi and Ryu 2007) propose the use of a control mechanism as an approach to maintain trust. This performance monitoring is intended to ensure that all transactions during the trust maintenance relationship are conducted according to the established standards for quality, delivery and performance. Pavlou (Pavlou 2002) suggested in his research that perceived monitoring by third party agents as a part of institutional trust can engender trust between buyers and sellers in an online B2B relationship. Perceived monitoring is defined as 'the extent to which buyer organizations believe that the third-party monitoring mechanism ensures that all the transactions in the marketplace are performed as expected' (Pavlou 2002).

Several researches such as the one carried out by (Gwebu, Wang et al. 2007), (Javernpaa, Knoll et al. 1998) proposed that proactive control, output-based control, process control, frequent and intensive communications will facilitate the development and maintenance of trust in virtual situations. Kartseva et al (Kartseva, Gordijn et al. 2006; Vlaar, Bosch et al. 2007) argue that the use of control mechanisms is significant in successful business networks. However, they note that little work has been done on developing a control mechanism for virtual environments. Their research provides a methodology for designing control mechanisms in inter-organizational virtual networks. Vlaar (Vlaar, Bosch et al. 2007) also stated that the evolution of trust from the existence of trust to distrust can be avoided by the mechanism of formal coordination and control in a relationship. Hence, formalization of control action is a critical factor to assist trust maintenance in a virtual collaborative relationship.

However, the existing literature does not provide a detailed explanation of how to conduct performance monitoring or provide a control mechanism in order to maintain trust. In Chapter 4, we provide an overview of a mechanism for conducting performance monitoring in interactions for trust maintenance purposes and in Chapter 7 we present the details of our performance monitoring framework.

2.6.4 **Reward and Incentive for Successful Service Delivery**

As was discussed in the previous section, several existing works suggest that the level of trust in such service relationships should always be monitored to ensure the success of interactions (Javernpaa, Knoll et al. 1998; Gwebu, Wang et al. 2007); Kartseva, Gordijn et al. 2006). Therefore, although trust has been established between the trusting agent and trusted agent in a transaction relationship, monitoring still plays an important role in ensuring that the partnership relationship continues to operate as intended (Sullivan 2007; Skopik, Schall et al. 2010). Therefore, even in situations where there is a sufficient level of trust between interacting parties, this trust needs to be underpinned by robust monitoring and, where necessary, reward and sanctioning processes could be utilized (Ferrin and Dicks 2003; Long and Sitkin 2006).

Burnett et al. (2011) consider three kinds of controls which can be used in those cases where trust is insufficient in such interactions: (a) Explicit incentives. These incentives are clearly stated in the contract and an agent will receive compensation (in terms of utility) depending upon the outcome; (b) Monitoring. The trustor expends additional effort/utility in order to observe the behavioural choices of the trustee, and (c) Reputational incentives. The trustor calculates the reputational gain (damage) that a trustee will experience as a result of good (or bad) feedback being communicated to the society and considers this as an additional incentive. In order to achieve this, rewards or penalties are incorporated in contracts. These kinds of incentive or penalties are intended to encourage interacting partners to behave according to the mutual agreement (contract). If the performance of the trusted agent approximates the specified behaviour stated in the contract, this trusted agent will be given rewards as stipulated in the contract.

Hence, it can be concluded that rewards and incentives are widely acknowledged as motivators which can encourage agents to improve their performance. Badenfelt (2010) stated that trusting agents may use rewards to increase trust levels. Additionally, Jahn (2010) argues that in an Agent-Principal relationship, incentive is a single factor with several functions as follows:

a. Activation function as a stimulation of motivation and cognitive abilities. With an incentive, an agent will be motivated to perform better according to their cognitive abilities in order to obtain reward (in this case a higher trust value).
b. Controlling function as an influence on the agent's behaviour. Incentive can be used as a control mechanism to influence the agent's behaviour. If an incentive is available, the agent will be motivated to obtain an incentive by performing well or better.
c. Information function, whereby incentive agents receive a signal regarding desirable behaviour
d. Selection function, where principals obtain information about an agent's performance
e. Coordination function which coordinates the single actions of agents. Such continuous performance monitoring activities enable performance discrepancies to be identified and resolved early.

Kumaran, Bishop et al. (2007) proposed a MDBT (Model Driven Business Transformation) for transaction monitoring between service provider, outsourcer and service requester. It provides a service delivery performance management platform which includes notification of any violation of SLAs. The performance is monitored by comparing actual performances against Key Performance Indicators (KPIs). The platform aims to model performance metrics for service delivery and describe how the monitoring and management of KPIs are supported as an integral part of the SDM (Service Delivery Management) platform. However, this platform does not provide any mechanism, using reward and incentive, to motivate the service provider to fully comply with SLAs.

Additionally, Ferrin and Dirks (2003) carried out laboratory experiments to examine whether rewards have a direct effect on trust or whether they represent a catalyst that may set in motion other processes that influence trust. Their research concludes that rewards have a strong impact on the formation of trusting beliefs. However, as previously discussed, the existing literature does not propose any mechanism that provides an incentive at intermediate intervals during the delivery of service to facilitate or ensure trust maintenance. Additionally, it fails to investigate the combined use of rewards / penalties with intermediate performance monitoring to maintain trust. The incentive is given after the completion of tasks at the end of the interaction or it is given after the trusted agent has completely delivered the service.

Hence, we conclude that a combination of a mechanism of proactive continuous monitoring and an incentive mechanism specifically designed to support successful service delivery would be valuable in the trust maintenance phase. In Chapter 4, we propose a solution overview of providing incentive mechanism for the successful interaction in the trust maintenance phase and in Chapter 7 we present detail mechanism of the framework

2.6.5 **Trust Re-calibration**

One basic assumption in trust maintenance is that a positive trust value has already been established in the previous phase (trust building phase) after some interactions between two entities. If both parties do not make significant, concerted and concerned efforts to maintain this trust level, then it might decline. The main purpose of trust maintenance is, therefore, to preserve the current trust value so that this trust value will remain stable or possibly increase. In order to achieve this, we need to know the level of the trust values prior to, during, and after the interaction. As both parties have an initial trust at the beginning of their interaction, it can be argued that trust is maintained if the level of trust after the interaction (final trust) is equal to or greater than the initial trust level. Hence, in determining final trustworthiness, the initial trust that was established during the building phase is subject to re-calibration or re-assessment in the maintenance stage.

The calibration or assessment of trustworthiness can be done by determining the correlation between actual behaviour and mutually agreed behaviour of the interaction (Hussain, Chang et al. 2004; Chang, Dillon et al. 2006). However, there are two streams of theorization or modelling of initial trust development. First, trust can be gained through direct observation or direct interaction with the trusting agent and secondly, trust can be gained through a reputation mechanism. In the existing literature, most work on trustworthiness assignment relates to reputation mechanisms. Existing works (Abdul-Rahman and Hailes 2000; Aberer and Despotovic 2001; Cornelli, Damiani et al. 2002; Yu and Singh 2002; Wang and Vassileva 2003; Xiong and Liu 2003; Wang and Vassileva 2005) propose a means for aggregating the reputation values from different recommendation peers who previously interacted with the trusted peers. Wang et al (Wang and Vassileva 2003; Wang and Vassileva 2003) propose a Bayesian network-based method for trust assessment. In order to determine whether Peer A can classify its interaction with Peer B as being satisfactory or otherwise, a weighted aggregate of the outcome of each of the criteria in the interaction is determined. Peer A can subsequently compute or determine the future probability of Peer B carrying out a satisfactory or an unsatisfactory interaction, in the given context or in any combination of the three contexts by making use of the Bayes rule. The primary shortcoming of their method is that the level of satisfaction or dissatisfaction with a given peer in an interaction can be expressed at just two levels, namely 0 and 1, thereby preventing the trusting peer from expressing a finer gradation in the level of satisfaction with the behaviour of the trusted peer. Additionally, they do not propose any method for weighting the criteria in an interaction according to their importance. Neither have they proposed any measure to account for scenarios where the criteria have not been mutually agreed upon by the interacting partners.

Hussain et al. (Hussain, Chang et al. 2004; Chang, Dillon et al. 2006) proposed a CCCI metrics as a method of assigning trustworthiness of a trusted agent through or after an interaction with the trusted agent, and then automatically assigning an initial trustworthiness value to the trusted agent. With this metrics, trustworthiness can be rated as the concurrence between the expected behaviour vs. the actual behaviour as perceived by the trusting peer. However, CCCI compares actual with agreed behaviour for the whole interaction and this is done only at the end of the interaction. Schmidt, Steele et al. (2007) propose an enhancement to the CCCI metrics proposed by Hussain et al. (Hussain, Chang et al. 2004; Chang, Dillon et al. 2006). They propose a method for fuzzy trust evaluation in multi-agent systems. However, the proposed methodological framework for trust re-calibration by Hussain et al.

(Hussain, Chang et al. 2004), Wang et al. (Wang and Vassileva 2003; Wang and Vassileva 2005) and Schmidt et al. (Schmidt, Steele et al. 2007) cannot be used in the trust maintenance phase. This is because during the trust maintenance phase, as pointed out by (Fachrunnisa, Hussain et al. 2009), the progress of an interaction is measured by periodic performance assessments at intermediate milestones (or checkpoints). This is in contrast to trust building, where performance assessment is carried out only at the end of the interaction. For trust maintenance purposes, we suggest having multiple intermediate performance assessments, resulting in multiple trust values from intermediate performance assessments.

Moreover, none of the existing literature considers the need for trust re-calibration in a trust maintenance effort where the trust value would be a function of the intermediate trust values during the actual interaction. In Chapter 4, we present an overview of the solution in terms of trust re-calibration in the trust maintenance phase and in Chapter 8 we present the details of the trust re-calibration mechanism in our methodology.

2.7 **Conclusion**

In this chapter, we carried out an extensive survey of the existing literature. We grouped the existing literature of trust evolution under several categories based on views about how trust evolves in a relationship. Following this review of various perspectives on trust evolution, we then presented an extensive survey on trust maintenance approaches and categorised these according to the types of proposals. Finally, we evaluated the existing literature critically and found that no work in the literature proposes a complete trust maintenance methodology. We then provide a summary of the shortcomings of the reviewed works and the extant research challenges. In the next chapter, we define the problem that we intend to address in this thesis.

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Chapter 3 - **Problem Definition**

3.1 **Introduction**

The first chapter highlighted the role and significance of maintaining trust in virtual environments. In the previous chapter, we presented a review of the existing literature. It was noted that a significant methodology to maintain trust in virtual environments is pivotal. Advances have been made by various researchers in the area of identifying important factors/variables/actions/mechanisms to maintain trust. However, it was noted in Chapter 2 that none of the existing literature offers a complete methodology for trust maintenance in virtual environments. Additionally, in the previous chapter, we identified seven main shortcomings within the existing literature that need to be addressed in order to propose a complete methodology for trust maintenance.

In Section 3.3 of this chapter, we formally define and present the problem that we intend to address in this thesis. In Section 3.2, we propose a set of definitions of those terminologies that will be used when defining the problem in Section 3.3. We break the problem down into seven cohesive research issues and formally define each of these in Section 3.4. In Section 3.5, we outline the solution proposal and choice of research method for the solving of the identified research issues. Finally, Section 3.6 concludes the chapter.

3.2 **Key Concepts**

In this section, we present a formal definition of those terms and concepts which will be used to introduce, elucidate and formally define the problem addressed in this thesis.

3.2.1 **The Evolution of Trust**

We define *the evolution of trust* as the process by which the level of trust in a relationship changes over time. Evolution is a theory in biology postulating that the various types of plants, animals, and other living things on the Earth have their origin in other pre-existing types and that the distinguishable differences are due to modifications in successive generations. The theory of evolution is one of the fundamental keystones of modern biological theory. The process of evolution may be interpreted as a biological term, but also as a cultural one or even as a process of learning in terms of trust and cooperation (Bateson 1988).

In a community, interaction and reciprocation are common forms of behaviour. Trust plays a role as a social capital to create reciprocal cooperation. The entities communicate more than once, if the community is small, or if they collaborate in the same area. If trust were not present, reciprocation would not occur, and collective collaboration would be worse off. Agents in the community 'will do better' if they trust others, than if they did not. Hence, in this case, trust, relationship and reciprocation have an evolutionary strength.

3.2.2 **Trust Modelling**

We define *trust modelling* as 'the process of determining the trust value of an entity either quantitatively or qualitatively' (Raza, Hussain et al. 2010).

3.2.3 **Trust Management**

We define *trust management* as 'the activity to determine how trust will be assigned, modified and revoked' (Ishaya, Mundy 2004).

3.2.4 **Trust Maintenance**

We define the *trust maintenance phase* as the period from the stage (point in time) at which positive trust has been established to the stage (point in time) at which trustworthiness values fall to a level corresponding to negative trust (Fachrunnisa and Hussain 2011). As pointed out in Chapter 2, in a trust-based relationship, the trust level follows an evolutionary pattern consisting of three phases: building, maintaining and declining. Once positive trust level is established in the trust building phase, the condition of the trust level may move to the trust maintenance phase.

3.2.5 **Hard Trust**

We define *hard trust* as trust that represents information derived from a security mechanism such as identity keys, credentials and certificates.

3.2.6 **Soft Trust**

We define *soft trust* as trust information that is inferred from experience and observation of others. It is grounded in social factors that link behavior with evidence. This link is achieved through mapping observable behavioral evidence.

3.2.7 **Trust-Based Interaction or Relationship**

We define a *trust-based interaction* or relationship as dealing between two entities or two agents to achieve certain pre-defined objectives or goals based on their trust level (Chang, Dillon et al. 2006). This interaction has either a monetary or non-monetary value attached to it.

3.2.8 **Time Space of Interaction or Relationship**

We define *time space* as the total duration of interaction time during which the behavior of the trusted agent will be analyzed and the trustworthiness assessment will be carried out (Chang, Dillon et al. 2006).

3.2.9 **Third Party Agent**

We define a *third party agent* as an agent who monitors the interaction of both interacting parties and provides real-time feedback in the case of 'performance discrepancies' (Fachrunnisa and Hussain 2011). This agent is a neutral, independent and unbiased entity who monitors the trust-based interaction between both parties.

3.2.10 **Proactive Continuous Monitoring**

We define *proactive continuous monitoring* as a real-time performance monitoring of the way the trusted agent delivers service to the trusting agent as agreed and vice versa (Fachrunnisa and Hussain 2011).

3.2.11 **Trust Re-calibration**

We define *trust re-calibration* as the re-assessment or re-calculation of the condition of the trust level based on updated information (Fachrunnisa and Hussain 2011).

3.2.12 **Positive Trust Level**

We define *positive trust level* as the trust level condition in a well-established relationship. 'It corresponds to an affirmative or sanguine belief that the trusting agent has about a given trusted entity' (Hussain 2006).

3.2.13 **Negative Trust Level**

We define *negative trust level* as the trust condition which 'corresponds to a pessimistic, cynical, disparaging, adverse, unfavorable belief that the trusting agent has about a given trusted entity' (Hussain 2006).

3.2.14 **Neutral Trust Level**

We define *neutral trust level* as the trust condition which 'corresponds to a mediocre or average belief that the trusting agent has about a given trusted entity' (Hussain 2006).

3.2.15 **Initial Trust**

We define *initial trust* as the trust level condition at the beginning of the interaction time space (Fachrunnisa and Hussain 2011). In this thesis, we use the terms 'initial trust' and 'initial trust value' synonymously.

3.2.16 **Intermediate Trust**

We define *intermediate trust* as the trust level condition in the intermediate time space of the interaction (Fachrunnisa and Hussain 2011). In this thesis, we use the terms 'intermediate trust' and 'intermediate trust value' synonymously.

3.2.17 **Final Trust**

We define *final trust* as the trust level condition at the end of the interaction time space (Fachrunnisa and Hussain 2011). In this thesis, we use the terms 'final trust' and 'final trust value' synonymously.

3.3 **Problem Overview and Problem Definition**

As discussed in Chapter 2, the trust maintenance phase is a critical point to which trusting parties in a trust-based relationship should pay more attention. The importance of trust maintenance can be evidenced from the previous research which concluded that trust has an evolutionary pattern and more attention must be paid to it after the trust level has been established. Additionally, in virtual environments, trust is recognized as being fragile (Meyerson, Weick et al. 1996; Javernpaa, Knoll et al. 1998; Javernpaa and Leidner 1999); hence, a constant effort to maintain it is crucial. Additionally, the building of trust requires much effort and cost from both the involved parties; hence, once it is well established, both parties must follow a maintenance program; otherwise, the relationship falls into a state of disrepair (Currall and Epstein 2003).

Several researchers have made a significant contribution to the issue of trust maintenance either in virtual environments or non-virtual environments. As we discussed in Chapter 2, in some parts of the literature, the notion of trust maintenance is used interchangeably or synonymously with the notion of trust building or trust development. This leads to a lot of confusion and distinction between trust building and trust maintenance and the methodologies / activities to achieve it.

Moreover, the dynamic nature of trust has been viewed as an occurrence during the whole time space of the interaction. However, as was noted in Chapter 2, there is little or no framework in the existing literature that illustrates how this trust level changes during one time space of interaction, especially in the trust maintenance phase. The condition of the trust level may be different at the beginning of the interaction (initial trust), middle or interaction (intermediate trust) and end of the interaction (final trust). The immediate shortcoming of this is that there is no definition of initial trust, intermediate trust and final trust to illustrate the dynamic nature of trust in one time space of the relationship.

Furthermore, as was pointed out in Chapter 2, the literature on trust maintenance focuses largely on identifying factors or variables or a single action or single practice that needs to be undertaken if an agent intends to maintain the trust of another agent. It also suggests various practices or strategies to maintain trust. However, those factors or variables are not generic, but based on a certain domain and may produce different results if applied to another domain. To some extent, the studies presented in the literature have been limited to one country or geographical area. Moreover, the literature does not discuss the details of the mechanisms or procedures for implementing those variable factors. Hence, to the best of our knowledge, the existing literature does not provide a complete methodology for maintaining trust. Given the importance of maintaining trust, there is the need for a methodology for maintaining trust in virtual environments. The methodology comprises five frameworks that can be used to achieve the objective of trust maintenance. As we pointed out in Chapter 2, as trust has a dynamic nature, the change(s) in the trust value of an entity could occur at any time due to changes in its behaviour over time.

As was also discussed in Chapter 2, one of the strategies that have been proposed to maintain trust includes the involvement of a neutral party in a relationship. However, most of the literature regards the third party agent as part of a hard trust or security platform that can be used to preserve the trust level. It does not investigate the use of third party agents to maintain soft trust. As argued by (Javernpaa and Leidner 1999; Greenberg, Greenberg et al. 2007), one way to ensure that trust is maintained is through an intermediary. An intermediary is an agent that acts as a link between trusting agent and trusted agent in order to achieve an agreement or reconciliation. In virtual environments, business entities might never or rarely meet in person, and they have an interest in doing business with their partners virtually because it is advantageous to both of them (Javernpaa, Knoll et al. 1998; Javernpaa and Leidner 1999).

However, the requirement of a third party agent in a relationship to maintain trust could be a significant problem in virtual environments. Since agents interact virtually and without restrictions, we need to have a framework for finding and selecting an appropriate third party agent. Nonetheless, the existing literature fails to provide a framework for third party agent selection.

Other approaches in the literature suggested that contract conformance or a Service Level Agreement is needed in order to preserve the trust level in a relationship. They noted that contract conformance which includes quality and timely delivery plays a significant role in maintaining trust. With a contract conformance, both parties can confirm whether or not they have adhered to all the stipulations in the business agreement. It provides a baseline for trust evaluation at the end of the interaction.

Contract conformance is defined as an agreement between two parties on how they create a virtual collaboration in software outsourcing. Additionally, (Gwebu, Wang et al. 2007) also noted that a well-defined relational contract is one of the mechanisms used for building trust in virtual networks. However, in the existing literature, there is no framework for formalizing and negotiating the service requirements in order to reach this agreement. Additionally, to the best of our knowledge, there is no proposal in the literature that considers the creation of an SLA for trust maintenance purposes. The existing literature widely discusses the need to create an SLA during the trust building phase, but very few proposals provide a way to formalize the service requirements.

The other most common factors or variables in the existing literature on trust maintenance are control and performance monitoring. It is suggested that the level of trust in such relationships should always be monitored to ensure the existence or maintenance of trust in a relationship (Das and Teng 1998; Jagers, Jansen et al. 1998; Kusari, Cohen et al. 2005). However, the literature does not provide any performance monitoring strategy for ensuring the maintenance or the continuity of trust in the relationship. Control and monitoring always take place at the end of the relationship to ascertain the level of completion of service delivery. Nonetheless, due to the dynamic nature of trust, trust levels can change(s) any time during the interaction time space. Hence, we need a monitoring or surveillance framework to ensure that the level of trust is maintained (and does not fall below a pre-defined threshold). This surveillance framework should be able to monitor or detect changes in the trust level in real time and respond to such changes. Such a mechanism for monitoring the progress of actual performance against agreed performance should be visible to all parties so that any early discrepancies can be resolved in real time. Moreover, in the existing literature, no effort has been made to develop a framework by which both parties can resolve the performance discrepancies without delaying the delivery time as agreed.

Moreover, as was discussed in Chapter 2, the basic assumption underlying trust maintenance is that both parties already have a certain trust level condition based on several previous interactions that occurred during the trust building phase. The success of the trust maintenance process can be determined if the condition of trust at the end of time space of interaction is greater than or equal to the condition of trust at the beginning. Hence, both parties need to re-calibrate or re-assess their trust condition at the end of the time space of interaction. However, there is no approach in the existing literature that can be utilized to re-calibrate the trust level. Hence, we need a framework with which both parties can re-calibrate their trust level at the end of interaction.

The problem described above leads to our proposal of a complete methodology for trust maintenance that takes into account the following frameworks: third party agent selection, formalization and negotiation of service requirements, proactive continuous performance monitoring, incentive mechanism and trust re-calibration. Hence, we formally define the problem that we intend to address in this thesis as follows:

In a virtual environment, how can a trusting agent and trusted agent maintain their positive trust level, taking into account the dynamic nature of trust, so that by end of the time space of interaction, the final trust is greater than or equal to the initial trust?

The next section describes the research issues that need to be addressed in order to solve the above problem.

3.4 **Research Issues**

In this section, we present and discuss in detail the research issues that need to be addressed in order to solve the aforesaid problem of trust modelling in a service-oriented environment. The research issues that need to be addressed are as follows:

1. In the context of trust evolution in virtual environments, define: the evolution of trust, trust building, trust maintenance and trust declining.
2. Propose a framework for third party agent selection. In our TMM, we introduce a third party agent into the relationship between two parties. This third party agent is a neutral party that will help both the interacting parties to establish a successful relationship. The proposed framework provides a rule on how to select a third party agent to supervise relationships in virtual environments.
3. Propose a framework for formalization and negotiation of service requirements. We need a framework by which two interacting parties may agree on an SLA during interaction in the trust maintenance phase. It involves activities such as both parties articulating the service requirements, negotiating on the service requirements, re-negotiating on certain service requirements, etc.
4. Propose a framework for real time and proactive continuous monitoring for service deliverability. We need a framework to proactively monitor the performance of both parties during the time space of interaction and to maintain the level of trust between both parties.
5. Propose a framework that provides an incentive mechanism to ensure successful service delivery. We need a framework that can be used to motivate interacting parties to perform as closely as possible to the terms of the mutual agreement.
6. Propose a framework for trust re-calibration. We need a framework to re-calibrate the condition of trust level from both interacting parties at the end of the interaction time space.
7. Validate the proposed methodology for proof of concept.

In the next section, we clearly define each of the aforesaid research issues that need to be addressed in order to solve the problem stated in Section 3.4.

3.4.1 Research Issue 1: Conceptual Definitions of Trust Evolution

The first research issue is to define, in the context of virtual environments, the concept of trust evolution which consists of three phases: trust building, trust maintaining and trust declining. As was discussed in Chapter 2, trust evolution has been defined in various ways by different researchers. The way in which trust evolves in an interaction has also been discussed from various perspectives by various scholars. Two different views emerge, classified as: continuous increasing and non-linear increment. It should be noted here that the aforementioned different definitions and approaches for trust evolution and its associated phases cannot be regarded as incorrect as they tend to define trust in terms of the interaction domain. The main objective of developing a pattern in trust evolution is to show that trust has a dynamic nature in the context of any interaction. The progress or movement of the trust level condition from one phase to another phase depends upon the effort of both parties to manage trust level condition in their mutual relationship.

In this thesis, we propose a definition of trust evolution in an interaction to which a monetary or financial value is attached. We classify the trust evolution process according to three phases. In Chapter 4, we propose a formal definition of trust evolution and its three associated phases namely: trust building, trust maintaining and trust declining. Additionally, we describe certain characteristics of the condition of trust level and relationship condition in each phase.

3.4.2 Research Issue 2: Propose a Framework for Third Party Agent Selection

As discussed in Chapter 2, several researchers acknowledge the role of a neutral party in a relationship. We argue that in order to gain the maximum benefit from a relationship for trust maintenance purposes in virtual environments, both parties (trusting agent and trusted agent) need a third party agent as a neutral party. This third party agent has a role as mediator/arbitrator/conciliator throughout the time space of the relationship. The role of this third party is 'proactive-corrective' and focuses on task performance monitoring of both parties and helping to resolve any conflict arising during the relationship in order to maintain trust.

However, there appears to be no service company that specializes in offering a professional third party agent for the purpose of maintaining trust. The common service business in this area is dispute resolution whereby a third party agent intervenes if there is some dispute or conflict in a business relationship. The role of this third party agent is corrective only. Both trusting parties seek this neutral service if any conflict occurs which they cannot resolve by negotiation. Furthermore, the type of relationship that is supervised by an agent for online dispute resolution is not for purposes of trust maintenance, but rather for transaction purposes only. Therefore, there is a need for a new service that offers a third party agent to ensure that trust is maintained in a relationship.

The main difference between this Arbitration Service for Trust Maintenance (ASTM) and the existing arbitration service is the role of the third party agent and the purpose of arbitration. In ASTM, the third party agent's role is proactive-corrective, whereas in online dispute resolution, it is corrective only. Further, the role of the arbitrator in Online Dispute Resolution is to determine who is wrong and who is right. However, in ASTM, the role of the arbitrator is to ensure that both parties maintain their level of trust in the business relationship. This third party agent is involved in both parties' relationship from beginning to end of the time space of transaction or interaction. Both parties would report their task performance to a third party agent and if there is any discrepancy between the mutually agreed to behaviour and actual behaviour during the interaction, this third party agent helps both parties to arrive at another agreement so that the interaction task can be concluded in such a way that the trust level condition between the two parties is maintained.

Moreover, the existing literature views the third party agent from a 'hard trust' perspective which means creating a security technology or platform to maintain the trust level. However, in this thesis, we intend to introduce a third party agent from the perspective of 'soft trust', where the agent is a human agent. Hence, this service could be provided by a professional service agency that comprises a large number of professional arbitration agents who specialize in trust maintenance in virtual business interactions. In Chapter 4, we propose a framework for selecting this third party agent. We explain the framework in detail in Chapter 5.

3.4.3 **Research Issue 3: Propose a Framework for Formalization and Negotiation of Service Requirements**

In this thesis, we take the viewpoint that the trusting agent needs to have a contract conformance with the trusting agent about the context of the interaction. This contract conformance or Service Level Agreement would be used to assist performance monitoring and assessment about the quality of service delivered by both parties. As was discussed in Chapter 2, contract conformance or business contract is acknowledged as a factor that can be used to maintain trust. However, the notion of creating an SLA as presented in the existing literature, is not mainly for trust maintenance purposes. Additionally, there is no framework by which both trusting parties can formalize their service requirements during the trust maintenance phase.

As trust in virtual environments is more cognitive than affective, the maintenance of trust can best be done by measuring the degree to which a service task has been accomplished. Further, Sako (1998) suggests that competence to deliver a service task and task responsibility are central elements in the measurement of trust in a transaction setting. In order to maintain trust, both parties should have a benchmark or a basis by which to evaluate their performance when carrying out an interaction. This is because trust level can be calculated by correlating actual performance and agreed performance (Hussain, Chang et al. 2004). Specifically, in a services environment, actual performance can be seen as the actual service delivery, while agreed performance is the set of agreed service requirements from both parties. Therefore, a formal agreement such as Service Level Agreement (SLA), which specifies service requirements, is needed for trust maintenance. An SLA is defined as a negotiated agreement between two parties where one is the service provider and the other is the service requester (Zulkernine, Martin et al. 2009).

Unlike the trust building phase, in the trust maintenance phase, each of the interacting parties has to make a concerted attempt to maintain or sustain the level of trust in the relationship. In contrast to trust building, it may involve activities such as both parties articulating the service requirements, negotiating on the service requirements, re-negotiating on certain service requirements, etc. However, in the existing literature, there is no framework by which two interacting business parties may agree on an SLA for trust maintenance. Therefore, a method for reaching an agreement of service requirements between both parties is an important step in the process of trust maintenance. In Chapter 4, we present the design overview of a framework that involves service requirements formalization and negotiation to draw up an SLA for interaction in the trust maintenance phase. In Chapter 6, we present the details of the mechanism of this framework.

3.4.4 Research Issue 4: Propose a Framework for Proactive Continuous Performance Monitoring

As discussed in Chapter 2, control and monitoring are other factors that have been considered in the existing literature as means of maintaining trust in virtual environments. The existing literature provides several ways to control and monitor service deliverability. Several works suggest that the level of trust in an interaction should always be monitored to ensure the success of the interaction. Therefore, although trust has been established between the trusting agent and trusted agent in an interaction, monitoring still plays an important role in ensuring that the partnership relationship continues to operate as intended (Sullivan 2007; Skopik, Schall et al. 2010). Therefore, even in situations where there is a sufficient level of trust between trusting agents, this trust needs to be underpinned by robust monitoring and, where necessary, reward and sanctioning processes could be utilized (Ferrin and Dicks 2003; Long and Sitkin 2006).

Unlike the existing works in the literature regarding control and monitoring of trust-based interaction, in this thesis we propose a mechanism of proactive continuous monitoring during the interaction in order to maintain the trust level. The performance is monitored at intermediate checkpoints rather than at the end of the interaction. We do not intend to check the performance of interacting partners at the end of the interaction; instead, it is monitored during the course of the transaction to minimize the discrepancy between actual performances and mutually agreed to performance. In Chapter 4, we present an overview of the framework for proactive continuous monitoring in order to maintain trust. Details of this framework are presented in Chapter 7.

3.4.5 Research Issue 5: Propose a Framework for Incentive Mechanisms for Successful Service Delivery

As discussed in Chapter 2, reward and incentive are widely acknowledged as motivators which can encourage agents to improve their performance. Badenfelt

(Badenfelt 2010) stated that trusting agents could use rewards to change the trust levels in organizations. Although several researches have shown that the use of incentives can successfully increase the performance of agents in a non-virtual environment, Ferrin and Dirks (Ferrin and Dicks 2003) suggested that the effects of rewards in trust management in the context of virtual environments should be examined.

The proactive continuous monitoring as described in research issue 4 is designed to monitor the service deliverability at every checkpoint. This continuous monitoring enables deviations in performance to be timely identified. Consequently, both parties will be able to quickly close the performance gap before it inflates into an unmanageable and undelivered service by the end of the transaction period. It is also suggested by (Ferrin and Dicks 2003; Long and Sitkin 2006) that, where necessary, reward and sanctioning processes could be utilized to maintain trust. Hence, reward and incentive can be used to encourage trusted agents to always comply at each checkpoint. It will guarantee successful delivery of that service.

However, in contrast to the existing works in the literature regarding incentives for task completion, in this thesis we combine a mechanism for proactive continuous monitoring with an incentive mechanism specifically intended to support successful service delivery. The service delivery is monitored at intermediate checkpoints and incentives are given at intermediate checkpoints rather than at the end of the interaction. We do not intend to provide an incentive after task completion; instead, it is given during the course of the transaction to minimize the discrepancy between actual performances and mutually agreed to performance. In Chapter 4, we present the overview of framework of an incentive mechanism during proactive continuous performance monitoring in order to maintain trust by sustaining the service deliverability. Details of this framework are presented in Chapter 7.

3.4.6 Research Issue 6: Propose a Framework for Trust Re-calibration

The next research issue that we need to address in this thesis in order to provide a complete methodology for trust maintenance is a framework for trust re-calibration. As the purpose of trust maintenance is to sustain the level of trust during the interaction, we need a framework for trust re-calibration. This trust re-calibration needs to take into account the proactive continuous monitoring and incentive mechanism that we proposed in the previous research issue. Moreover, since at the beginning of the interaction both interacting parties have a mutual agreement about service context and its service criteria, the trust re-calibration also needs to consider the mutual agreement which would serve as the basis for trust re-calibration. In Chapter 4, we present an overview of the framework for trust re-calibration in our TMM. Details of this framework is presented in Chapter 8.

3.4.7 **Research Issue 7: Validate the Proposed Methodology by Simulation Experiments**

In order to verify the soundness of the proposed methodology, we need to validate the solution proposed for our research issues. By validation, we mean building an approximation or representation of a prototyping system that is based on the proposed TMM. This is in order to establish confidence that the methodology is suitable for trust maintenance efforts. In order to validate the methodology, we use a prototype approach. We present the solution overview for this research issue in Chapter 4, and in Chapters 9 - 10 we present the prototypes for validation of the proposed TMM.

3.5 **Research Methodology**

In addressing the stated problem, this thesis focuses on the development and subsequent testing and validation of a methodology for trust maintenance in virtual environments. In order to propose a solution for the seven research issues listed in the previous section, we need to follow a systematic scientific approach to ensure that the methodology development is scientifically-based. Therefore, in this section we give an overview of the existing scientifically-based research methods and justify our choice of a particular research approach.

3.5.1 **Research Approach**

Due to the nature of the research study, we identify that the science and engineering based research approach is the most appropriate for our purposes. Science and engineering research leads to the development of new techniques, architecture, methodologies, devices or a set of concepts, which can be combined to form a new theoretical framework. This research approach commonly identifies problems and proposes solutions to these problems. (Galliers 1992; Hevner, March et al. 2004) provide a concise conceptual framework for design science research and state that it deals with understanding the problem domain and designing a solution by building applications or design artefacts. This type of research is concerned with confirming theoretical predictions, and particularly in the engineering field, the spirit of ‘making something work’ is essential (Galliers 1992).

This thesis deals with the development of a new methodology for trust maintenance in virtual environments. We are not intending to build and evaluate a hypothesis; rather, we intend to create or design a methodology and validate it using experimental simulation. Therefore, our research falls into the science and engineering based approach with the type of research being design science. The Design Science Research follows three stages in the research life cycle (Jay F Nunamaker, Chen et al. 1991), namely: conceptual stage, development stage or perceptual stage and impact stage or validation stage.

3.5.2 **Conceptual Stage**

In the first stage, problems are identified and formally defined through a rigorous process of analysis. Furthermore, ideas, concepts and the construction of conceptual framework are also initially developed. The framework is elaborated on in the next stage.

3.5.3 **Development Stage or Perceptual Stage**

After problems have been formulated, a conceptual framework for the proposed methodology is constructed and a tool is developed. In this stage, implementations and prototyping are conducted. These instantiations are necessary to challenge or support the theory built on the previous stage.

3.5.4 **Impact Stage or Validation Stage**

In this last cycle, testing and validation through experimentation with real-world examples, using laboratory or field testing is carried out. The validation and assessment of the methodology are needed to recognize the benefits in both technological and social contexts and to identify future work which will improve on the proposed methodology. In this stage, the key aspects of the methodology would be related to fine-tuning.

3.5.5 **Choice of Design Science Research**

In this thesis, we apply a design science research approach, which originated from the work of Simon in 1969 (Simon 1996) in his study of the science of the artificial (as opposed to the natural). The design science research involves the development of an artefact to solve problems, and therefore emphasizes the utilitarian nature of the constructed artefact (March and Smith 1995; Hevner, March et al. 2004). It also encompasses behavioural science and engineering which deal with the development and justification of a theory as well as creating and evaluating artefacts features to the research, respectively. An overview of this research approach is depicted in Figure 3.1.

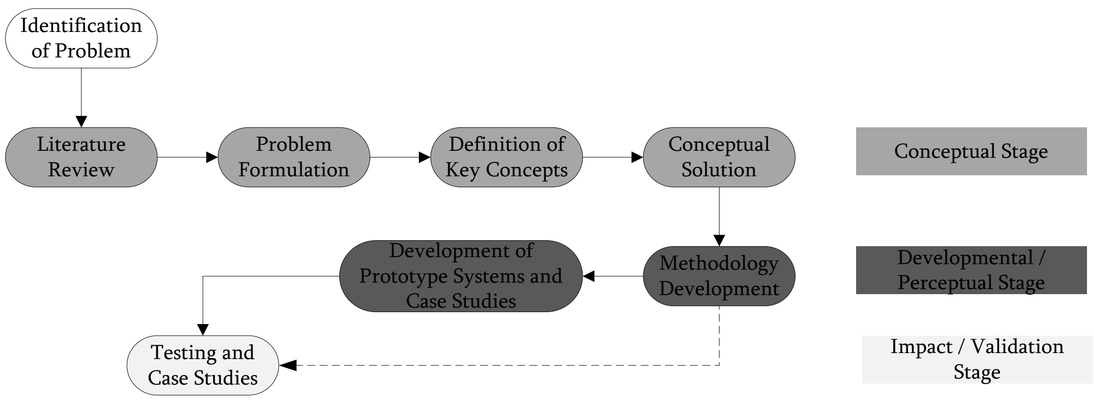

Figure 3.1: Overview of design science research

We began by identifying the research problems. We collected and analysed extensive literature on topics related to maintaining trust. Based on this review, we formulated the problem that needs to be addressed. This problem was formally articulated in Section 3.3. Subsequently, we defined several key concepts (such as trust evolution, time space, time slot...etc) taking into account the dynamic nature of relationships or interactions. These definitions will be used when developing the conceptual solution. Then, we formulated the conceptual solution for the problem being addressed in this thesis. Our processes comprised the literature review, the problem formulation, defining the key concepts and proposing the conceptual solution framework. This process belongs to the conceptual stage.

At the development stage, we developed the methodology for trust maintenance in virtual environments taking into account the type of interaction which involves a monetary value. During this stage, the detailed working of the methodology would be developed. The mathematical model and frameworks that underpin and drive the working of the methodology would be developed in detail in this stage. The techniques for choosing and selecting third party agent, techniques for service requirements formalization and iterative negotiation, techniques for proactive performance monitoring, techniques for providing incentive to ensure the service deliverability, and techniques for trust re-calibration will be developed in this phase.

Subsequently, we engineered prototype systems to evaluate the frameworks in the methodology and developed several case studies to use later for the testing of our proposed methodology. We engineered a multi-agent system using the JADE Multi Agent-Based Framework. The engineered multi-agent system has an interface, wherein the user can specify the parameters prior to the execution. The processes of methodology development and development of prototype systems and case studies belong to the development stage.

Once the prototype systems were engineered, we used them together with the developed case studies to validate our proposed methodology. At the impact stage or validation stage, based on the results obtained, we then evaluated and validated our proposed methodology. Based on the evaluation and validation, we then fine-tuned our proposed methodology. The process of evaluation and validation of the developed methodology occurs in the impact stage.

3.6 **Conclusion**

In this chapter, we presented a formal definition of the problem that we intend to address in this thesis. The identified problem was subsequently decomposed into a set of seven key cohesive research issues, which need to be solved in order to address the problem in which is the motivation for this thesis. Each of the seven identified research issues was explained in depth in relation to the existing literature and were subsequently defined formally. Furthermore, we outlined the different approaches to research and pointed out that we intend to implement a science and engineering research methodology in conjunction with the Design Science Research approach.

In the next chapter, we present an overview of the solution to the problem being addressed in this thesis. Additionally, we present an overview of the solutions for each of the seven research issues that encompass the problem being addressed in this thesis. The detailed framework of the trust maintaining methodology is then described in Chapters 5-8.

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Chapter 4 - **Solution Overview**

4.1 **Introduction**

As explained in Chapter 2, several research works have presented factors/variables/mechanisms that may be used to maintain trust. However, as is evident from the discussion in Chapters 2 and 3, no literature provides a complete methodology for maintaining trust in virtual environments. In Chapter 3, we identified seven research issues that need to be addressed in order to solve this pivotal problem.

In this chapter, we present an overview of the solutions to each of the seven research issues. We propose definitions for trust evolution and its three phases of evolution: building, maintaining and declining in the context of business in virtual environments in Section 4.2.1, Section 4.2.2 and Section 4.2.3 respectively. In Section 4.3, we present an overview of the solution for trust maintenance and we clarify the basic assumptions underlying our TMM. Subsequently, the solution for each of the research issues identified in the last chapter is presented from Sections 4.4 – Section 4.9. Section 4.10 concludes the chapter.

4.2 **Overview of the Solution for Definition of Trust and Relationship Evolution**

As was discussed in Chapter 3, the existing literature does not propose a generic definition of trust evolution in a (long-term) relationship. Additionally, no literature provides the specific characteristics of the various phases during trust evolution process. However, if we correlate the trust evolution with the relationship evolution, we may find that different levels of trust exist at different stages of the relationship. In this section, we identify and present three phases of trust evolution which are: trust building, trust maintenance and trust decline. Subsequently, we also discuss the three phases of relationship evolution which are: transaction/exchange/ ad hoc relationship, partnership/collaboration/cooperation relationship, and separation/termination/dissolution. The research outcome discussed in this section has been documented in a research article (Fachrunnisa and Hussain 2011). Figure 4.1 illustrates the pattern of the trust evolution.

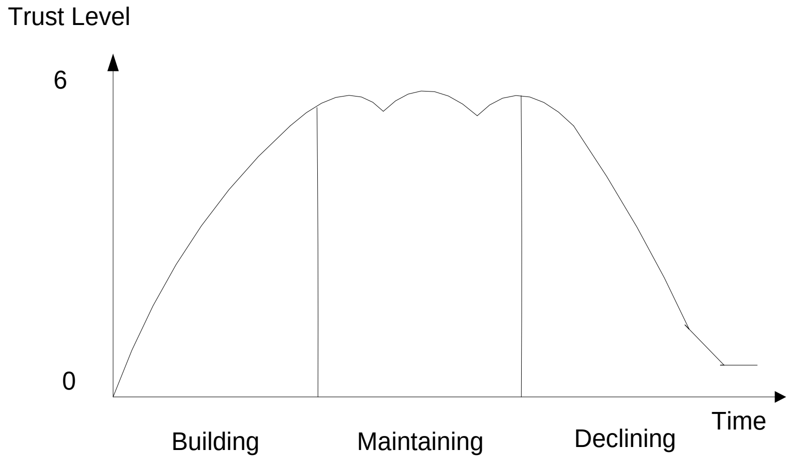

Figure 4.1: Trust evolution pattern

In this research, we use a trust scale (0 to 6) that was proposed by (Hussain, Chang et al. 2004). Each numerical value denotes a level of trust. Negative trust is denoted by ‘1’ and ‘2’, while ‘3’ and ‘4’ denote neutral trust, and ‘5’ to ‘6’ denote positive trust. The value of ‘0’ is assigned to newcomers or unknown entities; thus, we term it ‘unknown trust’. We defined positive trust, negative trust and neutral trust respectively in Chapter 3.

Furthermore, we present the definition of each phase and describe the characteristics of a relationship at each phase of trust evolution, which are summarised in Table 4.1. In this discussion, we introduce a third party agent into a relationship. This third party agent is a neutral party that will help both the interacting parties to establish a successful relationship.

No.	Criterion	Trust Building	Trust Maintenance	Trust Decline
1.	Phase of Relationship	• Exchange/transaction only • High object related	• Partnering/collaboration / cooperation • High object and process related	• Termination / Separation
2.	Trust Level Condition	Low / negative Pre-condition ($Trust_{initial}$) = 0 $Trust_{final}$ = positive levels	High / positive Pre-condition ($Trust_{initial}$) = positive levels $Trust_{final}$ = positive levels	Low / negative Pre-condition ($Trust_{initial}$) = positive levels $Trust_{final}$ = negative levels
3.	Value of Relationship	Discover / Explore	Established value	Disappear / Nil
4.	Decision to manage trust level	Unilateral or bilateral	Bilateral	Unilateral and or bilateral
5.	Involvement of third party agent in	Nil	High	Nil or High

	relationship			
6.	The Nature of Business Activities	Unplanned	Planned	Planned or Unplanned
7.	Relationship Experience	Low or inexperience $n < N$ *)	High or mature $n \geq N$ *)	Low or High $n < N$ or $n \geq N$ *)
8.	Key Strategic Implications	• Creating Interest • Analyzing Behavior • Collecting Trustworthiness Information • Increasing Trust Level	• Sharing Interest • Bounded Rationality • Confirm Trustworthiness Information • High adaptation in Problem Solving • Sustaining Trust Level	• Common Goals may not exist • Decreasing trust level

*) n is the number of current interaction, N is the perceived number of being confidence to further engages in such relationship.

Table 4.1: Characteristics of trust evolution phases

Based on the evaluation presented in Table 4.1 above, viewing the whole span of the relationship from the trust perspective, during the trust building stage, both parties collect trustworthiness information about each other. During this phase, trust may be established between the parties. Once trust has been established, the relationship between the two parties becomes formalized. In other words, trust is a pre-requisite for the formation of a relationship. As the relationship progresses, with the subsequent conduct of interactions between both the interacting partners, it may reach a stage where both parties can see value in continuing the trust-based relationship.

Typically, at this stage, both the interacting parties have interacted n times ($n \geq N$), where 'N' denotes the threshold corresponding to the number of interactions required by the trusting agent in order to determine whether the relationship with the trusted agent should be sustained, and 'n' denotes the actual number of interactions that have occurred between trusting agent and trusted agent. It is important to note that 'N' is a subjective variable determined by the trusting agent and may vary depending on the trusting agent, trusted agent, and context in question. This phase can be regarded as the 'trust maintenance phase'. In other words, a stable partnership is another outcome once trust has been built. In a partnership relationship, both parties acknowledge that a value or strategic advantage can be derived from their relationship. As we assume that trust has already been established, trust maintenance is a key issue in this phase. Both parties perceive that several current strategic advantages that they have gained as a result of numerous previous interactions need to be preserved. In order to retain these advantages, they make an arrangement to maintain trust that reflects their confidence in each other. If, however, both parties do not take the necessary steps to maintain trust, the relationship may terminate (or decline prematurely).

In order to establish a valuable relationship (from business perspective), interacting agents may need to follow the different phases of the relationship and their correlation with trust evolution at every phase. It is a dynamic process that requires both parties to follow this evolutionary pattern. However, it always starts with the initial phase of building the relationship. The next phase of the relationship evolution depends on the effort that each party makes when dealing with the other. The relationship may move to the second stage or directly to the third phase. In the next sections, we present the trust and relationship condition at each phase of trust evolution.

4.2.1 **The Trust Building Phase**

In this phase, the interacting parties are entering into a new relationship. They identify their needs and willingness to enter into or initiate an arrangement during this stage. As this is an initial relationship, the trust level may be at the base level. With the passage of time and with further subsequent interaction, each other's willingness and ability to interact productively is communicated, clarified and verified. Hence, during this phase, the perceived trustworthiness becomes either positively or negatively reinforced. The trust level may increase or decrease depending upon the way that an agent tries to build the level of trust in this relationship.

Moreover, in the trust building phase, the decision to build trust may be unilateral or from one party only. For example, a service provider may try to build trust in the service requester, (e.g., by creating interest in product/service packages, deliver a diversity of product/service package options etc.). However, the service requester may not necessarily be aware that the trusting agent is trying to initiate a relationship. Conversely, the service requester may try to build trust in the service provider by demonstrating good paying performance and making a repeat purchase without the service provider being aware of this. Hence, both parties are trying to discover value in their relationship. Their exchange is motivated by object-related or transactional purposes only and with unplanned behaviour.

Therefore, one may say that the purpose of this level of the relationship is exchange or transaction only. Exchange means giving and receiving something of value without any deep meaning being attached to this value. Therefore, any uncertainties about the future of this relationship are greater in this phase. If both parties successfully discover some value in maintaining the relationship, then the relationship and the trust level enters the second phase. It can be characterized by the establishment of a mutual positive trust level and a certain number of successful interactions being experienced.

Hence, we define *building trust* as "the phase which spans the period from the stage (point in time) corresponding to the initiation of the relationship at the stage (point in time) at which positive level of trust has been established". The focus of both parties (trusting agent and trusted agent) in this phase is to construct the trust level and relationship value.

4.2.2 **The Trust Maintaining Phase**

Relationship experience and value discovery in the previous phase (trust building phase) create a certain degree of confidence for both parties to advance to the next level of their relationship. In this phase, both parties recognize the importance of establishing and preserving some of the strategic advantages of their relationship. This established relationship value needs to be preserved as both parties will gain additional advantages by continuing their business relationship. Further, the trust level has been established at a positive level and needs to be maintained; it may even increase to a higher level. At this stage, both of the interacting entities have shared value.

As for the relationship evolution, this moves forward from an exchange relationship to a partnership relationship. In a partnership relationship, both parties consider successful cooperation, rather than exchange only, as a means of preserving value. The partners are able and willing to cooperate with each other on the basis of mutual trust. Therefore, trust needs to be maintained in this phase in order to sustain a long-term relationship. However, the decision to sustain or maintain trust should come from both parties. If one party does not agree to maintain this relationship, the trust maintenance effort is pointless. For example, in a stable relationship between buyer and seller, the seller continues to invest heavily in the relationship, while the buyer may be seeking a replacement vendor. Without initial planning or explanation given in advance to the seller, the seller may face considerable losses. Therefore, in contrast to building trust, a bilateral decision to maintain trust in a relationship is important.

Further, with trust maintenance efforts, both parties try to maintain the stability of the partnership. If an unplanned event occurs, both parties will negotiate solutions without undermining the stability of the relationship. In order to ensure the stability of a partnership, a third party agent is involved in the relationship. This third party takes the role of an independent and unbiased agent to monitor the trust relationship between two interacting agents.

Hence, we define *trust maintenance* as "the phase which spans the period from the stage (point in time) at which positive trust has been established to the stage (point in time) at which trustworthiness values fall to a level corresponding to negative trust". The common goal of both parties (the trusting agent and the trusted agent) is therefore to sustain an adequate level of trust in their relationship.

4.2.3 **The Trust Declining Phase**

The trust declining phase may occur as a result of dissatisfaction on the part of either one or both parties, resulting in the termination of their relationship. For example, if a customer's demand increases sharply and cannot be met by the seller, the relationship may be threatened. From the trust perspective, the level of trust may decline, going from a positive level to a negative level, or may move from trust to distrust. In this phase, neither party perceives any value in persisting with the relationship. Further, the decision to terminate such a relationship could come from either one or both parties. It could be either unplanned or under negotiation with the help of a third party agent trying to obtain a win-win solution for both parties. In this phase, common goals may no longer exist, in contrast to the trust building phase.

Hence, we define *declining trust* as "the phase starting from the stage (point in time) corresponding to when negative trust has been established to the stage (point in time) at which the trust relationship does not exist".

However, the vast majority of existing literature on trust focuses on 'building' or 'developing' trust. Very few works explore the notion of trust maintenance (Fachrunnisa, Hussain et al. 2009). In this chapter, we clearly differentiate the various phases and review the characteristics of each. Additionally, in this research we focus on the maintenance phase as the aspects of this phase have not been studied in detail. In the next section, we present an overview of the methodology for maintaining trust, which to date and to the best of our knowledge, is the only one of its kind.

4.3 Overview of the Solution for TMM

As was pointed out in the previous chapters, the existing research does not propose a complete methodology for trust maintenance in virtual environments. In this section, we provide a detailed overview of the proposed methodology for maintaining trust in order to address the issues discussed in the previous chapter. The focus of this methodology is not on building trust between the new interacting parties, but on the ways by which interacting entities can preserve the existing level of trust in their relationships or exceed their minimum threshold of trust in order to successfully carry out an interaction in virtual environments.

Before we introduce the details of the methodology, the basic assumptions underlying the methodology need to be stated as follows:

a. Both parties (trusting agent and trusted agent) have previously been involved in a certain number of relationships involving the same criteria or relationship context. The trust level in this context has reached a positive level of 5 or 6.
b. Both parties need to be sincere in their efforts to maintain trust. In other words, both the interacting parties need to be honest in their intention to maintain trust. This methodology provides a systematic framework by which two interacting parties can maintain the existing level of trust.
c. In order for trust to be maintained, we propose the use of a third party agent. The role of the third party agent is ‘active corrective’. The third party agent uses both mutually agreed to behaviour and actual behaviour on a real-time basis to identify when performance discrepancies occur and provide real-time feedback to the non-complying party. This third party agent could be a mutual friend or an agent from a professional service.

The conceptual framework of the methodology for maintaining trust is depicted in Figure 4.2 below.

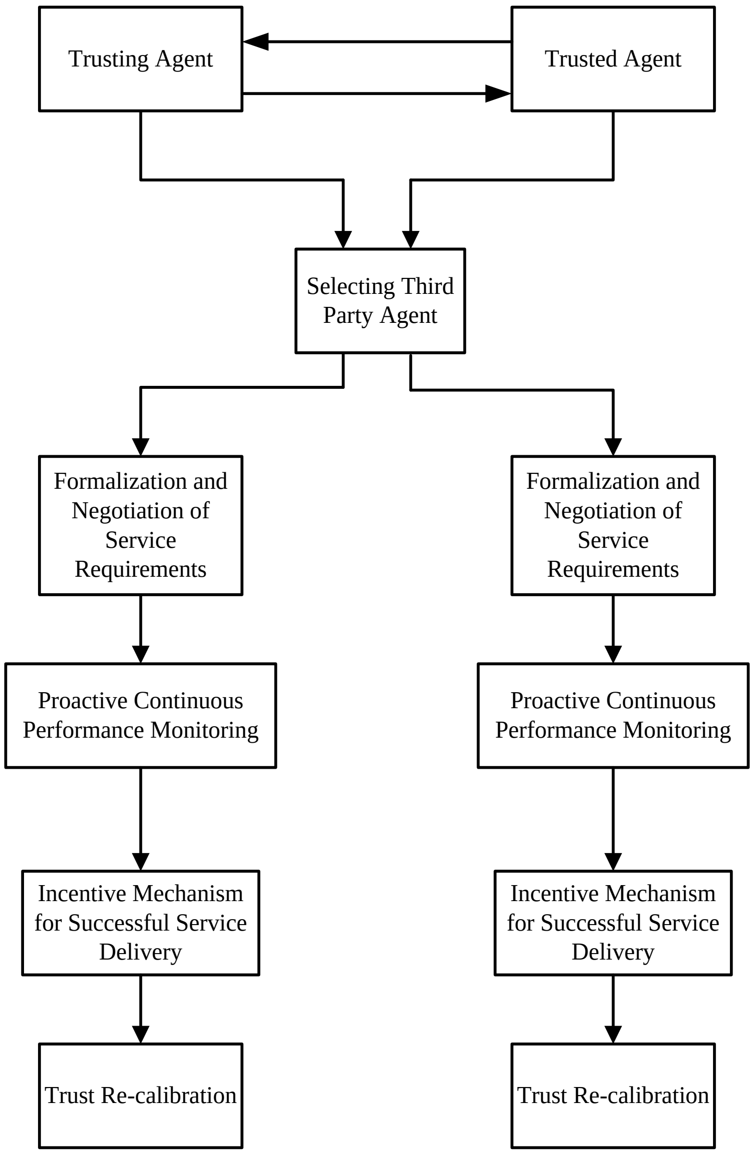

Figure 4.2: Conceptual framework of the proposed methodology for maintaining trust in virtual environments

The whole workflow of the TMM is as follows:

1. First of all, before both parties start to interact for the purpose of maintaining the trust level, they select a third party agent that will be involved for the entire duration of the relationship. This is a pre-interaction activity.
2. The second step is formalization and negotiation of Service Requirements. In the formalization of service requirements, both parties start to formalize their service requirements. These service requirements are an input for the next sub-step, negotiation of service requirements. After both parties have determined their service requirements, they iteratively negotiate those requirements to reach a Service Level Agreement (SLA). This SLA is used as the basis for measuring the trust performance at the end of time space relationship.

3. Once both parties have an SLA for mutually agreed performance, they conduct their service requirements as stated in the SLA. At the same time, they are monitoring and evaluating the performance progress of service deliverability. The third party agent's role here is to monitor the interaction performance and help both parties to resolve any conflict or performance discrepancies that may occur.
4. Incentive mechanisms, in conjunction with proactive continuous monitoring are employed to ensure the success of service deliverability.
5. Finally, the trust level is re-calibrated at the end of the relationship.

As discussed in the previous chapter and the above section, our methodology is comprised of five frameworks which are: third party agent selection, formalization and negotiation of service requirements, proactive continuous performance monitoring, incentive mechanisms, and trust re-calibration. These are research issues 2 – 6 as discussed in Chapter 3. In Sections 4.4 – 4.9, we present an overview of the solution for these research issues and in Section 4.10 we present an overview of the solution for research issue 7 which is validation of the methodology.

4.4 Solution Overview of Framework for Third Party Agent Selection

In this section, we present an overview of the framework for third party agent selection. As mentioned previously, the selection of a third party agent is the first step in our TMM. In this step, both parties (trusting agent and trusted agent) choose and select a third party agent. Before the parties start their relationship, their first task is to discuss and choose this third party agent. Both parties will choose an agent that they agree will be involved in their relationship for trust maintenance purposes. This third party agent is independent and provides its service either gratis or for a fee. The intermediary role of third party agent involves performance monitoring, conflict resolution and ensuring the interacting parties' satisfaction during the trust maintenance phase.

There are two options when choosing this third party agent. Firstly, this third party agent may be selected from mutual trusted friends. This option is chosen if the volume of business transactions is not too high. The service provided by this friend is gratis. Secondly, the third party agent may be a paid professional agent who is hired to provide a service as an arbitrator for trust maintenance purposes. The mechanism to find a mutual friend or professional agent is as follows:

4.4.1 Mutual Trusted Friend as Third Party Agent

One simple way to find this third party agent in virtual environments is by benefiting from a mutual trusted friend. If both parties have a mutual friend in whom they both have a sufficient level of trust as their arbitrator, then the trusting agent and trusted agent will arrive at some agreement about this third party agent.

However, this third party should be an agent that also is mutually trusted by the interacting parties. Therefore, both trusting parties will agree to and select an agent to monitor their relationship, especially in activities related to maintaining trust. This step comprises two options: (a) find a mutual friend from a list of friends; or (b) find a mutual friend from a list of friends of a friend (FoAF).

a. List of Friends (Basic Approach)

   In our proposed framework, firstly both trusting parties (trusting agent and trusted agent) create a list of their friends. Both parties should consider the rank of trust level in their friend. The friend with the highest level of trust would be placed first on the list and so on. This is in order to create a list of trusted friends. Then both parties try to establish a list of mutual friends. If they find one mutual trusted friend, they solicit this friend to agree to arbitrate in their relationship in order to maintain trust. If this person is able and ready to be the third party agent for the duration of the relationship, then this person becomes a third party agent.

   However, if both parties have more than one mutual friend, both parties would establish some criteria for selecting one of their mutual friends to become a third party agent. The criteria to select this third party agent is defined and agreed by both parties.

   This is the first stage of the process of finding a mutual friend to act as a third party agent. If in this first stage, both parties cannot find a mutual trusted friend, they proceed to the next stage of the process by creating a list of friends of a friend (FoAF).

b. Friends of a Friend List (FoAF-based Approach)

   There is a possibility that both parties cannot not find a mutual trusted friend in the first stage (from their direct mutual list of friends). If this occurs, they go to the second stage in which both parties ask their first ranked trusted friend to make a list of friends. Therefore, now both parties have a first friends of friend list. Then, the process to obtain a mutual trusted friend is repeated as in the first stage. If, however, there is no mutual friend from this first list friend of friend, they should ask the following rank of trusted friend to create list of friends. The mechanism repeats until end of list of friends.

There is also a chance that both parties could not find a mutual trusted friend in the FoAF-based approach. If this is the case, both parties ask the friends of the first friend to make a list of friends. Therefore, both parties have a second friends of friend list. The process of selecting a mutual trusted friend is the same as for the first and second stages, until both parties obtain a mutual trusted friend from the friends of friend list to be an arbitrator. However, the task of compiling a friends of friend list is limited to the sixth friends of friend list. This is based on 'six degrees of separation'. Six degrees of separation (also referred to as the "Human Web") is the notion that, if a person is one step away from each person they know and two steps away from each person who is known by one of the people they know, then everyone is, at most, six steps away from any other person on Earth. In the next chapter, we present the detailed mechanism of this framework.

4.4.2 **Professional Service as Third Party Agent**

The second option is to select a third party agent by hiring a professional service. This option can be utilized if both parties cannot find a mutual friend by using the Basic approach and the FoAF-based approach. Moreover, if both parties have a high volume of business transactions, the task that needs to be finished by both parties is highly important, and the initial level of trust is also at a positive high, then the trusting parties may need a professional third party agent. A professional third party agent is one who has specific knowledge about a particular field of business, conflict management, and business law that suits both parties' business context. Furthermore, this third party agent might have experience as an arbitrator in dispute resolution.

However, as was pointed out in the previous chapter, there is little or no service company that specializes in offering a professional third party agent for the purposes of maintaining trust. Therefore a new service company is needed that specializes in offering a third party agent to ensure trust maintenance in a relationship. We term such a company 'Arbitration Service for Trust Maintenance' (ASTM). This service company may take the form of a collective business system or collective business model. A collective business model is a business organization or association typically composed of relatively large numbers of businesses, tradespersons or professionals in the same or related fields of endeavour, which pools resources, shares information or provides other benefits for their members (Teece 2010). Hence, the company that provides a third party agent for trust maintenance purposes could be a professional service company comprised of a large number of professional arbitration agents who specialize in trust maintenance in virtual business relationships.

Therefore, to build an ASTM as a 'new service company', we propose a service business model that supports its interoperability. Details of this service business model are presented in Chapter 5.

4.5 **Solution Overview of Framework for Formalization and Negotiation of Service Requirements**

Step 2 of the methodology focuses on the formalization and negotiation of service requirements by both parties. In this section, we present an overview of the framework for formalization and negotiation of service requirements. This framework comprises three steps as follows:

4.5.1 **Step 1: Formalization of Service Requirements**

In this stage, both parties formalize and express the service requirements in a formal manner. The activities comprise three steps:

a. Determination of service requirement

Determination of service requirements is the process of discovering the needs of interacting partners in this relationship.

b. Articulation of service requirements
   Service requirement articulation is the process of expressing the service requirements in terms of service criteria and their quality descriptors.
c. Prioritization of service requirements.
   Prioritization of service requirements is the process of determining the level of importance of each service criterion.

Therefore, the outcome of this reciprocal action is a clear statement about the service requirements of both parties. It contains service criteria, service quality descriptors and level of importance. Once both parties have each other's service requirements, they will use this statement to negotiate in step 2. Both trusting agent and trusted agent are expressing the service that they want and expect from the interaction. Based on these three activities (determining service requirement, articulating service requirements and prioritizing service requirements), both parties will have an initial proposal of service requirements which contains service criteria, quality descriptors and the level of importance of each service criterion. The number of service criteria might be different for each party ('n' from trusting agent and 'm' from trusted agent). From their initial proposal, both parties can classify or identify any of their conflicting service requirements which need to be negotiated in the next step, the negotiation phase.

4.5.2 **Step 2: Negotiation of Service Requirements**

The next step of this framework focuses on negotiation of service requirements. Once both parties have established a set of service requirements, they make an iterative negotiation about those requirements. Both parties either agree or disagree to the service criteria and their corresponding quality descriptors. Repeated negotiation is needed until an agreement on a specific service from both parties is achieved. The outcome of this negotiation is a service commitment that must be achieved. Once both parties agree on specific service requirements, they make an iterative negotiation again to reach a mutually agreed behaviour that contains finite services in time slots, the number of checkpoints per time slot, how they will evaluate each other's performance, how they will give a report to the third party etc. All the results of this negotiation are documented in a contract.

Hence, the outcome of this step is an agreement contract and a mutually agreed behaviour that will guide each party's behaviour to achieve a common goal. The third party agent comes into action to help both trusting parties define the number of checkpoints in each time slot. Additionally, during this step, both parties negotiate iteratively on each conflicting service requirement. Once they reach an agreement about all the service requirements to be carried out during the interaction, they will have an SLA which is an agreement about a set of service requirements. In Chapter 6, we present the details of the mechanism for formalizing and negotiating service requirements.

4.5.3 Step 3: SLA Construction

Once both parties reach an agreement about all the service requirements to be carried out during the interaction, the third party agent will translate the formalization and negotiation result into an SLA. This is the phase of SLA construction. The SLA is an agreement about a set of service requirements. Additionally, during SLA construction, the third party agent comes into action to help both trusting parties define the number of checkpoints in each time slot. In Chapter 6, we present the details of the mechanism for formalizing and negotiating service requirements.

4.6 Solution Overview of Framework for Proactive Continuous Performance Monitoring

The third phase of our methodology is performance monitoring. In this section, we present an overview of proactive continuous performance monitoring. Once both trusting agent and trusted agent have a mutual agreement or SLA, they start to deliver their agreed service. In order to ensure the service deliverability and to maintain the level of trust between two parties, we develop an intelligence mechanism to automatically detect and intelligently respond to the differences between mutually agreed behaviour (MAB) and actual behaviour. This intelligence mechanism is designed to detect events and automatically respond by adjusting performance thresholds and maintaining a service performance history. It will help both interacting parties and the third party agent to ensure continuity of performance, make accurate decisions based on the most up-to-date information, and meet compliance and control regulations. Therefore, changes in behaviour and events are promptly detected, well documented and reacted to appropriately. It allows trusting parties to remain alert to behaviour changes and respond quickly if there occur any unmet performance events that will impact significantly on the relationship.

This mechanism also ensures that both parties preserve the deliverability of service and proactively respond if some service failure occurs. Without such continuity, performance monitoring solutions are of little or no value, given the dynamic nature of trust. Moreover, this platform will also provide a system of configuration management database (CMDB) to the third party agent. It maintains accurate and up-to-date information, together with any behaviour changes of either party. By automatically applying these behaviour updates, the third party can continue to rely on its CMDB as a single, accurate 'source of truth', guaranteeing service levels, avoiding risky changes, and reducing incident response times, especially in the face of execution of task service.

Another key purpose of performance monitoring is to identify service deliverability and/or its problems as early as possible so that corrective actions may be taken to prevent/minimize performance discrepancies that will result in a decrease of trust. Moreover, monitoring helps provide qualitative observations and data on how well services are being delivered based on the mutually agreed behaviour or an SLA.

The framework for proactive continuous performance monitoring comprises several steps as follows:

a. In order to ensure the deliverability of service, the third party agent creates a time window which consists of time space, time slots, and number of checkpoints. Time space is defined as ‘the total duration of time over which the behaviour of the trusted agent will be analysed and the trustworthiness measure and prediction will be carried out’ (Chang, Dillon et al. 2006).
b. At each time space of interactions, the task service is decomposed into several time slot(s). Time slot(s) is defined as a finite number of non-overlapping, mutually exclusive and equally spaced sectors of time. It is the number of intermediate sections of task that should be delivered at those intermediate times for the duration of the time space (Chang, Dillon et al. 2006).
c. Each time slot is then divided into several checkpoints. We define *checkpoints* as the number of points used to check the performance in each time slot (s) (Fachrunnisa and Hussain 2011). A checkpoint is designed to ensure the continuity of service delivery. At each checkpoint, the agreed intermediate performance of service delivery is expressed. This checkpoint system is intended to facilitate proactive continuous performance monitoring during the transaction. With the designed time slot, the trusting agent can observe or track changes in the performance of the trusted agent over a time space. The agreed performance for each time space is divided into several checkpoints which are the points within a time space where the trusting agent evaluates the performance of the trusted agent in delivering the service.
d. The number of checkpoints or intermediate performances is determined by the third party agent using a pre-defined measure. In this step, the third party agent acts as an active-corrective agent by monitoring task performance and helping to resolve any conflict during the relationship in order to maintain trust. The third party agent has the responsibility to monitor the performance and administer the SLA between service requester and service provider. Performance monitoring always takes place within the set time space and occurs on an ongoing basis throughout the term of the SLA. The proactive continuous monitoring and progress of the interaction between the interacting parties would produce real-time performance information. It would additionally allow ‘proactive performance monitoring’ whereby each interacting agent would be able to proactively determine when its Mutual Agreed Behaviour (MAB) is not in line with the Actual Behaviour, and take appropriate remedial action(s).

In Chapter 7, we present the details of the mechanism of this proactive continuous monitoring. Several case studies involving various scenarios are also presented for elucidation purposes.

4.7 Solution Overview of Framework for Incentive Mechanisms for Successful Service Delivery

In the previous step, an overview of the mechanism for proactive continuous performance monitoring as a kind of control was presented. In order to support the continuity of service delivery, an incentive mechanism to encourage both parties to comply as closely as possible with the terms of the mutual agreement is needed. In this section, we present an overview of the framework for an incentive mechanism for service deliverability.

Unlike the existing works in the literature regarding incentives for task completion, in this research, we combine a mechanism of proactive continuous monitoring and incentive mechanism specifically to support successful service delivery. The service delivery is monitored at intermediate checkpoints and incentives are given at these checkpoints rather than at the end of the interaction. The framework is not intended to provide an incentive after task completion; instead, incentive is given during the course of the transaction to minimize any discrepancy between actual performances and mutually agreed to performance. We propose three different mechanisms for providing incentive to facilitate successful service deliverability as follows:

a. Performance-driven-based Incentive
   Incentive is given if the performance at the current checkpoint is greater than or equal to that at the previous checkpoints and the parties show an improved performance level in response to receiving an incentive.
b. Error-tolerance-based Incentive
   Incentive is given if the performance at any checkpoint is greater than or equal to a specific threshold agreed to by both parties.
c. Occurrence-based Incentive
   Incentive is given if the performance in current checkpoint is greater than or equal to that at the previous checkpoints. The increasing performance occurs by means of chance.

Details of the mechanism for each approach and various benchmarks to measure the effectiveness of each approach are presented in Chapter 7.

4.8 Solution Overview of Framework for Trust Re-calibration

In order to have a complete methodology for trust maintenance, we need to have a framework for trust re-calibration by the end of the interaction time space. This methodology facilitates a system for periodic assessment of trust level in each time slot(s) and for a one-time assessment of final trust at the end of the interaction.

Additionally, this methodology facilitates the maintenance of a trust relationship by using historical data from both their trust level records and performance records.

In this step, both parties re-calibrate the final trust. The calibration or calculation of trust after an interaction during the trust maintenance phase is determined by the correlation between actual behaviour and mutually agreed behaviour during the interaction. We employed CCCI metrics (Chang, Dillon et al. 2006) to measure this final trust. We propose three different approaches for trust re-calibration in TMM as follows (Fachrunnisa and Hussain 2011):

a. Outcome-based Approach
   The trust re-calibration for this approach is computed based on the correlation of actual outcome performance with the agreed performance in the interaction. The actual outcome performance is determined by the final outcome at the end of the interaction. In the outcome-based approach, the trusting agent does not consider how the trusted agent performs at each intermediate checkpoint. This approach considers only the final service delivered by the trusted agent to the trusting agent. In other words, this metric measures or captures whether or not the service in question has been successfully delivered at the end, without considering whether the intermediate SLA requirements were successfully met. In contrast, as mentioned above, the outcome-based approach would capture and reflect the conformance to the SLA by a given agent at the end of the interaction only.

b. Checkpoint-based Approach
   In this approach, a final trust value is computed by measuring accumulated evidence of intermediate trust during the entire time of the relationship. The evidence of trust experienced is collected / accumulated at each checkpoint. With this approach, a fine-grained view of an agent's performance over the whole interaction is aggregated to find the final trust value. The checkpoint-based approach captures and reflects the trust value of a given agent as a function of compliance between the mutually agreed behaviour and actual behaviour at all the intermediate checkpoints.

c. Weighted-based Approach
   As discussed above, we have proposed the outcome-based approach (measured by SLA compliance only at the end of interaction) and checkpoint-based approach (measured by compliance at all the checkpoints throughout the interaction) for computing the final trust value. However, for objective trust assessments, it would be optimal to determine the final trust value using a weighted approach between the outcome-based trust and checkpoint-based trust values. Such a metric would take into account the successful delivery of the service at both the end of the interaction and at the intermediate checkpoints.

   A weighted-based approach is an approach for calculating final trust as a function of real-time trust value (checkpoint-based approach) and outcome-based approach. This approach is proposed to give some weight to the different types of compliant agents. As in the TMM, there is a proactive continuous monitoring of performance. The agent who always complies at every checkpoint might be different from the agent who does not comply at every checkpoint but delivers the full service by the end of the interaction.

In Chapter 8, we present the details of the mechanism of the trust re-calibration framework. We also present several scenarios and case studies to show the utilization of the framework.

4.9 Solution Overview for Validation of Methodology

In this thesis, we make use of simulation experiments in order to validate the methodology for trust maintenance in virtual environments. In order to determine the effectiveness of our methodology, we engineered a multi-agent system using JADE Multi Agent-Based Framework. The engineered multi-agent system has an interface with which the user can specify the parameters prior to the execution. The user could specify the total number of interactions (or transactions) that need to be simulated. Additionally, the user specifies the total number of agents in the multi-agent system that need to be grouped into six classes, with each class corresponding to one particular trustworthiness value.

During the bootstrapping phase, the agents are created and each of them is assigned a given behaviour to represent their level or degree of compliance. Each compliant behaviour corresponds to one trustworthiness value. For example, the behaviour belonging to agents with trustworthiness value '1' (TV_1) would contain a behaviour that would spell out the action or the way that agents carry out a transaction.

Hussain (2006) defines the behaviour of an agent as 'the way in which it conducts itself in a given situation or circumstance'. The behaviour of an agent in turn depends directly on the trustworthiness value assigned to it by the multi-agent system. In this research, we propose that the behaviour of an agent is the degree to which an agent complies with the terms of a formal contract or mutually agreed performance. Davies et al. (Davies, Lassar et al. 2011) define compliance as 'an outcome of commitment, motivation and cognitive process that jointly drive decisions of one party to do what the other party desires'. From the perspective of performance behaviour, an agent's compliance is a reflection of the degree of conformance to a contractual agreement. Since there are six different trustworthiness values, there are six different compliance behaviours.

In the experiment simulation, we propose a correctness of agent's compliance level using four counts: Crisp Compliance Level, Fuzzy Triangular Compliance Level, Fuzzy Trapezoidal Compliance Level, and Fuzzy Hybrid Compliance Level. We have 7 (seven) broad objectives of the simulation which we divided into several sub objectives. The first three objectives (objective 1, objective 2, and objective 3) focus on performance testing of TMM under three conditions as following:

a. Performance testing of TMM assuming static behaviour of agents (objective 1)
b. Performance testing of TMM assuming dynamic behaviour of agents (objective 2)
c. Performance testing of TMM assuming that incentives are awarded (objective 3)

The subsequent four objectives (objective 4, objective 5, objective 6, and objective 7) are concerned with the validation of the finer elements of the methodology as follows:

a. Determining the accuracy of recommendations by a third party agent (objective 4)
b. Ability to identify all the non-complying agents (objective 5)
c. Ability of the methodology to maximize community social welfare (objective 6)
d. Modelling the impact of our methodology for improving community sustainability (objective 7)

The first 3 (three) broad objectives of the validation measurement are presented in Chapter 9 and the 4 (four) broad objectives are presented in Chapter 10, along with the results obtained.

4.10 **Conclusion**

In this chapter, we presented a generic formal definition of trust evolution and described the three phases of trust evolution namely, trust building, trust maintenance and trust decline. In addition, we present the characteristic feature of interaction at each phase. Furthermore, we proposed the solution overview for each of the seven cohesive research issues that we had identified in Chapter 3. Finally, we presented the solution overview to the problem that is being addressed in this thesis. In the next chapter, we propose the framework for third party agent selection, which was identified in this chapter as being the first step of our methodology to maintain trust.

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Chapter 5 - **Framework for Third Party Agent Selection**

5.1 **Introduction**

In this chapter, we present a framework for third party agent selection. The third party agent is a neutral agent that will be used to supervise the interaction between the trusting agent and the trusted agent during the course of the interaction at any point in time during the trust maintenance phase. Hence, the purpose of this interaction is to maintain the existing level of trust. The process of selecting this third party agent is the first step in our proposed methodology to maintain trust. Before both trusting agent and trusted agent start their transaction, their first activity according to our proposed methodology for trust maintenance is to discuss and choose who would be the third party agent in their transaction. Both parties will choose an agent that they agree will be involved during the course of the interaction in the trust maintenance phase.

Section 5.2 presents a framework for third party agent selection by means of taking advantage of the availability of a mutual trusted friend. A case study is presented in this section to illustrate the operability of the framework. Section 5.3 presents a framework whereby the trusting agent and trusted agent could hire a professional third party agent to supervise their interaction. We also present a service business model proposal for a professional third party agent service company. Details of the Arbitration Service for Trust Maintenance (ASTM) company are presented in this section. Section 5.4 concludes the chapter.

5.2 Mutual Trusted Friend as Third Party Agent

As was discussed in the previous chapter, there are two options for choosing and selecting the third party agent. Both parties have to agree on the choice of the selected third party agent in their interaction for trust maintenance purposes. The first option is to select a third party agent from mutual trusted friends. This option is viable if the volume of business transactions is not too high. Moreover, the service provided by this friend could be gratis. The second option is that the third party agent might be a paid professional agent who could be hired from a service company to act as an arbitrator in an interaction for trust maintenance purposes. In this section, we present a detailed framework for agent selection from mutual trusted friend (basic approach) and mutual friend of a friend (FoAF based approach).

As was explained in the previous chapter, one simple way to find this third party agent in virtual environments is by benefiting from a mutual trusted friend. We define a mutual trusted friend as an agent who is a friend of both trusting agent and trusted agent. If both parties have a mutual trusted friend, then the trusting agent and trusted agent will arrive at an agreement with this mutual friend to be the third party agent in their interaction. However, the chosen third party agent should also be an agent that is mutually trusted by the interacting parties. We present the details of these two mechanisms in the next sections.

5.2.1 Mutual Friend from List of Friends (Basic Approach)

The first stage in finding a mutual trusted friend is from the list of the friends of both the trusting agent and the trusted agent. This section explains how to find a mutual trusted friend from a list of friends. Firstly, both trusting agent and trusted agent create a list of their friends. They have to create a list of friends based on the rank of trust value that they have toward their friends. The friends list of both the trusting agent and the trusted agent is sorted by the trust value of the trusting agent and the trusted agent toward them. Once both parties have their own list of friends, they try to establish a list of mutual friends. If they find one mutual trusted friend, they ask this friend to agree to be a third party agent in their interaction in the trust maintenance phase. If this mutual friend is able and ready to be an arbitrator for the duration of the relationship, then this mutual friend becomes a third party agent. However, if both parties have more than one mutual friend in the list of mutual friends, they would make use of pre-defined criteria when selecting one of their mutual trusted friends to become their third party agent. Hence, the steps involved in this first stage are as follows:

a. Step 1: Trusting agent and trusted agent draw up a list of their friends
b. Step 2: The order of friends on the list is based on the level of trust both parties have in a friend. Friend with highest trust value is placed first on the list and so on.
c. Step 3: Identify mutual friends from both friends' lists

d. Step 4: If there is one mutual friend, this mutual friend would be selected as a third party agent
e. Step 5: If there is more than one mutual friend, several criteria should be used to select the one who will be chosen as a third party agent. The criteria that can be considered by both interacting parties but not limited to the following:

   i. The level of trust in their mutual friend(s)
   Both parties agree on a certain threshold of trust level in a friend who will be the third party agent in their transaction. If the level of trust in a particular mutual friend is greater than the specified threshold, this friend would be selected as the third party agent.

   ii. The reputation of the friend
   The reputation of being fair and unbiased is another criterion that needs to be considered. It may be helpful to choose a neutral agent or third party agent who is familiar with the service criteria in the interaction so that any performance gap that might appear during the interaction can be resolved in a real-time manner.

   In the algorithmic design, we use the function C_1 (mutual friend 1) to C_n (mutual friend n^{th}) to refer to user defined function for selecting one mutual friend if the search returns multiple potential mutual friend. In this case C_1 could refer to the level of trust and C_2 could refer to the reputation value.

f. Step 6: The friend with the highest trust and/or reputation value would be contacted and selected as the third party agent. It is important to note here that the critical point is that both parties agreed to select this particular friend. On the other hand, the selected friend should agree to and be able to act as the third party agent for both trusting agent and trusted agent in the transaction for trust maintenance purposes.

The mathematical expression and algorithm framework for this approach is depicted in Table 5.1.

Input: T = trusting agent
D = trusted agent
F_T = Set of friends of T
F_D = Set of friends of D
Mutual Friend = set of mutual friends = null
Selected mutual friend = null
Cn (mutual friend) = user defined criteria for selecting the mutual friend from amongst the mutual friend list

Begin Procedure
Sort F_T in descending order of trust value of T
Sort F_D in descending order of trust value of D
Mutual Friend = $F_T \cap F_D$
if (size (mutual friend) = 1), then
Selected mutual friend = mutual friend [1]

else
Selected mutual friend =
C_1 (mutual friend) and
C_2 (mutual friend) and
…….
C_n (mutual friend)
End if
 	
End Procedure

Table 5.1: Algorithm framework for third party agent selection (basic approach)

This is the first stage of the process of finding a mutual friend to act as a third party agent. If in this first stage, the parties cannot find a mutual trusted friend, they proceed to the next stage of the process by creating a list of friends of a friend. The next section presents a framework for finding mutual friend from friends of a friend list.

5.2.2 Mutual Friend from List of Friends of a Friend (FoAF-based Approach)

There is a possibility that both parties may not be able to find a mutual trusted friend in the first stage (from their direct mutual list of friends) as explained above. If this is the case, they go to the second stage in which both parties ask their trusted friend to make a list of friends. Therefore, now both parties have a first friend of friends list.

The steps involved in this stage are as follows:

a. Step 1: Both parties ask their respective trusted friend with the highest degree/level of trust. Therefore, both parties have a first list of friends of a friend (FoAF list). From this list, the process of finding a mutual friend is the same as that for the basic approach.
b. Step 2: If no mutual friend can be found from the list of FoAF, ask trusted friend with the next highest degree/level of trust to make a list of friends and apply the mechanism as above (steps 5 and 6 from basic approach) as explained in Section 5.2.1.
c. Step 3: Repeat this mechanism until the end of the friends list has been reached.
d. Step 4: If there is no mutual friend from the first list of FoAF, both parties ask their first friends of friend list to make a list of their friends. Therefore, now both parties have a second list of FoAF and the process specified above in steps 1, 2, and 3 are recursively identified until a mutual friend is found.
e. Step 6: The creation of a friends of friend list is limited to six separations or sixth FoAF list.

The mathematical expression and algorithm framework for this approach is depicted in Table 5.2 below:

```
Input:  T = trusting agent
        D = trusted agent
        Fx is a function that returns friends of agent x
        F_T = Set of friends of T
        F_D = Set of friends of D
        Mutual Friend = set of mutual friends = null
        Selected mutual friend = null
        Cn (mutual friend) = user defined criteria for selecting the mutual friend from amongst the mutual
        friend list
        M = degree of separation = 1
       n = 1
       n is a variable to index friends of agent x

Begin Procedure
        Sort F_T and F_D in descending order of trust value of T and D respectively
        Mutual Friend = F_T ∩ F_D
        if size (mutual friend = = 0)
        then
        Repeat (while (size(mutual friend = = 0)))
            Sort F_T and F_D in descending order based on trust value of T & D     respectively.
                Mutual Friend = F_T ∩ F_D
                Repeat (while (size(mutual friend = = 0)))
                        n = 1
                        Repeat ( while(m ≤ 6))
                           Compute F_FT [n] and F_FD [n]
                           Sort F_FT [n] and F_FD [n] in descending order of trust value  of F_T and F_D
                           Mutual Friend = F_FT [n] ∩ F_FD [n]
                        End Repeat
                        if (size mutual friend = = null), then
                        F_T [n] = F_T [n + 1]
                        F_D [n] = F_D [n + 1]
                        End if
                End Repeat
        End Repeat

        if size ((mutual friend = = null))
        Mutual friends cannot be located in 6 degrees of separation use ASTM
        else
                if (size (mutual friend) = = 1)
                then selected mutual friend = mutual friend [1]
                else
                Selected mutual friends =
                        C_1 (mutual friend) and
                        …
                        Cn (mutual friend)
               End if

        End if
End Procedure
```

Table 5.2: Algorithm framework for third party agent selection (FoAF-based approach)

5.2.3 **Illustrative Example of Finding Mutual Trusted Friend from List of Friends (Basic Approach)**

In this section, we illustrate the process of finding a mutual trusted friend in a virtual environment to act as a third party agent by using basic approach.

a. First Scenario of Basic Approach

The first scenario is where both trusting agent and trusted agent find a mutual trusted friend in the first stage. Consider for example, that there is a trusting and trusted agent each with a list of their friends. From these lists, there is a mutual friend, Charlie. Both parties might request that Charlie be the third party agent in a transaction during the trust maintenance phase.

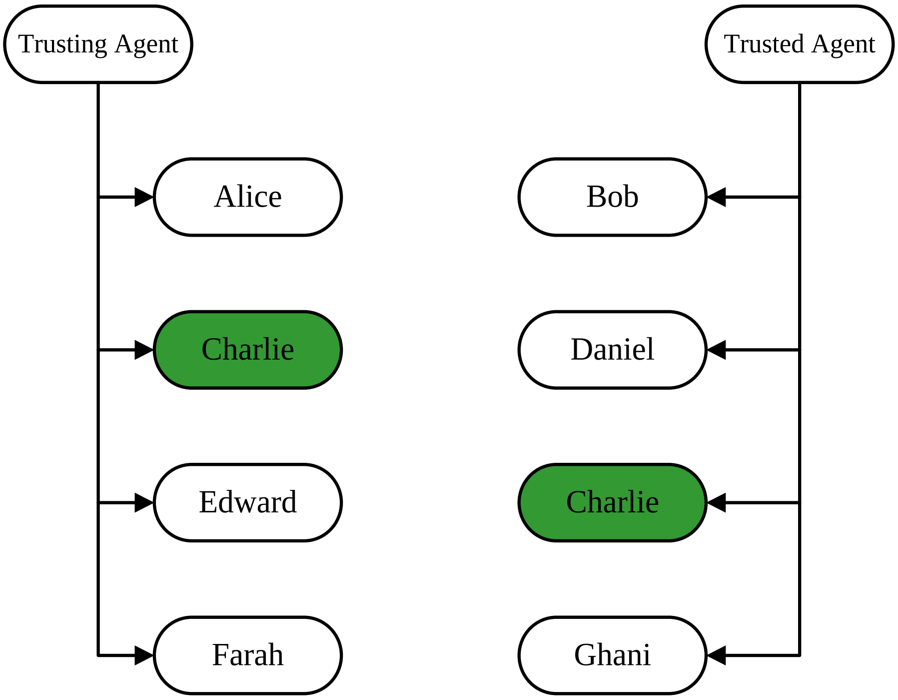

Figure 5.1: First scenario of basic approach

Figure 5.1 above illustrates that each party provides a list of trusted friends. As we can see from the list, there is one mutual friend: Charlie. Hence, Charlie qualifies as the third party agent in a transaction between trusting agent and trusted agent. The workflow of this process of identifying the mutual friend is as follows:

a. Both parties provide their list of friends
b. There is one mutual friend: Charlie
c. Charlie is selected as a proposed third party agent
d. If Charlie is willing and able to be their third party agent, then Charlie becomes the third party agent.

b. Second Scenario of Basic Approach

In the second scenario, there is more than one mutual trusted friend. For example, both Alice and Charlie are the mutual trusted friends of both trusting agent and trusted agent. Let us assume that both Alice and Charlie are able to be third party agents. In this case, both parties have to decide on who will be their third party agent - Alice or Charlie. This scenario is depicted in Figure 5.2 below.

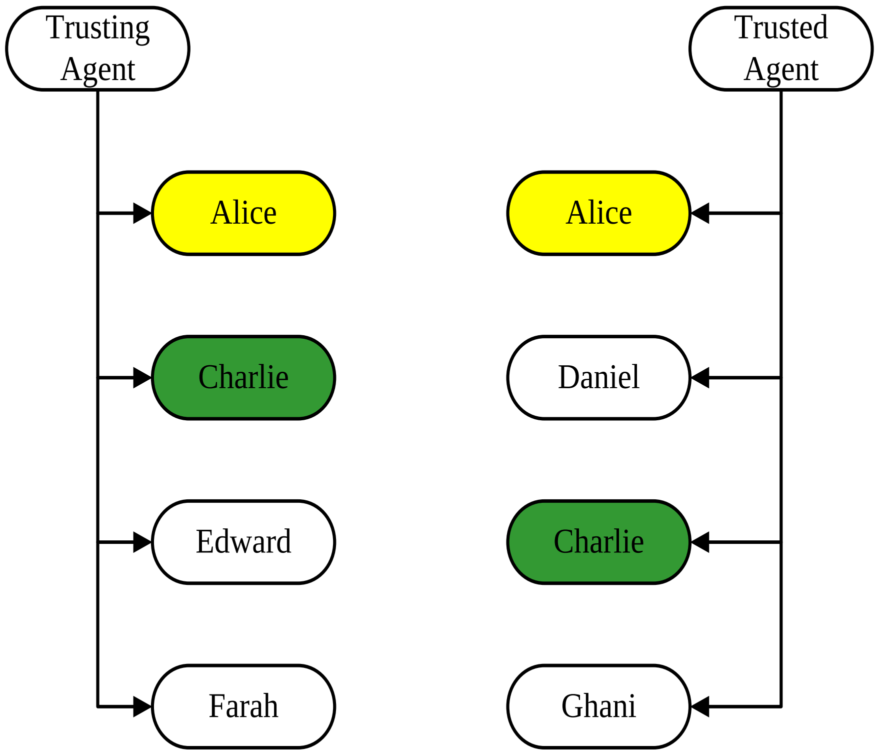

Figure 5.2: Second scenario basic approach

a. Both parties have a list of friends
b. There are two mutual friends: Alice and Charlie
c. Assign pre-defined criteria in order to select one of them: trust and reputation value
d. The friend with the highest trust and/or reputation value would be contacted and requested as the third party agent. In this case, let us assume that Alice is the first option.
e. If Alice is available and agrees, then Alice becomes the third party agent.
f. If Alice is not available, then both parties contact Charlie.

c. Third Scenario of Basic Approach

The third scenario is where the parties do not find a mutual friend in the first stage. As a result, they enter the second stage which involves finding a mutual friend from a list of friends of a friend. Let us consider the following example in Figure 5.3.

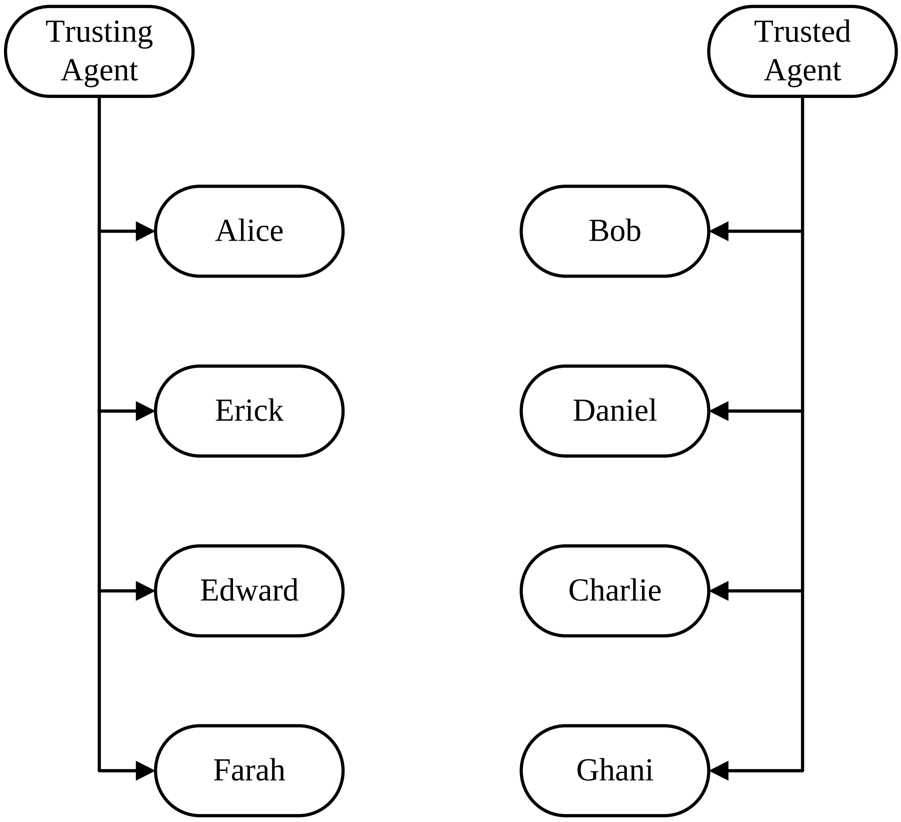

Figure 5.3: Third scenario of basic approach

a. Both parties have a list of friends
b. They do not have a mutual friend
c. They ask Alice and Bob, as the most trusted friends of both parties, to list their friends.

In this case, the framework for third party agent selection uses the FoAF-based approach. In the next section, we present a case study to illustrate the finding of a mutual friend using the FoA-based approach.

5.2.4 **Illustrative Example of Finding Mutual Trusted Friend from List of FoAF (FoAF Based Approach)**

In this section, we illustrate the process of finding a mutual trusted friend in a virtual environment to act as a third party agent by using the FoAF-based approach.

a. First Scenario of FoAF-based approach

The first scenario for the FoA-based approach is when both parties have a mutual friend from the first degree of friend of a friend. If this occurs, the mutual friend from first list of FoAF is chosen and selected as a candidate for the third party agent. If this agent agrees and is available, then s/he becomes a third party agent. Figure 5.4 below illustrates the first scenario for the FoAF-based approach.

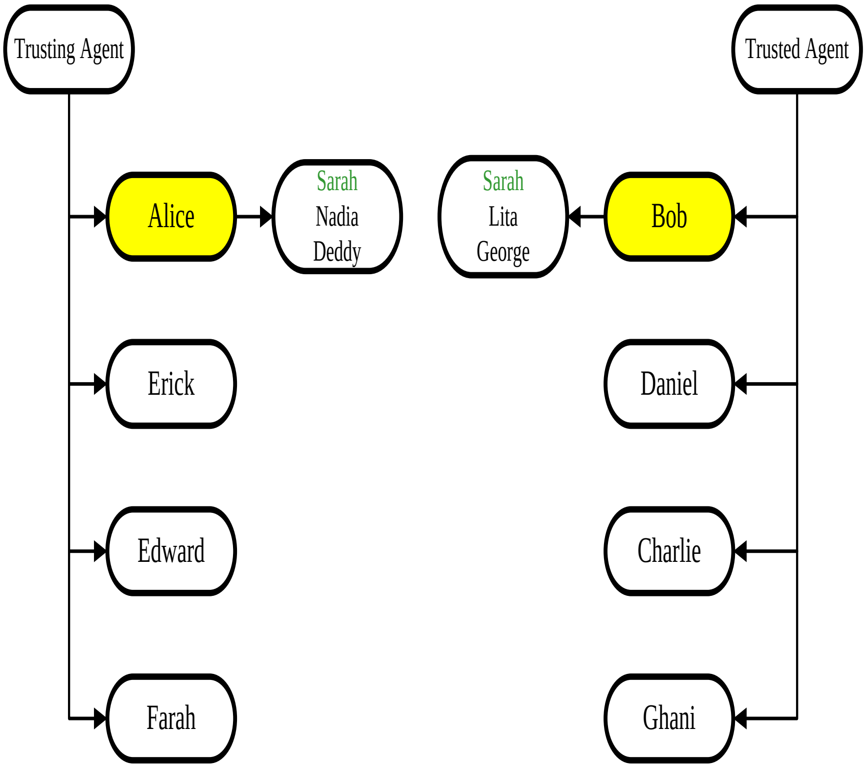

Figure 5.4: First scenario of FoAF-based approach

a. Both parties have a friends of first friend list
b. There is one mutual friend: Sarah
c. Sarah is proposed as a third party agent
d. If there is more than one mutual friend, use the procedure to find mutual friend by assigning the pre-defined criteria (the mechanism as for the second criteria)
e. If there is no mutual friend, ask the second highest trusted friends of both parties (Erick and Daniel) to list their friends and follow the same procedure as above
f. Repeat the same procedure until the end of the friends list: Farah and Ghani

b. Second Scenario of FoAF-based Approach

The second scenario of FoAF based approach is where both parties do not find a mutual friend from the first list of FoAF. If this occurs, both parties may ask friends in the first list of FoAF to create their friends and find a mutual friend from the list.

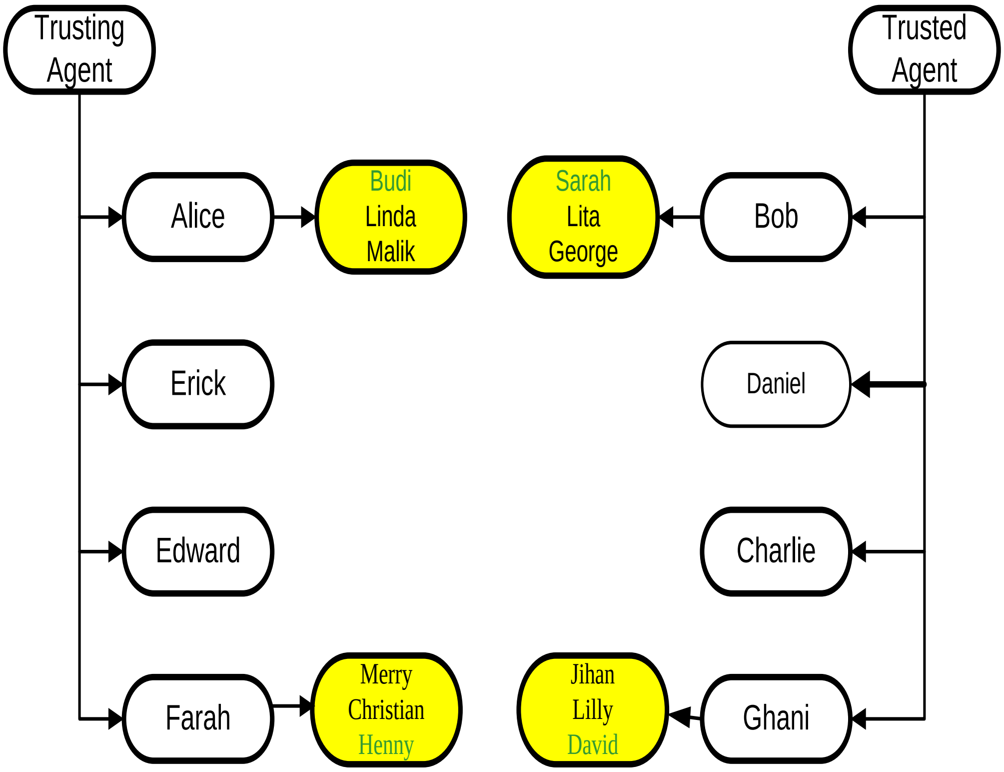

Figure 5.5: Second scenario of FoAF-based approach

a. There is no mutual friend from the list of friends of friend until the end of the friend list (Farah and Ghani)
b. Ask Budi and Sarah to make a list of their friends. Both parties now have a second list of friends of a friend. If there is still no mutual friend, ask Linda and Lita to list their friends
c. Continue this procedure until the end of the list of friends of Farah and Ghani (Henny and David)
d. Repeat the same procedure until both parties find a mutual friend from the friends of a friend list

If the search process (using algorithm for basic approach and FoAF basic approach) does not return a successful result, then a professional third party agent could be used. We explain the professional third party agent in the next section.

5.3 **Professional Third Party Agent**

The second option for finding a third party agent could be to hire a professional third party agent. This option may be chosen if the business transaction volume of both parties is high, the task that needs to be finished by both parties is of high importance, and the initial level of trust is also positive and high. This option can also be used if both trusting agent and trusted agent cannot find a mutual friend from basic approach and FoAF based approach. A professional third party agent is one that would have a great deal of knowledge about business, conflict management, and business law and would therefore be able to provide advice for both parties' business activities to achieve a successful outcome. Furthermore, this third party agent might have had prior experience as a judge or arbitrator in dispute resolution.

However, currently there is little or no service company that specializes in offering a professional third party agent for the purposes of maintaining trust. More commonly, the type of business service being offered is dispute resolution where the third party agent acts only if some dispute or conflict occurs in the business relationship. The role of this third party agent is corrective only. Both trusting parties access this service if a conflict occurs which they are unable to resolve or negotiate. Furthermore, the type of relationship is not for the purpose of trust maintenance. Therefore, we need a new service company that specializes in offering a third party agent to help maintain a trust relationship. We shall call this new service company 'Arbitration Service for Trust Maintenance' (ASTM). Arbitration Service for Trust Maintenance (ASTM) company is a service company that offers a complete service to help business entities improve their performance, primarily by maintaining companies' trust relationship with their clients, partners and customers in virtual environments. In this chapter, we present a business model proposal for this ASTM company which specializes in providing professional agents. Both trusting agent and trusted agent can hire one of these professionals as a third party agent if required.

5.3.1 **Business Model Proposal for ASTM company**

A business model, put simply, describes how a business makes (or intends to make) money. It is central to the business plan. The construction of a business model is the first step in planning when starting a business (Keskinen, Maenpaa, and Saaristo 2007; Osterwalder, Parent, and Pigneur 2004). The purpose of a business model is to ensure that all the factors needed to operate a successful business are considered and analysed to ensure that they are reasonable and achievable. Business models describe the products and services offered for sale, the business infrastructure required to produce and sell these products and services, the target customers that the business expects will buy these products and services, and the financial results and profit the business expects to achieve. In short, a business model defines how the enterprise creates and delivers value to customers, and then converts payments received to profits (Teece 2009).

The main difference between this ASTM company and the existing arbitration service company is the role of the third party agent and the purpose of arbitration. The role of the third party agent in the ASTM company is proactive-corrective; whereas, in online dispute resolution, it is corrective only. Further, the purpose of the arbitrator in Online Dispute Resolution is to decide who is wrong and who is right. However, with the ASTM company, the purpose of the arbitrator is to ensure that both parties maintain their trust level in the business relationship. This third party agent is involved in the parties' interaction from beginning to end. It is important to note here that the interactions between the parties are carried out during the trust maintenance phase or in the phase where the relationship is mature. The third party agent monitors both parties' performances and if there is any discrepancy between the mutually agreed behaviour and the actual behaviour during the time of the relationship, this third party agent helps both parties to reach an alternative agreement regarding the delivery of service. Table 5.3 presents the differences between the role of third party agent in an existing arbitration service company and the ASTM company.

Indicators	Corrective (Existing Arbitration Company)	Proactive – Corrective (ASTM company)
Involvement of third party agent	Is not involved during the whole time space of interaction, only if the parties need help to address conflict or performance gaps	Is involved from the beginning until the end of interaction between two parties
Purpose of arbitration	Decides who is wrong and who is right if performance gaps occurs	Helps both parties by suggesting or recommending alternative(s) to close the performance gaps
Trust Objective	Does not pay attention to existing level of trust between both interacting parties	To maintain (or increase) the existing level of trust between both interacting parties
Monitoring action	Provides no monitoring action during the interaction time space	The third party agent monitors the performance progress of both parties during the interaction time space

Table 5.3: The differences between corrective and proactive–corrective roles

Moreover, the structure of this service company could be that of a collective business system or collective business model. The latter is a business organization or association typically composed of relatively large numbers of businesses, tradespersons or professionals in the same or related fields of endeavour, which pools resources, shares information or provides other benefits for their members (Teece 2009). Hence, the company that provides a third party agent for trust maintenance purposes could be a professional service company that comprises a large number of professional arbitration agents who specialize in trust maintenance in virtual business relationships.

Therefore, in order to establish an ASTM as a 'new service company', in this thesis, we propose a service business model that supports its interoperability. The literature provides various definitions of a business model, such as (Teece 2009; Hamel 2002; Osterwalder 2004; Keskinen, Maenpaa, and Saaristo 2007). In the most basic scenario, a business model is the method of doing business by which a company can sustain itself, by means of generating revenue. The business model spells out how a company makes money by specifying where it is positioned in the value chain. The modelling approach proposed by (Osterwalder 2004) is suitable for the ASTM context that we propose, as the detailed model structure comprises the basic principles for the establishment of a new company. These basic principles are important to offer the product/service, the infrastructure needed, the target customer and how to reach customers, and the financial set-up by which a new company ascertains its costs and generates revenue from its activities The details of the four components of our proposed business model for the ASTM company are as follows:

1. The business offering (value proposition)

    The first component is the business offering which contains a value proposition. Value proposition is a description of the products and services the business offers and the reasons that customers will be compelled to buy them. The value proposition describes the problem the customers are experiencing and how the products and services being offered will help solve that problem. It describes how the features and characteristics of the products and services will contribute to resolving the customers' problem.

    The ASTM company will provide a professional, neutral and independent third party agent to monitor interacting parties' activities involved in a trust maintenance relationship. The third party agent will remain with both trusting agent and trusted agent throughout the entire transaction for trust maintenance purposes (from start to end of service delivery) and apply a dedicated conflict management style to resolve any conflict that might arise during the relationship.

    Additionally, this ASTM company relies on the assumption that since business in virtual environments relies mainly on trust value, it is very important for the trusting agent and trusted agent to maintain their trust level. With the intention of maintaining trust, some tasks with certain milestones should be finished so that the trust level can be re-calibrated and maintained at the current level, if not improved. In the relationship for trust maintenance purposes, trusting parties need a neutral and independent third party who will monitor the progress of task performance and also act as a mediator if there is any lapse in performance during the transaction relationship.

    Business entities who buy or hire this service will gain the benefits of (a) neutral supervision of their interactions, (b) recommendation to other potential agents in the business community, and (c) proactive-corrective recommendations for the progress of the interaction. Additionally, they will receive external (and presumably objective) advice, access to the consultant's specialized expertise, or simply as extra temporary help during a one-time project (trust maintenance), where the hiring of a more permanent arbitrator is not required. The main advantage of using this third party agent is that it encourages the trust level between two parties to remain stable or increase as a result of the delivery of service as agreed. Moreover, the other benefit is that the third party agent will provide a recommendation for any other party that wants to establish a relationship for trust maintenance purposes with both parties.

2. The infrastructure

   This is the part of the business that incurs expenses and includes basic facilities, skills, manpower, partnerships, and production process needed to exploit the business opportunity. It includes:

a. Core capabilities
   Core capabilities are the capabilities and core competencies necessary to operate the business. These include land, facilities, equipment, personnel and their required skills needed to create and provide the products or services described in the value proposition.

   This ASTM company will require persons with specialized knowledge about a particular business field. In particular, professional agents in this service company are professional arbitrators with solid experience in mediation and arbitration services in some field of business. The ASTM company has a panel of skilled, experienced and neutral third party agents covering many commercial areas and professional disciplines. These agents will assist customers with matters regarding the most appropriate procedures or the re-scheduling of the whole process to meet time demands. The business equipment required consists primarily of computer and communication tools for the purpose of communicating with customers.

b. Partner network
   Partner network refers to the business alliances needed to operate the business. Most businesses need alliances, agreements, licenses, or other types of third party assistance (legal, accounting, insurance, security, etc.) which are usually purchased from specialized service providers.

   Complementary capabilities are required on a larger scale for the ASTM company. These include the cooperation with partners such as government agencies, business associations and professional corporations. A government agency is a public agent that provides arbitrators who are employed directly as civil servants. Moreover, a business association is a union of business entities whose members are involved in a particular business or trade, such as retail and wholesale, fabrics, food stuff, transportation, etc. A professional corporation is a registered or incorporated entity that provides professional services (which generally require a license from a professional body) such as accounting, legal advice, medical care, etc. Collaboration with those partner networks will help the ASTM company to build a reputation as a professional service company, to select members as employees and to acquire customers that need a third party agent for trust maintenance purposes.

c. Value configuration
   Value configuration is the process by which the products or services are produced and presented to the customer. The value configuration describes how the materials, supplies, and other required resources will be obtained and transformed into usable products or services and how they will be made

available to buyers. It describes the process that will be used to create the products and services described in the value proposition.

An ASTM company would help to ensure the long-term relationship of both trusting agent and trusted agent by maintaining their trust value. It is committed to promoting, encouraging and maintaining a positive relationship. The aim of an ASTM company is to serve entities in the business community, commerce and industry by providing a neutral third party to monitor and solve problems in task performance relationships for trust maintenance purposes.

In terms of task performance monitoring and unmet performance in a trust maintenance relationship, there are at least five capabilities that ASTM can offer to customers. These capabilities are derived from the intelligence of our proposed TMM:

a. Preventative
   This is used to anticipate the low performance level of both parties in delivering service as agreed. The third party agent would help to predict it in advance using our proposed TMM. For example, our proposed TMM design includes proactive continuous monitoring to address any lapse in service delivery performance in real time manner. This also provides a guideline for the construction of an SLA using a defined number of time slot(s) and checkpoints.
b. Collaborative
   The third party agent encourages both parties to collaborate and cooperate in resolving any problems or difficulties that arise.
c. Facilitating
   The third party agent intervenes to assist the parties if there is any disagreement during an interaction.
d. Fact Finding/Advisory
   The third party agent takes a role as case appraiser/non-binding arbitration/expert appraisal. In this case, the professional third party agent will assist the process of conciliation/mediation/arbitration.
e. Mandatory
   In this option, a third party agent makes a decision that is binding on both parties.

3. Customers – this is the part of the business that generates revenue
   We describe several ways whereby the ASTM company can generate revenue from providing service as professional third party agent as follows:

   a. Target customer: the process of targeting customers should consider the demographics, purchasing patterns, and location of the potential buyers of the products or services described in the value proposition.

      The customers of this ASTM company will be a big company which wants to maintain its relationship with customers, clients and partners in virtual environments. The customers will be drawn from a range of companies and institutions including government, manufacturing, service, and public companies. The type of relationship could be Business-to-Business (B2B) or Business-to-Customers (B2C). The role of this third party agent can be extended to include resources and to meet the requirements of other user communities interested in maintaining their trust level; these may include industry, government, hospitals, etc.

b. Distribution channel: The means by which the business delivers products and services to customers. This includes the business's marketing and distribution strategy.

   The ASTM company can use a partner network to publicize its service or advertise independently in the open market. Parties are able to select their third party agent from a panel of professionals, or the ASTM company will nominate a suitable agent on request. The process begins with an agreement between the parties to use this third party agent. The third party agent activities are constituted and conducted in accordance with that agreement, and the third party agent is involved only with matters within the scope of the agreement.

c. Customer relationships: the process of interacting with the business's customers. It includes communicating, selling, supporting, and assisting customers to purchase and use the business's products or services.

   The ASTM company can use its past or existing customers to help in finding new customers. In this case, parties who have used the ASTM company's services may spread a positive word of mouth to promote the benefit and advantage by buying service at ASTM company. In another way, the ASTM company can create a customer relationship management service through which existing customers can share their experiences and information with future customers who wish to use the ASTM company.

4. Finances - this is the part of the business that determines its financial performance and profit. We define several structures that might be included in an ASTM Company as follows:

   a. Cost structure: the monetary representation of the means employed in the business model

      Administrative costs relating to the operation of this company include operation, maintenance, and advertising. This administrative cost can be covered by a nominee fee that generates a revenue stream.

      Initially in terms of costs, the president or chief operating owner can use his own money to operate this company. Alternatively, the company charge a certain amount to professional agents if they want to be members or employees. This fee is an initial once-off payment. On payment of a joining fee, they are registered as professional arbitrators and acquire the right to be nominees as third party agents for trust maintenance purposes.

The company will promote them and help them to acquire clients or customers in virtual environments.

b. Revenue streams: the way to runs business, makes money through a variety of revenue flows

The ASTM company can generate revenue by charging some fees to customers or parties through a nomination fee, list and searching fees, and usage service meter.

i. Nomination fee
Full search and nomination fees set by the president or chairman of a suitable third party agent company can be categorized based on size of matter or volume of business transaction between two parties. Table 5.1 below presents a simple example for classification of charged nomination fees.

Transactions Size (volume of transaction between two parties)	Fee
Transactions over $ 1,000,000	***
Transactions between $100,000 and $999,999	***
Transactions under $100,000	***
Etc...	

Table 5.4: Nomination fee at ASTM company

i. Listing and search fee
This fee is charged to customers if they want to select a third part agent by themselves. The ASTM company will provide a brief resume of each nominator. Table 5.2 below provides a simple example on how listing and search fee may be charged to the customer.

Search Type	Fee
Simple - customers want 3 - 5 candidates of third party agents and they will choose one of them. A brief resume of each will be provided	***
Complex – to find up to 3 suitable third party agents, check availability, reputation, conflict of interest and provide a detailed resume	***
Etc...	

Table 5.5: Listing and search fee at ASTM company

ii. The utility model

    The utility or ‘on-demand’ model is based on metering the usage or a ‘pay as you go’ approach. Unlike subscriber services, metered services are based on actual usage rates. Therefore, this fee is charged based on the duration of third party agent involvement (relationship duration). For example, if the duration is less than 3 months, 6 months or 1 year, the charge would be different for each period.

c. Profit streams:

   Profit can be generated by a nominee fee (revenue sharing). In this case, the fee paid by customers including nomination fee, listing and searching fee and usage meter goes to the third party agent who accepts formal nominations from the company. However, in order to generate revenue that will be used to cover administration costs, the company will retain a percentage of the nominee’s fee. For example, 10%-20% of professionals’ fee applies to third party agents who accept formal nominations and fulfil their task as mediator/arbitrator in business trust maintenance.

In this section, we present our proposal of service business model for an ASTM company to demonstrate its practicability and viability. The second option requires the hiring of a professional third party agent for trust maintenance purposes. However, currently there are few if any arbitration service companies that specialize in hiring out agents for trust maintenance purposes. If such a company were established, parties needing to hire a professional agent to supervise their relationship in the trust maintenance phase could contact this ASTM company. Moreover, this ASTM company would enrich the business network in virtual environments by providing a third party agent who is dedicated to maintaining the relationship between business entities in the network.

5.4 Conclusion

In this chapter, we presented our framework for third party agent selection. The selection of a third party agent is the first step of our TMM. There are two options when choosing a third party agent in an interaction between trusting agent and trusted agent in a trust maintenance interaction. The first is by taking advantage of the availability of a mutual trusted friend. In order to find this mutual friend, we present a framework for selecting the mutual friend from a list of friends and a list of friends of a friend. We present algorithmic frameworks of the different third party selection approaches. The second option is to hire a paid professional third party agent who specializes in mediating for trust maintenance purposes. However, few, if any companies currently offer this service. Therefore, in this chapter we present a service business model proposal for an ASTM company. The validation of this framework is presented in Chapter 10. In the next chapter, we present the second step of our proposed TMM which is a framework for the formalization and negotiation of service requirements.

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Chapter 6 - **Framework for Formalization and Negotiation of Service Requirements**

6.1 **Introduction**

In this chapter, we present a framework for the formalization and negotiation of service requirements. Formalization and negotiation of service requirements are the second step of our methodology to maintain trust. In this step, both parties formalize, express and prioritize the service requirements. Once they have formalized the service requirements, they carry this on to the negotiation phase. The negotiation process may take iteratively until an agreement is reached. Formalization of service requirements is a way of gathering information about the other party's requirements. Negotiation of service requirements is a process by which an agreement can be reached if there are any conflicting requirements. The outcome of this activity is a Service Level Agreement (SLA) for the time space of an interaction. The research outcome of the proposed framework has been documented in an article for publication (Fachrunnisa and Hussain 2011).

In the next section, we present a case study involving an interaction between a trusting agent and trusted agent in formalizing and negotiating their service requirements. In Section 6.3, we present our proposed framework, including the step-by-step procedure whereby the trusting agent and trusted agent carry out the formalization and negotiation process to reach an SLA. Section 6.4 concludes the chapter.

6.2 **Case Study**

As discussed in Chapters 2 and 3, service formalization would enable each interacting party to ascertain and document its service requirements. This would additionally enable each party to get an idea of its interacting party's requirements. Subsequently, during the negotiation process, each interacting party can negotiate the service requirements, keeping in view its service capabilities. Therefore, a framework of formalization and negotiation to create an SLA that requires effective communication between trusting agent and trusted agent is pivotal in TMM.

In this section, using a case study we will explain the process of formalization and negotiation of service requirements. Let us consider the following example of the relationship between a mobile phone manufacturer as service provider (trusting agent) and a retail mobile phones dealer as service requester (trusted agent). The case study is as follows:

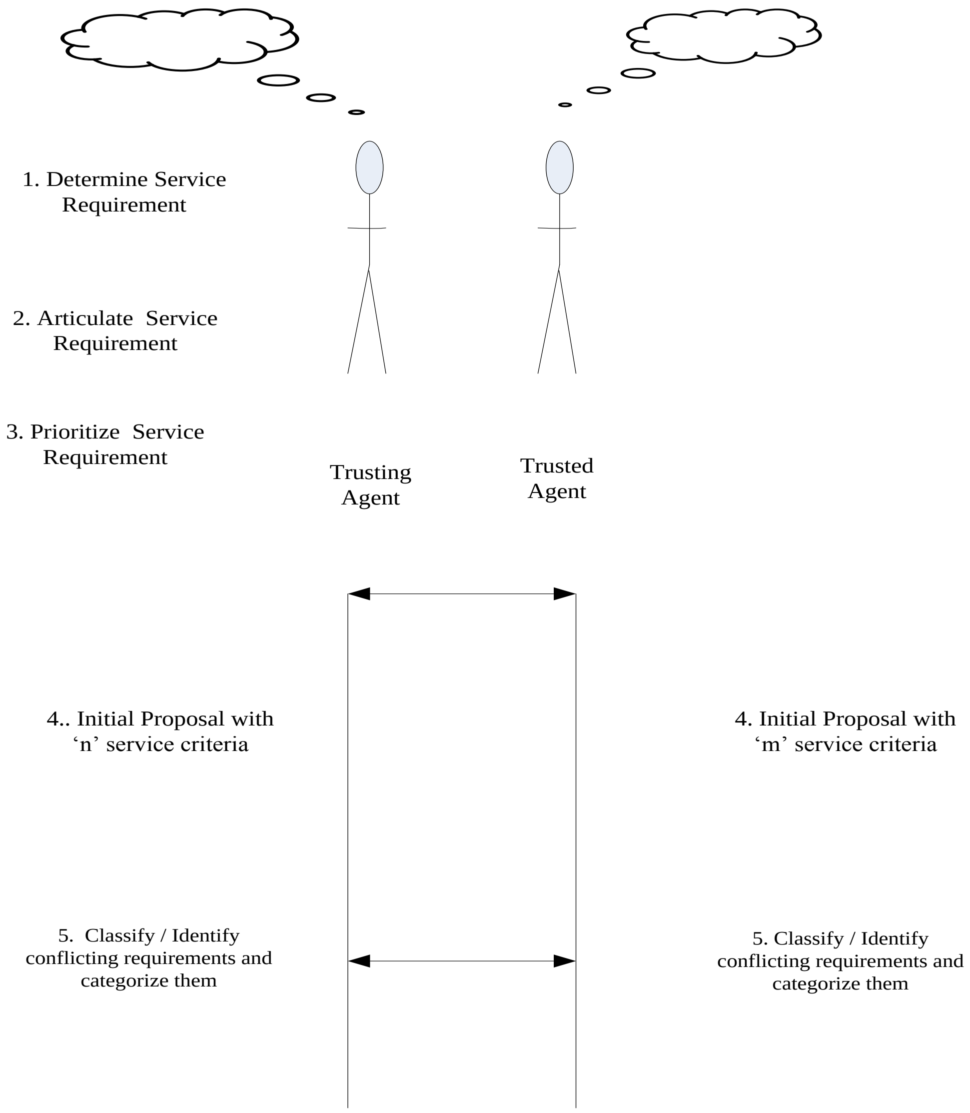
Easy Phones is a large mobile phone manufacturer. In order to distribute their products, Easy Phones engages with several wholesalers or retailers. Let us consider that Easy Phones has three retailers: Angela, Budi and Cherry. Of these retailers, Easy Phones has found that, over time, Angela is a trustworthy retailer. This is because Angela always reaches the highest sales volume and has been prompt in payment. Additionally, let us consider that as a retailer, Angela also has many suppliers, one of which is Easy Phones. From Angela's point of view, Easy Phones is also a trustworthy supplier since they always deliver their service on time and meet Angela's requirements. In this case, both Easy Phones and Angela see that their relationship, which has been established over time, is highly valuable. Let us assume that the trust level in the relationship has been positive for a pre-defined duration of time. To continue a healthy relationship, both parties need to maintain their relationship value. Easy Phones and Angela agree that they would like to maintain trust in order to provide the best possible outcome to each other. In other words, both the interacting parties (Easy Phones and Angela) would like to get a clear idea of their interacting parties' requirements from the interaction, so that (a) they can make a decision on whether they can deliver on the other parties' requirements, and (b) know clearly what is expected of them from the interaction.

Since Angela and Easy Phones have decided to maintain their trust relationship, they need to clearly determine and articulate their business requirements for the duration of their relationship. Once the business requirements have been articulated, subsequent negotiations between them can occur. In order to obtain information on what interacting parties want from a relationship, a service requirement statement / formalization is needed. Service formalization is a method of determining what they require and need from each other during the phase of trust maintenance. This formalization framework will allow Easy Phones and Angela to formalize their requirements and standards in the interactions conducted during the trust maintenance phase. A negotiation framework is required to establish an agreement on service requirements. This is due to the fact that Angela's service requirements may differ from Easy Phones' service requirements. Therefore, there is a need for a negotiation process by which both parties can discuss any conflicting requirements and reach an agreement. A process for deriving an SLA-based on formalization and negotiation is needed. The SLA would serve as the assessment platform for their trust relationship in trust maintenance. With this SLA, Easy Phones and Angela can check their performance positions which in turn measure their trust level. In the next section, we present the proposed framework and the steps involved.

6.3 **The Proposed Framework**

In this section, we present our proposed framework for formalization and negotiation of service requirements. The framework consists of three steps: (a) formalization of service requirements, (b) negotiation of service requirements, and (c) SLA construction. Details of the framework are depicted in Figure 6.1 below:

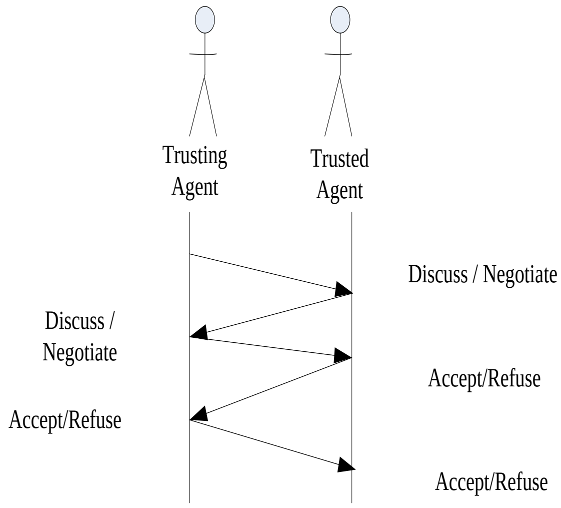
a. Step 1: Formalization of Service Requirements



b. Step 2: Negotiation for each conflicting requirement

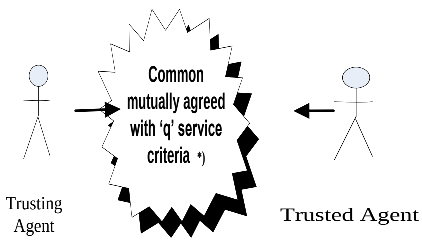
- S_1 Negotiation / Negotiation for Conflicting Service Criteria 1 (one)

- S_2 negotiation / Negotiation for Conflicting Service Criteria 2 (two)
- ……
- S_n negotiation / Negotiation for Conflicting Service Criteria n



accepted / agreed

c. Step 3: SLA Construction



*) $q \geq m \geq n$

Figure 6.1: The proposed framework for formalization and negotiation of service requirements

The above framework in Figure 6.1 shows that initially, both trusting agent and trusted agent are starting to re-formalize their service requirements. Both trusting agent and trusted agent are expressing the service that they want and expect from other interacting party in the interaction. It includes the following three steps or activities: (a) determining service requirements, (b) articulating service requirements, and (c) prioritizing service requirements. Based on these three activities, both parties will have an initial proposal of service requirements which contains service criteria, quality descriptors and the importance level of its service criteria. The number of service criteria might be different for each party ('*n*' from trusting agent and '*m*' from trusted agent). From their initial proposal, both parties can classify or identify any of their conflicting service requirements which need to be negotiated during the negotiation phase.

In the negotiation phase, both parties negotiate iteratively on each conflicting service requirement. Once they reach an agreement about all the service requirements to be carried out during the interaction, they will have an SLA which contains an agreement about a set of service requirements. As mentioned previously, the number of service criteria of the trusting agent is denoted as ‘n’ and the number of service requirements from the trusted agent is denoted as ‘m’. Therefore, in an SLA, the number of agreed service requirements (denoted as ‘q’) could be the same as ‘n’, ‘m’ or the accumulation/combination of ‘n’ and ‘m’. We present the details of this framework in the next section.

6.3.1 Step 1: Formalization of Service Requirements (Pre-negotiation)

We define *formalization of service requirements* as ‘the process of deciding and articulating the service requirements with a quantitative, qualitative or hybrid expression’. Hence, the service requirements can be stated as a numerical value, text value or a combination of numeric and non-numeric measures. Service requirement formalization is an extremely important step that contributes to the successful delivery of service requirements. Before the interaction, if the service requirements or criteria are not carefully constructed or thought out by the interacting parties and articulated in unambiguous terms, it will not be possible for the interacting partner to know what is expected of it. In order to address this, we propose the step of service formalization that leads to service negotiation. Understanding or coming to know the interacting parties’ needs about the service is an extremely important step in eventually delivering on the requirements. Service formalization would additionally serve the purpose of the other interacting party knowing what is required or expected of it.

Additionally, trust maintenance can be viewed as providing service (possibly customized service) to a special, valued partner. In order to do so, each interacting party needs to ascertain (a) its service requirements, and (b) the service requirements of its interacting partner. The provision and delivery of service based on customized requirements makes the trusting agent feel that the trusted agent values its needs. This is an important element of maintaining trust. In a relationship with trust maintenance purposes, a close connection between service requester (trusting agent) and service provider (trusted agent) must be facilitated in order to obtain a quick response on what both parties want. Trust can be maintained only by consistently delivering on the agreed service requirements. The significance of this step arises from the fact that the trusted agent will be better able to deliver on the service requirements if it has a clearly articulated idea of the corresponding requirements.

The steps involved in the service formalization phase are as follows:

Step 1 – Service Requirements Determination
Step 2 – Service Requirements Articulation
Step 3 – Service Requirement Prioritization

These are depicted in Figure 6.2 below.

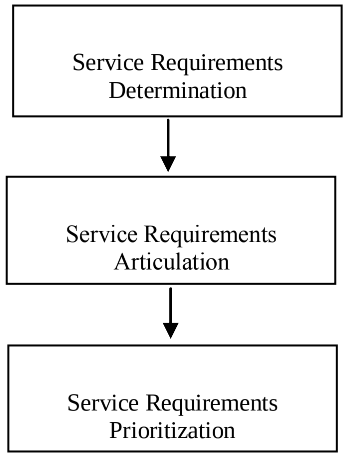


Figure 6.2: Formalization of service requirements

a. Step 1: Service Requirements Determination

We define *service requirements determination* as 'the process of ascertaining service requirements or needs'. In other words, it can be construed as the process of ascertaining the needs that the interacting party wants to fulfil with the interaction.

Let us continue with the above example involving Easy Phones and Angela. The first phase of this framework is formalization of service requirements. Without the formalization phase, neither party will know exactly what is required of it in the business relationship. It is also a kind of mutual self-learning for both parties by which service provider and service requester can learn about their own potential needs in the interaction. This phase allows the service provider and service requester to determine their business requirements from the interaction.

In this phase, both trusting agent and trusted agent start to determine their service requirements. Both service requester and service provider state the service that they want and expect from the interaction. As the purpose of this activity is to maintain trust, both parties try to provide a high-end service to their interacting party. For trust maintenance purposes, both parties are aware of their service context. However, the subsequent context details and requirements of the service delivery need to be expressed clearly in order to increase the trust level during the trust maintenance phase.

b. Step 2: Service Requirements Articulation

We define *service requirements articulation* as 'the process of expressing the service requirements in terms of service criteria and their associated quality descriptors'. Moreover, in order to provide a mechanism to articulate service requirements, we propose a template of service formalization that is suitable for structured information. By designing a service formalization template, business parties may implicitly declare or articulate their service requirements clearly in a manner that is easily understood by the interacting parties. This template varies depending on the type of service and parties' interaction. It contains service criteria, quality descriptors and preference or level of importance. As this SLA creation is for trust maintenance (the phase subsequent to trust building as pointed out in Chapter 3), the interaction context and service criteria already established during the trust building phase would serve as the basis for choosing and determining the context and criteria of trust maintenance. The service criteria in this phase may be derived from several previous interactions or may be augmented versions of the previous criteria.

c. Step 3: Service Requirements Prioritization

We define '*service requirements prioritization'* as the process of evaluating the importance of each service criterion. This can take two values as follows:

0 – Unimportant, which refers to supplementary criteria
1 – Important, which refers to mandatory criteria

In order for both parties to express their service requirements and associated metrics, we propose a service formalization template as depicted in Table 6.1. With this template, both parties can state their service requirements. This template is used by both trusting agent and trusted agent. Therefore, the outcome of service formalization is a statement of service requirements from the trusting agent and a statement of service requirements from the trusted agent. Table 6.1 below shows the template for the formalization of service requirements. It contains service criteria, quality descriptors and level of importance. We define *service criteria* as a 'decisive factor or requirements of the service being requested or provisioned'. For example, if the service is about providing logistics transportation, one service criterion would be '*time*' to deliver goods from city A to city B.

We define *quality descriptor* as 'a statement expressing the quality requirements for those criteria'. The quality requirements could be either quantitative, qualitative or hybrid. Let us use the above example of '*time*' as a service criterion in logistics transportation. In order to state the description of service criterion '*time*', '*5 days*' or '*a month*' is a service descriptor or quality descriptor for 'time'.

a. Service Requester (Trusting Agent) Requirements' Statement

Service Criteria	**Quality Descriptors**	**Level of Importance**
S_1	C_{11} ... C_{1n}	Imp_1
...	...	...
S_n	S_{n1} ...... S_{nN}	Imp_n

b. Service Provider (Trusted Agent) Requirements' Statement

Service Criteria	Quality Descriptors	Level of Importance
S_1	C_{11} ... C_{1m}	Imp_1
...	...	...
S_m	S_{m1} ...... S_{mn}	Imp_m

Table 6.1: Service formalization template

Let us explain the process of determining, articulating and prioritizing service requirements by continuing with the previous example and illustrating how Easy Phones and Angela formalize their service requirements.

Service Criteria	Quality Descriptors	Level of Importance
S_1= Quantity of order	C_{11} = 2500 units	1
S_2 = Price	C_{21} = 500 $	1
S_3= Delivery time	C_3= Once in three months	1
S_4=Order and purchase method	C_{41} = Fax C_{42} = Email C_{43}= Online ordering form	1
S_5= Payment method	C_{51} = Credit Card C_{52}= 30% before shipping and 70% after shipping	1
S_6= Additional services	C_{61} = Two years spare part warranty C_{62} = Product advertisement network $C6_3$ = Product upgrade information	0
S_7 = Bonus	C_{71} = Holiday voucher C_{72} = Cash back C_{73}= Workshop decoration	0

Table 6.2: Trusting agent's (Angela) requirement statement

Table 6.2 describes the service requirements statement from Angela's perspective. In this case, Angela proposes seven (7) service criteria for the service that she requires and expects from Easy Phones. For each service criterion, quality descriptors explain the quality requirements for that particular service criterion from Angela's perspective. For example, for service criterion 4 (S_4) which is order and purchase method, Angela wants ordering and purchasing to be done through fax, email or online ordering form.

On the other hand, let us assume that, based on numerous previous interactions, Easy Phones also have service criteria that they want and need from Angela. The number of service criteria from the Easy Phones' perspective is only five (5) as shown in Table 6.3. They do not offer the additional services and bonus that Angela wants. Table 6.3 below represents Easy Phones' requirements statement.

Service Criteria	Quality Descriptors	Level of Importance
S_1 = Quantity of order	C_{11} = 3000 units	1
S_2 = Price	C_{21} = 550 $	1
S_3 = Delivery time	C_3 = Monthly	1
S_4 = Order and purchase method	$C4_1$ = Online ordering form	1
S_5 = Payment method	C_{51} = Cheque C_{52} = 100% before shipping	1

Table 6.3: Trusted Agent's (Easy phone) requirement statement

Once both parties have each other's service requirements, they start to negotiate on any conflicting requirements. In the next section, we discuss how both parties negotiate their conflicting service requirements.

6.3.2 **Step 2: Negotiation of Service Requirements**

In order to enable the trusting agent and trusted agent to carry out negotiations in a structured manner, we propose a service description map (SDM). SDM is a template which can be used by both parties to compare their desired or required service requirements and associated factors against those offered by the interacting party for each service criterion. After both parties (trusting agent and trusted agent) formalize their service requirements, they translate these requirements into an SDM which represents a comparison of service requirements from the perspectives of the trusting agent and the trusted agent. The structure of the SDM is shown in Table 6.4 below:

Transaction ID:								
Time Frame:								
Time Slot (s):								
Number of Checkpoint(s):								
Trusting Agent ID:								
Trusted Agent ID:								
Service Criteria	**Trusting Agent's Offer**				**Trusted Agent's Offer**			
	C_1	..	C_n	Imp	C_1	…	C_n	Imp

Table 6.4: Service description map template

In this step, both parties review and discuss their service requirements. If the service requirement from the trusting agent's perspective is difficult or cannot be delivered by the trusted agents or vice versa, an adjustment to the requirements should be performed to accommodate the interests of both parties.

Continuing with the above example of Easy Phones and Angela's service formalization, there are some differences in the requirements of both parties. In order to reconcile these two different views during the negotiation process, both parties would translate their service formalization to a service description map. Table 6.5 is an expression of both parties' service requirements via the Service Description Map.

Transaction ID: xxx								
Time Frame: 1 January 2011 – 31 December 2011 Time Slot(s): 4 (Four) Number of initial checkpoints at each time slot: 4 (Four)								
Trusting agent ID: Angela								
Trusted agent ID: Easy Phones								
Service Descriptors	**Angela's Offer**				**Easy Phones' Offer**			
	C_1	C_2	C_3	Imp	C_1	C_2	C_3	Imp
S_1 = Quantity	*2500*			*1*	*3000*			*1*
S_2 = Price	*500$*			*1*	*550$*			*1*
S_3 = Delivery time	**1 * 3 months**			**1**	**1 * 3 month**			**1**
S_4 = Order and purchase method	*Fax*	*Email*	*Online Form*	*1*	*Online Form*			*0*
S5 = Payment method	*Credit Card*	*30% before and 70% after shipping*		*1*	*Cheque*	*100% before shipping*		*1*
S_6 = Additional services	*Two years warranty*	*Advertise-ment network*	*Product upgrade information*	*0*	*n/a*	*n/a*	*n/a*	*n/a*
S_7 = Bonus	*Holiday voucher*	*Cash back*	*Workshop decoration*	*0*	*n/a*	*n/a*	*n/a*	*n/a*

Table 6.5: Service description map (SDM) between Angela and Easy Phones

The SDM compares the trusting agent's offer with the trusted agent's offer for each service criterion. By checking this service description map, both parties can identify criteria or quality descriptors for which they have conflicting service requirements. The sets of the conflicting requirements would be the ones that require negotiation between the interacting parties. We propose the following steps in the negotiation phase:

- *Step 1: Identify contradicting requirements*
  Based on the service description map, both parties can identify the service requirements to which they have not yet agreed. These contradicting or conflicting requirements would be the main issues to negotiate.

- *Step 2: Prioritize the contradicting requirements*
  The objective of this phase is to prioritize the set of all conflicting requirements. Once both parties have identified these requirements, they should prioritize them in order to make a deal through negotiation. Each contradicting requirement has a certain importance level value. The negotiating parties (trusting agent and trusted agent) can determine a comparative

preference value in their service description map. If there is more than one conflicting requirement, the service criteria with the highest importance level would be the first to be considered for negotiation in step 3 below.

- *Step 3: Negotiate contradicting requirements*
  Any information about contradicting requirements and their level of importance is available from the second step. During the negotiation process, both parties should be able to adjust their conflicting requirements until an agreement is reached.

Based on the above SDM from the interaction between Easy Phones and Angela, there are several conflicting requirements (*italicized*) and several same value (**in bold**) requirements from both parties. The negotiation process starts with the highest level of importance of conflicting requirements. In this case, it starts from service criteria 1 (S_1), S_2, S_5, S_4, S_6 and S_7. The T_1, T_2, T_3....T_n is the number of iterations over the negotiation time. Once both parties have agreed on each of the service requirements, the negotiation is concluded and both parties reach an agreement on service criteria, quality descriptors, and level of importance.

S_2: Quantity						
Trusting Agent's level of importance: 1						
Trusted Agent's level of importance: 1						
	Trusting Agents' Offer			**Trusted Agents' Offer**		
Time	C_1	C_2	C_3	C_1	C_2	C_3
T_1	2500	0	0	3000	0	0
T_2	2700	0	0	2800	0	0
T_3	2725	0	0	2725	0	0
T_4	Agreed					

Table 6.6: Process of negotiation for S_1

S_2: Price						
Trusting Agent's level of importance: 1						
Trusted Agent's level of importance: 1						
	Trusting Agent's Offer			**Trusted Agent's Offer**		
Time	C_1	C_2	C_3	C_1	C_2	C_3
T_1	500$	0	0	550$	0	0
T_2	510$	0	0	550$	0	0
T_3	525$	0	0	525$	0	0
T_4	Agreed					

Table 6.7: Process of negotiation for S_2

S_5: Payment Method						
Trusting Agent's level of importance: 1						
Trusted Agent's level of importance: 1						
	Trusting Agents' Offer			**Trusted Agent's Offer**		
Time	C_1	C_2	C_3	C_1	C_2	C_3
T_1	Credit card	30% before shipping and 70% after shipping	--	Cheque	100% before shipping	0
T_2	Cheque	30% before shipping and 70% after shipping	--	Credit Card	100% before shipping	0
T_3	Cheque	100% before shipping	--	Cheque	100% before shipping	0
T_4	Agreed					

Table 6.8: Process of negotiation for S_5

S_4: Order and Purchase Method						
Trusting Agent's level of importance: 1						
Trusted Agent's level of importance: 0						
	Trusting Agent's Offer			**Trusted Agent's Offer**		
Time	C_1	C_2	C_3	C_1	C_2	C_3
T_1	Fax	Email	Online Form	Online Form	--	--
T_2	Online Form	--	--	Online Form		
T_3	Agreed					

Table 6.9: Process of negotiation for S_4

S_6: Additional Services						
Trusting Agent's level of importance : 0						
Trusted Agent's level of importance: n/a						
	Trusting Agent's Offer			**Trusted Agent's Offer**		
Time	C_1	C_2	C_3	C_1	C_2	C_3
T_1	2 years warranty	Advertisement network	Product upgrade information	--	--	--
T_2	--	Advertisement network	--	--	--	--
T_3	--	--	--	--	--	--
T_4	Agreed					

Table 6.10: Process of negotiation for S_6

S_7: Bonus						
Trusting Agent's level of importance: 0						
Trusted Agent's level of importance: 0						
	Trusting Agent's Offer			**Trusted Agent's Offer**		
Time	C_1	C_2	C_3	C_1	C_2	C_3
T_1	Holiday voucher	Cash back	Workshop decoration	--	--	--
T_2	--	Cash back	--	10% discount	--	--
T_3	--	--	Workshop decoration	--	--	Workshop decoration
T_4	Agreed					

Table 6.11: Process of negotiation for S_7

As we can see from Table 6.6 – Table 6.11 (above), in S_1, S_2, S_5, S_4, S_6, S_7 Easy Phones and Angela could reach an agreement on the service requirements using the negotiation process. The number of iterations required for an agreement to be reached on a given each conflicting service requirement varies. For example, in S_1 (Quantity of delivery) both parties reached an agreement after four iterations. During the negotiation process, the quality service descriptor value of a given criteria could be a value proposed by one agent and agreed to by the other agent; or it could be a new negotiated value. There is a possibility that both parties may not reach an agreement value for certain service criteria. In this case, if the importance level of this service criterion is '0' which means that it is unimportant or a supplementary criterion, the service criterion would be excluded from the final agreement contract. However, if the importance level of the criterion is '1' meaning that the service criterion is an obligatory criterion, the SLA cannot be constructed and therefore the transaction cannot proceed. In this case, the parties would be required to re-negotiate to reach an agreement as shown in Figure 6.4. Once the negotiation phase is completed, both the interacting parties examine the set of requirements, which have been mutually agreed to. If, based on the negotiated and agreed requirements, both the interacting parties agree to proceed with the interaction, it goes ahead. This process is depicted in Figure 6.3 below.

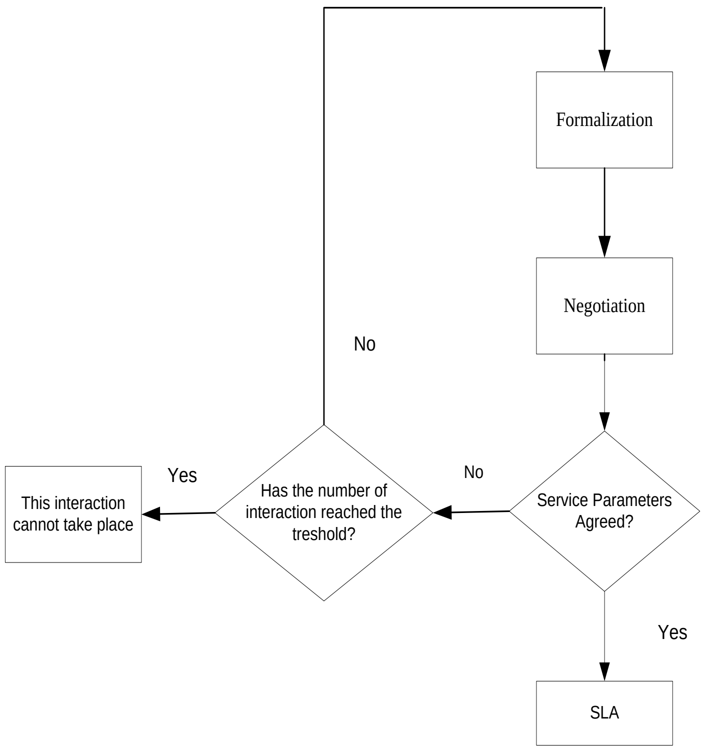


Figure 6.3: Negotiation process

In order to illustrate this, let us consider the negotiation process between Easy Phones and Angela on Service Criteria 6 (S_6: Additional Services). Angela demands three options of additional service; however, none of them is being agreed to by Easy Phones. After some iterative negotiation interaction threshold, both parties agree to remove this service criterion from the relationship agreement. Once both parties finish bargaining on each conflicting service requirement, they send this agreement to the third party agent. The third party agent creates a service level agreement for both parties. In the next section, we illustrate how this agreement can be translated into an SLA.

6.3.3 **Step 3: SLA Construction (Post Negotiation)**

Once all service criteria and their quality descriptors have been agreed upon by both parties during the negotiation phase, the agreement documented in a service description map would be sent to the third party agent whose role is to monitor the interaction. The third party agent will translate the SDM to an SLA. The outcome of this is an SLA or a mutually binding contract for both parties. An SLA is a documented written agreement between service provider and service requester about the required levels of service. SLAs should state the performance and satisfaction metrics that will be used by both parties to measure the success level of interaction. Additionally, based on this SLA, third party agent will determine the time window which consists of time space, number of time slots and number of initial checkpoints per time slot for the interaction. Details of how the third party agent determines this time window are presented in the next chapter.

The following important points should be included during the drafting of SLAs:

- The contact information of each agent
- The context or description of service relationship
- The criteria of service
- The agreed quality descriptor for each criteria
- The level of importance of each criterion
- The time window of SLA
- Measurement of the success of the interaction

This SLA would be used as a basis for both parties to monitor their interaction. The trust level would be calculated based on the correlation of agreed requirements as stated in the Service Level Agreement and the actual value that is delivered by the trusting agent and trusted agent (Hussain, Chang et al. 2004). With this SLA, both parties will have a clear idea of the interacting parties' requirements and subsequently the third party agent will take the role of judge or arbitrator to monitor the performance progress of both parties during trust maintenance. We argue that if both parties' requirements are formalized and negotiated, they will be able to deliver service based on their needs and wants. It will ensure that the trust level remains significantly positive and should even increase by the end of the relationship. The details of the SLA based on the SDM in the interaction between Angela and Easy Phones is provided in Table 6.12.

Transaction ID:	Xxx
Time Frame:	1 January 2011 – 31 December 2011
Time Slot (s):	4 (Four)
Number of Initial Checkpoints	4 (Four)
Trusting agent ID:	Angela
Trusted agent ID:	Easy Phone
Service Context	Mobile Phones Trading

Service Criterions	**Quality Descriptors**	**Level of Importance**	
		Trusting Agent	Trusted Agent
S_1: Quantity	C_{11}: 2725 unit	1	1
S_2: Price	C_{21}: 525 $	1	1
S_3: Delivery Time	C_{31}: Once in three months	1	1
S_4: Order and Purchase Method	C_{41}: Online Form	0	1
S_5: Payment Method	C_{51}: Cheque C_{52}: 100% before shipping	1	0
S_6: Bonus	C_{61}: Workshop Decoration	1	0

Table 6.12: Service level agreement between Angela and Easy Phone

Our proposed framework of formalization and negotiation of service requirements is designed to create an SLA with the purpose of trust maintenance in a relationship. It contains three activities: (a) formalization of requirements, (b) negotiation of requirements and (c) SLA construction. The outcome of these three activities is an

SLA which contains a set of service criteria, along with their quality descriptors and importance level, as agreed to by the trusting agent and the trusted agent.

For trust maintenance purposes, given that the parties have already been involved in a previous trust-based relationship which occurs during the trust building phase, the service requirement negotiation and formalization needs to take into account the previous service criteria, their level of importance and other factors based on which the refined SLA for trust maintenance would be constructed. This SLA provides a benchmark or a basis for evaluating the performance of both parties when carrying out a business interaction. It is also a guide to how both parties should carry out the interaction. For trust maintenance purposes, both trusting agent and trusted agent will monitor each other's performance in service delivery to ensure that they perform as prescribed by the SLA. There are various points of the monitoring process (which we term as checkpoints. This is presented in Chapter 7), at which each of the parties can recalibrate their actual performance with the agreed performance. Firstly, there are input controls, which are the formalization of service requirements. Secondly, process controls**,** by controlling the trusted agent's performance, ensure that they employ prescribed service requirements, and thirdly, output controls measure the outputs of the trusted agent and trusting agent against established metrics that have been pre-defined in the SLA. This ensures that prescribed performance standards are met. We present the details regarding evaluation of the performance of both parties in the next chapter (Chapter 7).

6.4 **Conclusion**

In this chapter, we present our proposed framework for the formalization and negotiation of service requirements. This is the second step of our methodology for maintaining trust. The output of the service formalization phase is the service requirements document, which is translated to the SDM. From the SDM, both parties can identify any conflicting requirements and start to negotiate about each conflicting quality descriptor, service criterion and its level of importance (importance value). Hence, the main purpose of negotiation is to discuss any conflicting requirements. The negotiation is an iterative process until agreement is reached. If all service requirements are agreed to, then this agreement is sent to the third party agent. The third party agent will then translate this to an SLA. In the next chapter, we discuss how a third party agent determines the time window of interaction which is the basis for proactively conducting continuous performance monitoring.

6.5 **References**

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Chapter 7 - **Framework for Proactive Continuous Performance Monitoring and Incentive Mechanism**

7.1 **Introduction**

In Chapter 6, we presented a framework for formalization and negotiation of service requirements. As was discussed, the outcome of this formalization and negotiation of service requirements is a Service Level Agreement (SLA). Based on this SLA, a third party agent will monitor the performance of both trusting agent and trusted agent during the delivery of service. Moreover, the third party agent will take action if there are any discrepancies between the actual performance and the mutually agreed to performance during the interaction.

In this chapter, we propose frameworks for proactive continuous performance monitoring that would enable the third party agent to (a) continuously monitor service delivery and compare it against the agreed plan for service delivery, (b) suggest / carry out corrective measures when the delivery deviates from the agreed-upon delivery according to a pre-defined threshold. In order to ensure that the actual service delivery is as close as possible to the agreed service delivery, we propose the use of incentive mechanisms. In this research, we propose three different incentive frameworks as measure to incentivise actual service delivery. This is the third step of our methodology for maintaining trust in a virtual environment. Section 7.2 and Section 7.3 present the details of the framework including mathematical formulae to express the requirements of this framework. In Section 7.4, we present a framework for an incentive mechanism to support the success of service delivery. In this chapter, we also present a simple case study to illustrate our framework. Section 7.5 concludes the chapter.

7.2 Framework for Proactive Continuous Performance Monitoring

In this section, we present our framework for proactive continuous performance monitoring. This framework consists of six steps, the details of which are presented in Section 7.3. We propose that proactive continuous performance monitoring of trust in a relationship is founded on an underlying philosophy of trust maintenance which is to 'build and examine often' (Currall and Epstein 2003). This clearly expresses that once trust has been well-established, it needs to be examined often if it is to survive. We propose the following mechanism for conducting proactive continuous performance monitoring and assessment:

a. Design a predefined number of time slots to divide the delivery time of agreed service requirements.
b. Determine the number of checkpoints needed to review the intermediate performance during the interaction.
c. Proactively monitor the performance of the trusted agent's actual performance against the agreed performance.
d. Take remedial action or corrective measures in case of discrepancy between actual intermediate performance and agreed intermediate performance.

As was discussed in Chapter 4, the proactive continuous monitoring enables performance deviations to be timely identified. Consequently, the trusting agent and trusted agent, with the help of the third party agent, will be able to quickly address performance discrepancies before they inflate into an unmanageable and final undelivered service outcome. In order to illustrate how our proactive continuous performance monitoring framework works, let us consider an example of an interaction between an international audit service company as service provider and a manufacturing company that requires audit service as service requester. Let us assume that 'Loyalty Company' is a goods manufacturer and 'ABS White' is an international company that provides an auditing service. Loyalty Company has had a business relationship with ABS White for a certain number of years. Their relationship is now in the cooperative and collaborative stage and they agree to maintain their business value and their current trust level over a specified longer duration of time. As a simple example, Loyalty Company requests that ABS White audit its 240 files of financial accounts within one month. Let us assume that both parties have been involved in steps 1 – 2 of our TMM. As a result, in their Service Level Agreement (SLA), ABS White agreed to audit and delivers 240 files of audited financial accounts over the next one month.

During the business interaction, with the passage of time, the number of accounts that have been audited should increase as specified in the SLA. For instance, by the end of Week One, 60 accounts should have been audited and verified. By the end of the month, 240 accounts should have been audited and the service should have been delivered as per the agreement with the customer. If however, there is no performance monitoring every week, it might be that the actual performance falls outside the parameters specified by the service agreement. The weakness of the one-off performance evaluation which is done at the end of the interaction is that Week One's performance discrepancies are compounded by Week Two's and so on, until a month passes by and in the end, the service is not fully delivered as mutually agreed upon by the two parties. With the passing of time, the small performance discrepancies that occurred initially may become a massive problem that no-one was concerned to fix earlier. And with every passing week, it becomes increasingly difficult to fix everything, thereby decreasing performance. Hence, there is a need for proactive performance monitoring rather than reactive performance monitoring. Consequently, the final delivered service falls outside the performance agreed to in, for example, the Service Level Agreement (SLA). This situation is depicted in Figure 7.1 below:

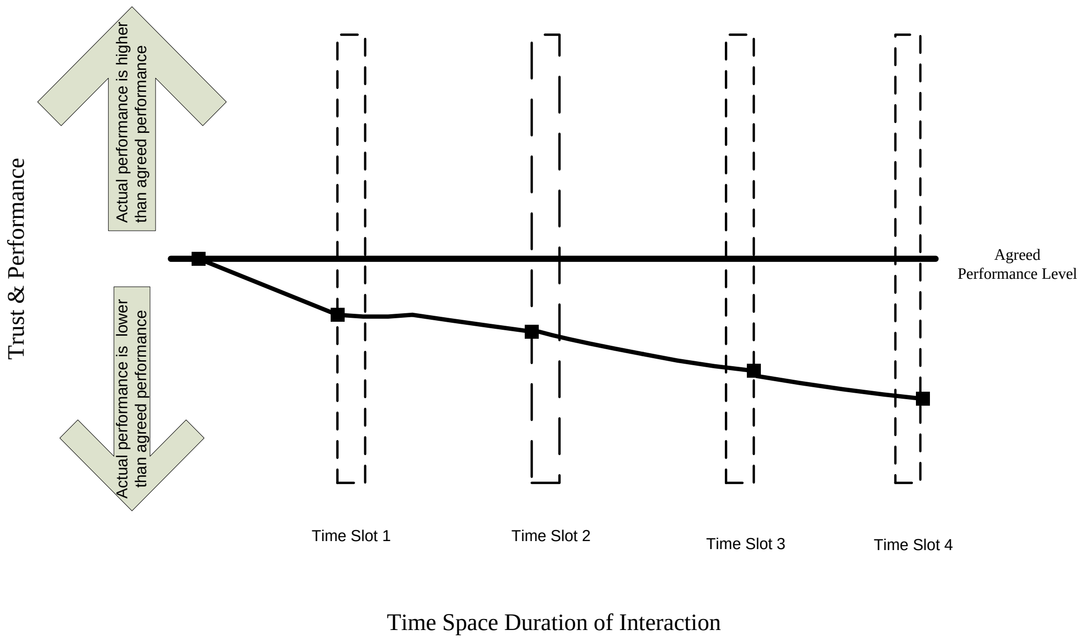

Figure 7.1: One-off performance evaluation

The proactive continuous performance monitoring model, however, can be used to eliminate this compounding effect because performance is tested and checked at every designated checkpoint. Hence, the performance discrepancies can be detected early and resolved quickly. Procedural steps may be required in order to solve the performance discrepancies. Given that an appropriate mechanism is employed to detect performance discrepancies and to ensure that these discrepancies are addressed, the proactive continuous performance monitoring approach delivers greater benefits resulting in better service delivery at the end. It reduces the risk of service failure because it ensures that a service will be delivered on time as promised (see Figure 7.2). In Figure 7.1, the dotted line indicates that the checkpoint is not actually present in the interaction process (since performance assessment is done only at the end of the interaction). We have shown this checkpoint during the interaction (in Figure 7.2) to illustrate that if proper checkpoints were in place, there would have been opportunities in Time Slot 1, Time Slot 2, Time Slot 3, and Time Slot 4 to formulate strategies to minimize the performance discrepancies.

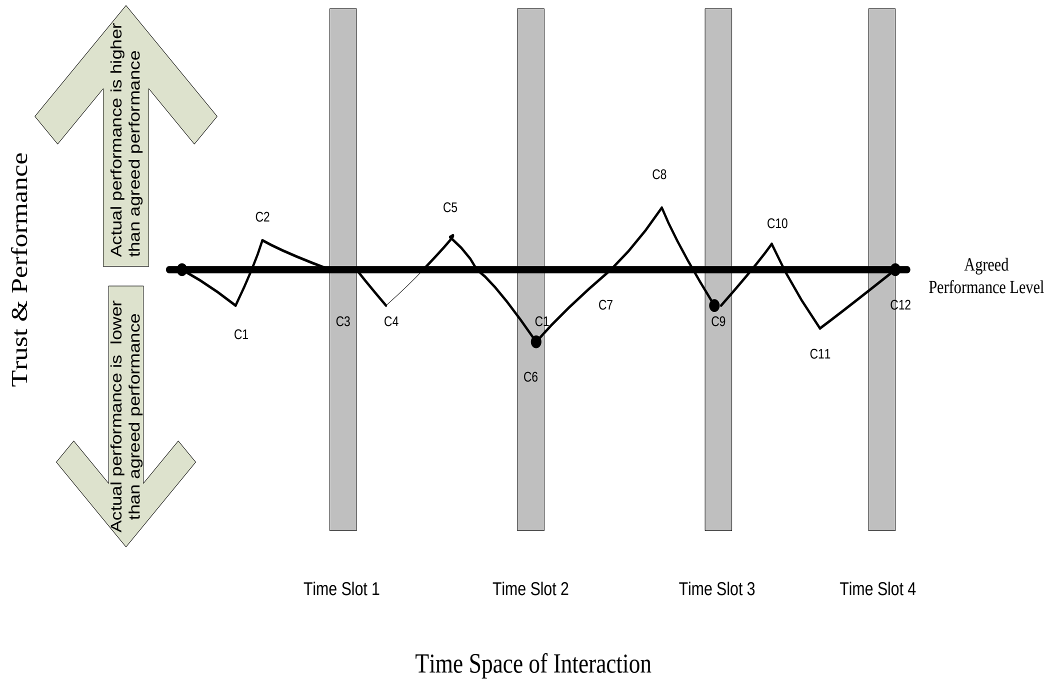

Figure 7.2: Proactive continuous performance monitoring

From the trust relationship perspective, trust can be seen as the execution of contracts or mutually agreed behaviour (Chang, Dillon et al. 2006; Debenham and Sierra 2008). We propose the use of time slots and checkpoints to help that trust to be maintained. In the case of unmet performance or a contract not being fulfilled, the discrepancy can be identified and addressed at the next checkpoint. In this case, the number of checkpoints in each time slot is designed to review the progress of service delivery. In the next section, we present the details of the proposed framework.

7.3 Details of Framework for Proactive Continuous Performance Monitoring

In this section, we present the step-by-step process of conducting proactively continuous performance monitoring. This framework consists of six steps that need to be carried out by the third party agent. Subsequently, both interacting parties have to agree with the entity who will act as third party agent and the role of this third party agent as proactive corrective recommender system.

7.3.1 Step 1: Determining the Time Window of Interaction

The first step of this framework includes an activity to determine the time window of interaction. As was discussed in Chapter 4, time window is a set of time statements which represent when the context of interaction is in question. The time window consists of time space, time slots, and number of checkpoints. As was discussed in the previous chapter (Chapter 6), each SLA would be used for one interaction within a time window.

7.3.2 Step 2: Determining the Time Space of Interaction

Time space is defined as 'the total duration of time over which the behaviour of the trusted agent will be analysed and the trustworthiness measure and prediction will be carried out' (Chang, Dillon et al. 2006). This time space clearly states when the interaction starts and when the interaction finishes. This time space is mutually agreed to by both parties. It is also clearly stated in the SLA as discussed in Chapter 6.

7.3.3 Step 3: Determining the Time Slot(s) of Interaction

Time slot is defined as a 'finite number of non-overlapping, mutually exclusive and equally spaced sectors of time' (Chang, Dillon et al. 2006). It is the number of intermediate sections of a task that should be delivered at those intermediate times for the duration of the time space.

7.3.4 Step 4: Determining the Initial Number of Checkpoint(s) at Each Time Slot

We define checkpoints as the number of points used to check the performance in each time slot(s) (Fachrunnisa, Hussain et al. 2011). The number of checkpoints is determined by the third party agent based on pre-defined formulae in Equations 7.1. However, both parties have to determine the number of initial checkpoints that they want to have during the interaction using Equations 7.4 and 7.5. The third party agent then determines the agreed number of checkpoints used to review performance in each time slot. The initial number of checkpoints is the maximum number or average number of checkpoints being proposed from trusting agent to trusted agent and the number of checkpoints being proposed from trusted agent to trusting agent. As a simple example, let us consider agent A as trusting agent and agent B as trusted agent. We denote the number of checkpoints being perceived from agent A to agent B as $CN(A \rightarrow B)$ and the number of checkpoints being perceived from agent B to agent A as $CN(B \rightarrow A)$.

The initial number of checkpoints can be formalized as a mathematical expression as follows:

$$CN = f(CN(A \rightarrow B), CN(B \rightarrow A)) \qquad \textbf{Equation 7.1}$$

Where,

The function '*f*' represents the maximum or average function corresponding to the checkpoints between A → B and B →A. If the third party agent is using the 'maximum function', the mathematical expression is follows:

$$CN = \max(CN(A \to B), CN(B \to A))$$ **Equation 7.2**

On the other hand, if the third party agent is using the 'average function', the mathematical expression is follows:

$$CN = avg(CN(A \to B), CN(B \to A))$$ **Equation 7.3**

Both parties initially determine the number of checkpoints that they want to be used to review the progress of performance of their interacting parties using equations 7.4 or 7.5. This formula is established based on their actual initial trust level and the current business value of the interaction and the maximum business value have been carried out between both parties. The mathematical expression of this calculation is as follows:

$$CN_{(A \to B)} = \frac{6}{T_{initial}(A \to B)} * \frac{m}{M_{max}}$$ **Equation 7.4**

$$CN_{(B \to A)} = \frac{6}{T_{initial}(B \to A)} * \frac{m}{M_{max}}$$ **Equation 7.5**

Where;

- CN denotes the number of initial checkpoints per time slot in an interaction.
- $CN_{(A \to B)}$ denotes the number of checkpoints from agent A to agent B
- $CN_{(B \to A)}$ denotes the number of checkpoints from agent B to agent A
- 6 denotes the highest possible level of trust level in a relationship
- $T_{initial\ (A \to B)}$ denotes the initial trust level from agent A to agent B and $T_{initial\ (B \to A)}$ denotes initial trust level from agent B to agent A
- m represents the monetary value of the interaction (current business interaction)
- M_{max} represents the value of the maximum worth of interaction carried out thus far between agent 'A' and agent 'B'.

7.3.5 Step 5: Solution for Performance Discrepancies

In this step, we present an approach for resolving the problem of performance discrepancies should these occurs during the interaction. The key purpose of proactive continuous performance monitoring is to identify the continuity of service deliverability and/or its problems as early as possible so that corrective actions may be taken to prevent/minimize performance discrepancies that will result in a decrease of trust. Moreover, monitoring helps provide quantitative observations and data on how well services are being delivered based on the mutually agreed to behaviour or an SLA.

In the SLA that has evolved from the previous step, it (the SLA) is decomposed into several intermediate time slots and checkpoints in order to provide a mechanism by which both interacting parties can incrementally monitor the progress of each other's activities. The number of checkpoints, or intermediate performance, is determined by the third party agent in the first step of our proposed TMM. In the proactive continuous performance monitoring step, the third party agent acts as a proactive-corrective agent. A proactive-corrective role means taking the lead by monitoring task performance and helping to resolve any conflict during the relationship in order to maintain trust. The third party agent has a responsibility to monitor the performance and administer the SLA between service requester and service provider. Performance monitoring always takes place within the set time space and occurs on an ongoing basis throughout the term of the SLA. The proactive continuous monitoring and progress of the interaction between the interacting parties would result in real-time performance information. It would additionally allow 'proactive performance monitoring' whereby each interacting agent would be able to proactively determine when its Mutual Agreed Behaviour (MAB) is not in line with the Actual Behaviour and take appropriate remedial actions.

Real-time monitoring of service deliverability can then be regarded as a sequence of thresholds trust testing. Service performance is monitored by both parties and the third party agent at every time interval or every checkpoint. This will lead to the measurement of intermediate trust levels by correlating real-time actual behaviour with agreed behaviour. The third party agent will obtain a performance report for both the trusting agent and trusted agent. By reviewing this performance monitoring report, each interacting party and the third party agent can review their performance status.

This proactive continuous performance monitoring may produce two possible outcomes. First, the actual behaviour at every checkpoint is equal to the expected behaviour. Second, the actual behaviour at each checkpoint is different from the expected behaviour. We discuss each of these two scenarios below:

Scenario 1. The actual behaviour is equal to the mutually agreed to behaviour for each of the checkpoints in the interaction. Assuming n_1, n_2, $\ldots n_n$ represent the checkpoints in the interaction, this may be formally expressed as follows

$$AB_i \neq MAB_i \ \forall \ i \in N$$ **Equation 7.6**

Where, N = {n_1, n_2,….n_n}, AB_i corresponds to actual behaviour at checkpoint i and MAB_i represents Mutually agreed behaviour at checkpoint i

Scenario 2. The actual behaviour is not equal to the mutually agreed to behaviour for at least one of the checkpoints in the interaction.

$$AB_i \neq MAB_i \; \exists \; i \in N$$ **Equation 7.7**

Where N = {n_1, n_2,….n_n}, AB_i corresponds to Actual behaviour at checkpoint i and MAB_i represents Mutually agreed behaviour at checkpoint i

In the first scenario, both parties are complying with the SLA. In this case, the third party agent takes no action as there is no problem and no performance discrepancies. The third party agent retains the information of both parties' performances in their databases. The third party agent can use one of two strategies to manage the continuity of service performance and trust relationship if the second scenario occurs. These are:

a. Reassign tasks within the time slot

   This option is chosen if there is more than one checkpoint remaining in the current time slot. There are two options to reassign tasks within the time slot. Firstly, if the error tolerance or unmet performance in the previous checkpoint is below error tolerance, the number of checkpoints within the time slot is not be changed; rather, the unmet performance in the current checkpoint is handed over to the next checkpoint within the time slot.

   Let us continue with the above example. In time slot 1 (TS_1), it is agreed that 60 files have to be audited. Let us assume that in TS_1, it has been agreed that there are three checkpoints. Hence, at checkpoint 1 (CP_1), checkpoint 2 (CP_2), and checkpoint 3 (CP_3), 20 files have to be finished audited. The error tolerance that has been agreed to in the SLA is 0.05 (3 files). Let us further consider that at CP_1, the trusted agent delivered only 19 files which is acceptable (as the discrepancy is 0.04); hence, the remaining unaudited work which is 1 file is carried over to the next checkpoint (CP_2). In this case, the agreed performance in CP_2 changed to be 21 files instead of 20.

   If however, at CP_1 the trusted agent delivers only 15 files which are above the error tolerance, the remaining number of checkpoints within TS_1 needs to be revised. The revised number of checkpoints is calculated using formula 7.8. The main point of this strategy is that agreed performance at each time slot has to be close within the time slot (equal to or less than the pre-defined performance threshold).

b. Restructures the number of checkpoints in the next time slot, so that the number of checkpoints in the next time slot is changed. This option is used if the performance discrepancy occurs at the end of a time slot. In this case, the level of performance against the error tolerance does not need to be considered. The number of revised checkpoints is based on the following formula:

$$CN' = \left(\frac{6}{T_{\text{int } compliant \rightarrow noncompliant}} * \frac{m_{remaining}}{m_{planned}} \right) * CN$$ **Equation 7.8**

Where,

- CN' denotes the revised number of checkpoints per time slot
- 6 represents the highest agreed level of trust
- $T_{\text{int compliant}\rightarrow\text{noncompliant}}$ denotes the intermediary trust level from compliant agent to non-compliant agent.
- $m_{\text{remaining}}$ denotes value of business interaction remaining within time slot or for the next time slot
- m_{planned} denotes value of business interaction planned within time slot or for the next time slot
- CN represents the original/initial number of checkpoints per time slot.

$T_{\text{int compliant}\rightarrow\text{noncompliant}}$ is measured by employing CCCI metrics. CCCI metrics are a suite of metrics proposed by Hussain et al. (Chang, Dillon et al. 2006) (Hussain, Chang et al. 2004), that can be used to measure the Quality of Service (QoS) of the service provider, subsequent to the interaction. The QoS value is expressed as 'the degree consonant or parallelism between the actual behaviour of a trusted agent and the mutually agreed behaviour of the trusted agent, as perceived by a trusting agent' (Chang, Dillon et al. 2006) (Hussain, Chang et al. 2004). However, in this case, the intermediate trust is calculated at every checkpoint; hence, we term it 'intermediate trust'. This can be expressed mathematically as follows (based on the adaptation of CCCI metrics):

$$T_{\text{int}} = 6 * \left(\frac{\sum_{C=1}^{N} In\ Agreed\ Perf_{criterionc} * Clear_{criterionc} * \text{Imp}_{criterionc}}{\sum_{C=1}^{N} In\ MAP_{criterionc} * Clear_{criterionc} * \text{Imp}_{criterionc}} \right)$$ **Equation 7.9**

Where,

- T_{int} denotes intermediate trust value
- 6 represents the highest level of trust value
- $In\ Agreed\ Perf_{criterionc}$ denotes the agreed criterion representing the fulfilment of each criterion of the trusted agent at an intermediate checkpoint.
- $Clear_{criterionc}$ represents the clarity of each criterion in the service agreement (contract) and whether it is understood in the same way by both parties. For a given criterion, $Clear_{criterionc}$ can have two levels (a) '0' – This criterion or its output or both have not been mutually agreed to by both parties and (b) '1' – This criterion along with its output has been mutually agreed to by both parties

- $Imp_{criterionc}$ denotes the importance of each criterion that affects the determination of trustworthiness. For a given criterion, $Imp_{criterionc}$ can have two levels: (a) '0' – not important (b) '1' – important.
- $InMAP_{criterionc}$ denotes mutually agreed performance of the trusted agent according to the given criterion at the intermediate checkpoint.

In the next section, we present a framework of incentive mechanisms to support successful service delivery by the end of the interaction. The incentive is used to encourage trusted agents to always comply at each checkpoint.

7.4 Framework for Incentive Mechanisms for Successful Service Delivery

As was noted in the previous section, a key research challenge relating to the formation of a successful transaction is product/service guarantee and its deliverability. By 'service deliverability', we mean a guarantee of continued delivery of service as mutually agreed to by both of the parties involved. Further, (Fachrunnisa, Hussain et al. 2011) argue that the capability of the trusted agent to deliver service as promised and agreed to by the trusting agent will increase the level of trust that the trusting agent has in the trusted agent. Trust is the degree of belief or faith that an interacting party has in another party (Chang, Dillon et al. 2006) that forms the basis of QoS and the subsequent establishment of a business relationship (Ruppel, Underwood-Queen et al. 2003).

In this section, we present our generic framework for an incentive to be provided in our proactive continuous monitoring. As was discussed in the previous sections, we divided the time space of interaction into several time slot(s). At each time slot(s) we designed a predefined number of checkpoint(s) whereby both parties have to track the performance of their interacting parties in delivering service requirements based on the SLA. This proactive continuous monitoring is carried out by a third party agent. In addition to proactive performance monitoring, we propose the use of rewards and incentives that can be used to motivate the trusted agent to behave or perform as closely as possible to the terms of the SLA. A reward or incentive is given during the course of transaction instead of at the end of the interaction. We propose three different approaches for giving incentive: (a) Performance-driven-based-incentive, (b) Error-tolerance-based incentive, and (c) Occurrence-based incentive. We present the details of each approach in the next sections. A research outcome regarding this framework has been documented in a published article (Fachrunnisa 2011).

7.4.1 Performance-driven-based Incentive

In this approach, an incentive is given if the performance of the trusted agent at the current checkpoint is greater than or equal to the performance at the previous checkpoint and the trusted agent shown an increased performance as a response of receiving incentive. In other words, in this approach, incentive is awarded only if parties show a minimum improved performance level in response to receiving an incentive.

The objective of this approach is to motivate trusted agents to increase their performance in delivering service to the trusting agent as closely as possible to the mutual agreement. The steps included in this approach are as follows:

a. *Step 1: Defining Incentive Requirements in SLA*

   For each transaction, both parties have agreed on a mutually agreed performance or SLA. This incentive and its requirement for providing incentive have to be clearly spelt out in the SLA. As was discussed in Chapter 6, the SLA would clearly state each service criterion and its associated level of importance. If both parties agreed to use reward and incentive as part of their interaction, the kind of incentive and details of requirements must be stated in the SLA.

b. *Step 2: Evaluating the intermediate performance or intermediate trust level at each checkpoint*

   Once both parties have agreed on the SLA including the details of the incentive, at every checkpoint, both parties need to evaluate the intermediate performance of their interacting partners. As a result, both parties would have an intermediate performance level at each checkpoint. Hence, the performance of the trusted agent in terms of delivering the service is monitored at each checkpoint. It is reflected in the correlation between actual performance and mutually agreed performance upon service requirements at each checkpoint. Hence, at each checkpoint, the trusting agent will allocate a value to intermediate performance. The performance of the trusted agent can be measured by correlating actual performance with mutually agreed to performance at each checkpoint(s). The intermediate performance is calculated using the following formula:

$$P_{\text{int}}\text{CPn} = 6 * \left(\frac{\sum_{C=1}^{N} In\ Actual\ Perf_{criterionc} * Clear_{criterionc} * \text{Imp}_{criterionc}}{\sum_{C=1}^{N} In\ MAP_{criterionc} * Clear_{criterionc} * \text{Imp}_{criterionc}} \right)$$

Equation 7.10

Where,

- $P_{\text{int}}CPn$ denotes intermediate performance at checkpoint n
- 6 represents the highest level of performance
- $In\ Actual\ Perf_{criterionc}$ denotes the actual / delivered criterion representing the fulfillment of each criterion of the trusted agent at an intermediate checkpoint.
- $InMAP_{criterionc}$ denotes mutually agreed performance of the trusted agent according to the given criterion at the intermediate checkpoint.

- $Clear_{criterionc}$ represents the clarity of each criterion in the service agreement (contract) and whether it is understood in the same way by both parties. For a given criterion, $Clear_{criterionc}$ can have two levels (a) ‘0’ – This criterion or its output or both have not been mutually agreed to by both parties and (b) ‘1’ – This criterion along with its output has been mutually agreed to by both parties.
- $\text{Imp}_{criterionc}$ denotes the importance of each criterion that affects the determination of trustworthiness. For a given criterion, $\text{Imp}_{criterionc}$ can have two levels: (a) ‘0’ – unimportant and (b) ‘1’ – important.

c. *Step 3: Determining an Incentive Checkpoint(s) (Incentive CP)*.

After the trusting the agent has evaluated the performance of the trusted agent at checkpoints, the trusted agent then can determine whether a checkpoint will be categorized as incentive checkpoint or not. In this approach, the incentive at each checkpoint will be issued if the performance of a trusted agent at the current checkpoint is higher than for the previous checkpoint. Hence, if $Pint_{CPn} > Pint_{CPn-1}$, where n > 1, the trusting agent will give an incentive to the trusted agent, while $Pint_{CPn}$ is intermediate performance at current checkpoint and $Pint_{CPn-1}$ is the intermediate performance at the previous checkpoint. We term the checkpoint which receives the incentive as the *‘incentive CP’*. During one transaction, there would be several checkpoints. It is important to note that the incentive is given only if the agent has shown an increase in performance at a certain level which is determined by equation 7.11.

3. *Step 4: Calculating Incentive value*.

As was discussed in Chapter 4, the trusting agent will give an incentive value as a kind of ‘trust value’. In this research, the highest accumulated value as an incentive during a transaction is ‘1’. Hence, the value of incentive for each ‘incentive CP’ is calculated as follows:

$$Incentive\ CP = \frac{1}{\text{total number of CP}}$$ **Equation 7.11**

4. *Step 5: Increasing performance as a response of incentive.*

Once an agent has received an incentive at a certain checkpoint, an agent will receive an incentive if he increases his performance to a certain level at the next checkpoint. The level of increased performance can be calculated as follows:

$$IPL = CL_{CPn} * \text{initial performance level} * \text{brake}$$ **Equation 7.12**

Where IPL denotes increasing performance level, CL_{CPn} denotes the compliance level at checkpoint n. This CL_{CPn} is chosen randomly by the system at each initial checkpoint. Initial performance is randomly assigned early in the simulation. Brake option is a value of 0 – 0.9, which represents the degree of performance increase after receiving an incentive.

5. *Step 6: The condition of incentive by end of the interaction*

   This approach is intended to motivate the trusted agent to deliver service as closely as possible with the agreed performance. However, in this approach, we employ an incentive deduction as a kind of punishment if the agreed service is not fully delivered by the end of the transaction. At the end of the interaction, the total incentive will be calculated based on the ratio of incentive CP by total number of CP in the course of interaction. It can be mathematically expressed as follows:

$$Incentive\ TV = \frac{Total\ CP\ in\ which\ incentive\ was\ awarded}{Total\ number\ of\ CP}$$

Equation 7.13

Where**,**

- *Incentive TV* denotes incentive trust value as total incentive that the trusted agent receives during the interaction.
- *Total incentive CP* denotes total checkpoints in interaction categorized as incentive CP
- *Total number of CP* denotes total number of checkpoints during the interaction.

If, however, by the end of the interaction, the agreed service is not fully delivered, the incentive deduction can be calculated by comparing the ratio between remaining units and total agreed units. Hence, the net incentive trust value can be calculated using the following formulae:

$$Net\ Incentive\ TV = \ Incentive\ TV - Incentive\ deduction$$

Equation 7.14

Where,

$$Incentive\ deduction = \frac{remaining\ agreed\ performance}{total\ agreed\ performance}$$

Equation 7.15

The mathematical formulation and algorithm of this approach is depicted in Table 7.1. As mentioned in Table 7.1, an incentive is awarded at a given checkpoint (say

CP_n) if either Condition 1 or Condition 2 is satisfied. Additionally, as mentioned in the table below, an incentive is not awarded at CP_n if Condition 3 is true.

$Incentive\ at\ CPn = \binom{yes}{no}$
Condition 1: $Incentive\ at\ CPn = yes,$ if $((P_{int}CP_n) - (P_{int}CP_{n-1})) \geq IPL_n$
$Given\ ((CP_{n-1} == yes) \&\& (P_{int}CP_{n-1} < 1))$
Condition 2: $Incentive\ at\ CP_n = yes, if\ (P_{int}CP_n = P_{int}CP_{n-1} = 1)$
Condition 3: $Incentive\ at\ CP_n = no\ if\ (P_{int}CP_n - P_{int}CP_{n-1}) < IPL_n$

Table 7.1: Mathematical formulation of conditions for performance-driven-based approach

Let us consider an example from the previous case study in the interaction between 'Loyalty Company' and 'ABS White' for elucidation purposes of performance-driven-based incentive. At each checkpoint in TS_1, it is agreed that ABS White will deliver 20 audited files. Let us consider that at the first checkpoint (CP_1), ABS White delivers only 19 units. At this first checkpoint, by using formulae in equation 7.10, the intermediate performance for this CP_1 is 5.7. In the framework of proactive continuous performance monitoring, we propose a mechanism by which the performance gap at the previous checkpoint is carried over to the next checkpoint if it is below the error tolerance. As described in the previous section, the agreed error tolerance is 0.05. Hence, in this case, the agreed performance for the second checkpoint is 21 units instead of 20 unit files. If at the CP_2, the performance level is greater than CP_1, this checkpoint is characterized as an incentive checkpoint. For example, if the agent delivers 21 units, using equation 7.10 the $P_{int}CP_2$ is 6. As $P_{int}CP_2$ is greater than $P_{int}CP_1$, this CP_2 is marked as incentive CP. As a result of receiving the incentive, this agent will increase his performance level at CP_3. The increasing performance level is calculated by using equation 7.12. This mechanism continues until the end of the transaction time space. At the end of the interaction, the third party agent will calculate the total number of incentives. Let us further assume that during the interaction, the trusted agent received an incentive at three checkpoints. By using the formula in equation 7.13, at each incentive CP, the value of the incentive is 0.083. Let us consider that there is no further change to the number of checkpoints during the interaction and finally the agent receives an incentive at three checkpoints as explained. At the end of the interaction, by using equation 7.13, the value of the incentive for this interaction is 0.25.

In this approach, if by end of the interaction, the trusted agent is not able to deliver all 240 audited files, the value of the incentive is deducted. Let us assume that by the end of the agreed time space, the trusted agent has delivered only 220 audited files. Hence, the incentive deduction is 0.091 as calculated using equation 7.15 and by using equation 7.14, the net incentive value for this interaction is 0.159.

7.4.2 **Error-tolerance-based Incentive**

In this approach, a trusted agent will receive an incentive if the performance at any checkpoint is greater than or equal to a specific threshold value agreed to by both parties.The objective of this approach is to motivate trusted agents to maintain their performance in delivering service to the trusting agent at least higher than error tolerance as determined and agreed to by both parties. Let us consider an example from the previous section between Loyalty Company and ABS White. Both parties have agreed that the level of error tolerance is 0.05. In order to encourage the trusted agent to perform higher than the error tolerance margin, we design an error-tolerance based incentive approach. Let us further assume that, both parties agree on a threshold value of 0.02 in this approach. It means that once the trusted agent complies on 0.02 higher than error tolerance, this trusted agent will receive an incentive. Unlike the previous approach, the trusted agent does not need to show an improvement of performance level after receiving the incentive. However, as long as the performance discrepancy is within the specified threshold, the agent will get an incentive. The steps included in this approach are as follows:

a. *Step 1: Defining Incentive Requirements in SLA*

   This step is exactly that same as that of the previous approach. In order to employ this approach, both parties have to agree on a certain threshold of requirements in order to give incentive. In this case, they agree on a certain value which determines when the trusted agent can receive incentive.

b. *Step 2: Evaluating the intermediate performance or intermediate trust level at each checkpoint*

   This step is also exactly the same as that of the previous approach. Once both parties have the mutual agreement which specifies the time slots, checkpoints and agreed performance, they can assess an intermediate performance at each checkpoint using equation 7.8. Based on the result of this intermediate performance, the trusting agent can then determine whether in that particular checkpoint(s), a trusted agent is eligible to receive incentive.

c. Step 3: Determining an Incentive Checkpoint(s) (Incentive CP)

   After the trusting agent evaluates the performance of the trusted agent at the specified checkpoints, the trusted agent can then determine whether or not a checkpoint will be categorized as an incentive checkpoint. In this approach, the incentive at each checkpoint will be issued if the performance of a trusted agent at any checkpoint is higher than a certain threshold which has been pre-determined.

   Hence, if $Pint_{CPn} \geq$ *agreed threshold value*, the trusting agent will give an incentive to the trusted agent, while $Pint_{CPn}$ is the intermediate performance at the current checkpoint and *agreed threshold value* is a value that is agreed by both parties to determine the minimum level for receiving an incentive. We term the checkpoint which receives the incentive the *'incentive CP'*. During one transaction, there would be several checkpoints. It is important to note that the incentive is given only if the agent has performed better than or equal to the agreed certain threshold value.

d. *Step 4: Calculating Incentive Value.*
Similar to the previous step, the trusting agent will give an incentive value as a kind of 'trust value'. In this research we fix the highest accumulated value as an incentive during a transaction is '1'. Hence, the value of incentive for each 'incentive CP' is calculated using formula 7.11.

The mathematical expression and algorithm of this approach is depicted at Table 7.2. As can be seen from the table below in the error-tolerance-based incentive approach, an incentive is awarded at a given checkpoint (say CP_n) if condition 1 is true and is not awarded is condition 1 is false and condition 2 is true.

$Incentive\ at\ CPn = \{^{yes}_{no}\}$
Condition 1: $Incentive\ at\ CPn = yes,$
$if\ (1 - P_{int}CPn) < (Error\ Tolerance - Threshold)$
Condition 2: $Incentive\ at\ CPn = no,$
$if\ (1 - P_{int}\ CPn) \geq (Error\ Tolerance - Threshold)$
Where n > 1, and threshold denotes the additional service delivery effort required beyond the error tolerance for an incentive to be awarded.

Table 7.2: Mathematical formulation of conditions for error-tolerance-based incentive

We continue with the example above concerning the interaction between 'Loyalty Company' and 'ABS White'. They have agreed that the error tolerance level is 0.05. Let us assume that they agreed on 0.02 as a threshold value for obtaining incentive. Hence, if the trusted agent delivers services equal to or greater than 0.97, this agent will receive an incentive. In this case, if the intermediate performance at any checkpoint is equal to or greater than 5.87, the checkpoint will be known as incentive CP.

Let us further assume that at the first checkpoint (CP_1), 'ABS White' delivers 18 units. At this first checkpoint, by using formula 7.10, the intermediate performance for this CP_1 is 5.4. As the intermediate performance in this CP_1 is lower than 5.87, this agent will not receive incentive; in other words, we cannot categorize this checkpoint as incentive CP. This mechanism continues until the end of the transaction time space. The formula for calculating the incentive CP and total incentive by the end of the interaction is exactly the same as that for the previous approach. However, there is no incentive deduction if, by the end of the interaction, the trusted agent does not deliver all the agreed performance.

7.4.3 **Occurrence-based Incentive**

In this approach, an incentive is given if the performance of the trusted agent at the current checkpoint is greater than or equal to the performance at the previous checkpoint. However, unlike the first approach (performance-driven-based), an agent does not need to increase his performance in response to receiving an incentive. The increased performance is a chance occurrence. The steps involved in this approach are as follows:

a. *Step 1: Defining Incentive Requirements in SLA*

   This step is similar to that in the previous two approaches. It has to be mutually agreed upon that whenever both parties show an increasing performance compared to that at the previous checkpoint, the agent will receive incentive. In the case that the agent fully performs (deliver service in 100%) at a particular checkpoint, an agent will receive an incentive if he performs at 100% at the next checkpoint.

b. *Step 2: Evaluating the intermediate performance or intermediate trust level at each checkpoint*

   This step is also exactly the same as that of the previous approach. Once both parties have the mutual agreement which specifies the time slots, checkpoints and agreed performance, they can assess intermediate performance at each checkpoint using equation 7.10. Based on the result of this intermediate performance assessment, the trusting agent can then determine whether at that particular checkpoint(s), a trusted agent has shown an increased performance.

c. *Step 3: Determining an Incentive Checkpoint (Incentive CP)*

   After the trusting agent has evaluated the performance of the trusted agent at checkpoints, the trusted agent can then determine whether or not a checkpoint will be categorized as an incentive checkpoint. In this approach, the incentive at each checkpoint will be issued if the performance of a trusted agent at the current checkpoint is higher than that at the previous checkpoint.

   Hence, if $Pint_{CPn} > Pint_{CPn-1}$, the trusting agent will give an incentive to the trusted agent, while $Pint_{CPn}$ is the intermediate performance at current checkpoint and $Pint_{CPn-1}$ is the intermediate performance at the previous checkpoint. The *'incentive CP'* is that checkpoint which receives the incentive. During one transaction, there would be several checkpoints. It is important to note that the incentive is given only if the agent has shown an increase in performance.

e. *Step 4: Calculating the Incentive Value.*

   Similar to the previous step, the trusting agent will give an incentive value as a kind of 'trust value'. In this research, the highest trust value as an incentive during a transaction is '1'. The value of incentive for each checkpoint can be calculated using formula 7.11 above.

The mathematical expression and algorithm framework for this approach is depicted in Table 7.3. As can be seen from the table below an incentive is awarded at a given checkpoint (say CP_n) if either Condition 1 or Condition 2 is satisfied. Additionally, an incentive is not awarded at CP_n if Condition 3 is true.

$$Incentive\ at\ CPn = \{{yes \atop no}\}$$

Condition 1: $Incentive\ at\ Cn = yes,$

$$if\ (P_{int}CPn > P_{int}CPn - 1),$$

$$given\ (Pint\ CPn - 1 < 1)$$

Condition 2: $Incentive\ at\ Cn = yes,$

$$if\ (P_{int}CPn = P_{int}CPn - 1 = 1)$$

Condition 3: $Incentive\ at\ Cn = no, if\ (P_{int}CPn \leq P_{int}CPn - 1)$

$$where\ n > 1, and\ P_{int}CPn\ refers\ to\ equation\ 7.10$$

Table 7.3: Mathematical formulation of conditions for occurrence-based incentive

Continuing with the example above from the interaction between 'Loyalty Company' and 'ABS White', in this approach, if the intermediate performance at any checkpoint is equal to or greater than that at the previous checkpoint, the checkpoint can be categorized as incentive CP. The increasing performance level occurs by chance only. Hence, the requirement to obtain incentive is very simple, once the agent has shown an increasing performance compared to that at the previous checkpoint, this particular checkpoint will marked as incentive CP. By the end of the interaction, the total incentive is calculated in the same way as that of the two previous approaches.

7.5 Conclusion

In this chapter, we present a framework for proactive continuous performance monitoring and an incentive mechanism for the successful delivery of service. Proactive continuous performance monitoring is designed to proactively monitor the performance of interacting parties. The aim of this framework is to identify the performance gap as early as possible and to provide a strategy to address any performance gap as soon as possible before it spirals out of control. Moreover, in order to ensure successful service delivery, we present a framework for the provision of an incentive. We present the use of reward and incentive to motivate both parties to comply as closely as possible with the terms of the SLA. There are three approaches that can be utilized to provide an incentive for successful service delivery. The main purpose of these frameworks (proactive continuous monitoring and incentive mechanism) is to facilitate successful service delivery. Hence, by the end of the interaction, the trust level has reached a positive level as the trusted agent has delivered service as agreed to by the trusting agent. We demonstrate the effectiveness of this framework in Chapter 9. In the next chapter, we present a framework for trust re-calibration at the end of the time space of interaction.

7.6 **References**

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Chapter 8 - **Framework for Trust Re-calibration**

8.1 **Introduction**

In Chapter 7, we presented details of a framework for proactive continuous performance monitoring and incentive mechanisms. These mechanisms are carried out during the course of the interaction. Hence, our methodology facilitates maintaining trust by using historical data of both the trust level records and performance records. This is to ensure that by the end of the interaction, both parties will deliver service as closely as possible to that specified in the mutual agreement. As mentioned previously, our methodology is intended for trust maintenance in virtual environments. The basic assumption is that trust has already been established in an interaction and needs to be maintained by consistently monitoring and examining the interaction. Hence, by the end of the interaction, both parties need to re-calibrate or re-examine their trust level. It is the last step of our methodology for maintaining trust whereby both parties can obtain the final trust level at the end of the interaction time space. In this chapter, we present our generic framework for trust re-calibration by the end of the interaction in the trust maintenance phase both for interaction with incentive and without incentive.

Section 8.2 describes the details of the framework. Section 8.3 explains several metrics that will be used to develop the approaches for final trust calculation. Section 8.4 presents three different approaches for calculation of trust final in an interaction without an incentive mechanism agreement. In order to illustrate the operability of our framework, we present a case study in Section 8.5 which continues from that in the previous chapter. Section 8.6 presents three approaches for calculation of final trust for the interaction with incentive, and Section 8.7 concludes the chapter.

8.2 Detailed Framework of Trust Re-calibration

As was explained in Chapter 4, the main purpose of trust maintenance is to preserve the current trust value so that it will remain stable or possibly increase. In order to achieve this, we need to know the level of the trust values prior to, during, and after the interaction. As both parties have an initial trust at the beginning of their interaction, we argue that trust is maintained if the level of trust after the interaction (final trust value) is equal to, or greater than, the initial trust level. Hence, in determining final trustworthiness, the initial trust value that was established during the building phase is subject to recalibration or re-assessment at the end of each interaction in the maintenance stage. Therefore, the methodological framework for computing the final trust value of an interaction during the trust maintenance phase would be different from that used during the trust building phase. This would be due to the different focus in these phases in terms of trust value calculation. In the trust building phase, the actual behaviour during the interaction is measured only at the end of the interaction whereas in trust maintenance phase, the trust value is re-calibrated. Since the trust level has already been established during the trust building phase, in the trust maintenance phase, trust is subject to re-calibration. In order to ensure that trust is maintained, we propose a model for formally testing trust levels during the relationship. This formal testing takes into account the dynamic nature of trust in a relationship. This model is based on a proactive continuous performance monitoring approach for trust maintenance that was presented in Chapter 7.

In the previous chapter, we proposed the use of time slots coupled with checkpoints to assist in the maintenance of trust. In the case of unmet performance or unfulfilled contract occurring, the discrepancy can be identified and addressed at the checkpoint bases. In this case, the number of checkpoints in each time slot is designed to review the progress of service delivery. Since at every checkpoint there is a review process of intermediate actual performance against intermediate agreed performance (for that checkpoint), the trusting agent can assign an intermediate trust value (reflecting the degree of compliance of the trusted agent at that checkpoint at the interaction). Therefore, given a finite number of checkpoints during the interaction, the trusting agent may have multiple intermediate trust values, each of which corresponds to the intermediate checkpoint. Debenham et al. (Debenham and Sierra 2008) state that this can be considered as the experience of trust during an interaction. Trust experience can be based on experience during the history of the transaction. Trust that is experienced throughout this relationship (checked and reviewed at every checkpoint) will determine or contribute towards the final trust value at the end of the interaction. The trust intermediate calculation at each checkpoint designed to represent the trust experienced during a transaction. In the next section, we propose three different approaches for final trust calculation as a result of proactive continuous performance monitoring.

Based on proactive continuous performance monitoring as explained in the previous chapter, by the end of the relationship, the trusting agent will have the following information:

a. Agreed Performance Information
   Agreed performance information is a statement of performance or behaviour that is agreed to by both parties. This statement can be found in the mutually agreed behaviour or business contract or Service Level Agreement (SLA). Continuing with the case study that we presented in Chapter 7 of a relationship between service auditor ('ABS White') and a business company ('Loyalty Company'), the finished auditing of 240 financial accounts within one month is the agreed performance. The outcome of the negotiation phase, which is a contract between the interacting parties denotes or manifests the agreed performance between the two interacting parties. In the contract, the agreed performance information would be specific using the following parameters for the service:
   - The criteria that comprise the service
   - A quantitative representation of each agreed criterion that comprises the service
b. Actual Outcome Performance Information
   We define the actual performance information as the actual delivery of service by the trusted agent at the end of the interaction. The outcome-based performance can be specified using the following parameters:
   - Actual criteria delivered by the trusted agent at the end of the interaction
   - Quantitative representation describing the actual number of units delivered for each criterion
c. Intermediate Agreed Performance Information
   We define the intermediate agreed performance as the agreed delivery of service between both the parties at the intermediate checkpoint. This delivery of service is agreed to by both parties. For instance, based on the previous example, 60 files of financial accounts is the intermediate agreed performance information (for Time Slot 1 (TS_1), TS_2, TS_3 and TS_4). The intermediate agreed performance can be specified using the following parameters. Moreover, the performance is checked at each checkpoint and it has been agreed that the intermediate agreed performance at each checkpoint is 20 files. Hence, initially, at C_1, C_2,....C_{12}, the agreed performance is 20 files per checkpoint (C_1 – C_{12}). However, as we use a proactive continuous performance monitoring mechanism with the purpose of capturing the dynamically changing performance, the agreed performance at each checkpoint may also change based on the occurrence of performance gaps and policies or behaviours to close the gaps. We explain this situation in point e below (adjusted agreed performance information). The intermediate agreed performance can be specified using the following parameters:
   - The criteria that comprise the intermediate service.
   - Quantitative representation of each agreed criterion at intermediate checkpoints.
d. Intermediate Actual Performance Information
   We define the intermediate actual performance as the actual delivery of service by the trusted agent at the intermediate checkpoints. The intermediate actual performance can be defined using the following parameters:
   - Actual criteria delivered by the trusted agent at each checkpoint

- Quantitative representation describing the actual number of units delivered for each criterion

e. Adjusted Agreed Performance Information

We define the adjusted agreed performance as the adjusted agreed delivery of service by the trusted agent at the intermediate checkpoint. This adjustment results from the mechanism of proactive continuous performance monitoring. The adjusted agreed performance information can be described using the following parameters:

- The adjusted criteria that comprise the intermediate service
- Quantitative representation describing each adjusted agreed criterion at intermediate checkpoints.

Let us continue with the above example, where the initial intermediate agreed performance at C_1 is 20 files. If, for instance, in C_1, the trusted agent delivers only 18 files, and let us further assumes that based on the policy for closing this performance gap, the 2 remaining files are adjusted in the next checkpoints, then the intermediate agreed performance in C_2 is adjusted upwards to 22 files.

Based on the above data that the trusting agent has obtained during the interaction, we propose three approaches to calculate the final trust value. The suite of metrics that we propose in this thesis are based on the CCCI metrics proposed by Hussain et al. (Chang, Dillon et al. 2006), (Hussain, Chang et al. 2004). CCCI metrics is a set of QoS, as a means of measuring the trusting agent's trust in the trusted agent after the interaction. The trustworthiness value is expressed as 'the degree consonant or parallelism between the actual behaviour of a trusted agent and the mutually agreed behaviour of the trusted agent, as perceived by a trusting agent' (Chang, Dillon et al. 2006) (Hussain, Chang et al. 2004). Hence, the trustworthiness value of an interaction can be expressed mathematically as shown below:

$$\text{Trust Final} = 6 * \left(\frac{Actual\ Performance_{interaction}}{Mutually\ Agreed\ Performance_{interaction}}\right) \quad \textbf{Equation 8.1}$$

$$\text{Trust Final} = 6 * \left(\frac{\sum_{c=1}^{n} APCorr_{\ criterion\ c} * Clear_{criterion\ c} * Imp_{criterion\ c}}{\sum_{c=1}^{n} MAP\ Corr_{criterion\ c} * Clear_{criterion\ c} * Imp_{criterion\ c}}\right) \quad \textbf{Equation 8.2}$$

As defined by Hussain et al. (Hussain, Chang et al. 2004; Chang, Dillon et al. 2006), the Actual Performance ($APCorr_{\ criterion\ c}$) is a metric that 'qualifies and expresses the actual performance of the trusted agent in the given criterion'.

Mutually Agreed Performance ($MAP\ Corr_{criterion\ c}$) is a metric that 'qualifies and expresses the mutually agreed performance of the trusted agent in the given criterion'.

Clarity of Criterion ($Clear_{criterion\ c}$) is a metric that qualifies the extent to which a criterion is mutually agreed upon by the trusting agent and trusted agent. For a given criterion, $Clear_{criterion\ c}$ can have two levels:

- 0 – This criterion or its output or both have not been mutually agreed to by both parties
- 1 – This criterion along with its output has been mutually agreed to by both parties

$Imp_{criterion\ c}$ or Importance is a metric that qualifies the extent of importance of a criterion for the trusting agent in the interaction. For a given criterion, $Imp_{criterion\ c}$ can have two levels:

- 0 – Unimportant, which refers to supplementary criteria
- 1 – Important, which refers to mandatory criteria

The actual performance and mutually agreed to performance metric will be adjusted based on a defined approach that will be used to calculate Final Trust Value.

8.3 **Approaches for Final Trust Calculation**

In this section, we present three approaches that can be utilized to measure final trust at the end of the interaction during the trust maintenance phase. These approaches are based on several benchmarking metrics gathered during proactive continuous performance monitoring for the duration of the transaction.

8.3.1 **Outcome-based Final Trust Value (OFTV)**

We define *outcome-based final trust value* as 'performance assessment done using outcome-based performance information and agreed performance information at the end of interaction'. At a conceptual level, this may be expressed as follows:

$$OFTV = f\ (outcome\ performance\ information, agreed\ performance\ information)$$

Equation 8.3

The trust re-calibration in this approach is based on the correlation of agreed performance with the actual outcome performance at the end of the interaction. The actual performance outcome is determined by the final outcome at the end of the interaction and by using the CCCI metrics proposed by Hussain et al. (Hussain, Chang et al. 2004; Chang, Dillon et al. 2006). In the outcome-based approach, the compliance or non-compliance of the mutually agreed performance at the intermediate checkpoints is not taken into consideration; rather the compliance or non-compliance (or degree of compliance) of all the mutually agreed goals at the end of the interaction determines the outcome-based trust value. This approach considers only the final service delivery by the trusted agent to the trusting agent. In this approach, we calculate the final trust value as follows:

$$\text{Trust Final} = 6 * \left(\frac{\sum_{c=1}^{n} Actual\ outcome\ Performance\ Corr_{criterion\ c} * Clear_{criterion\ c} * Imp_{criterion\ c}}{\sum_{c=1}^{n} MAP\ Corr_{criterion\ c} * Clear_{criterion\ c} * Imp_{criterion\ c}}\right)$$

Equation 8.4

8.3.2 **Checkpoint-based Final Trust Value (CFTV)**

We define the *checkpoint-based final trust value* as 'performance assessment done using intermediate performance information and agreed intermediate performance information'. At a conceptual level, this may be expressed as follows:

$$CFTV = f\begin{pmatrix} intermediate\ agreed\ \ performance\ information, \\ agreed\ intermediate\ performance\ information \end{pmatrix}$$

Equation 8.5

In this approach, a final trust value is determined by aggregating the intermediate trust values during the entire time of the interaction. The evidence of trust experienced is collected / accumulated at each checkpoint. The intermediate checkpoint-based trust value is measured by the correlation between intermediate actual performance and intermediate agreed performance. With this approach, a fine-grained view of an agent's performance is aggregated to determine the final trust value. In contrast to the outcome-based approach, during the transaction, the trusting agent confirms the intermediate performance of the trusted agent at every checkpoint. Therefore, by the end of the interaction, the final trust value can be determined by calculating the average of the intermediate trust levels.

$$\text{Trust Final} = \left(\frac{\sum_{c=1}^{N} T\ in}{n}\right)$$ **Equation 8.6**

where

$T\ in$ is intermediate Trust and η denotes the total number of checkpoints in an interaction. $T\ in$ Value can be calculated as follows:

$$T\ in = 6 * \left(\frac{\sum_{c=1}^{N} Intermediate\ Actual\ Performance_{criterion\ c} * Clear_{criterion\ c} * Inf_{criterion\ c}}{\sum_{c=1}^{N} Intermediate\ MAP_{criterion\ c} * Clear_{criterion\ c} * Inf_{criterion\ c}}\right)$$

Equation 8.7

Where;

$Intermediate\ Actual\ Performance_{criterion\ c}$ is the actual service delivered by the trusted agent at each checkpoint

$Intermediate\ MAP_{criterion\ c}$ is the intermediate service delivery that is agreed to by both parties at each checkpoint. It is important to note here that, whenever this mutually agreed to intermediate performance is adjusted, we use the adjusted information to calculate intermediate trust.

8.3.3 **Weighted-based Final Trust Value (WFTV)**

We define *weighted-based final trust value* as 'performance assessment done using combination between outcome based final trust value (OFTV) and checkpoint-based final trust value (CFTV)'. At a conceptual level, this may be expressed as follows:

$$WFTV = f\ (OFTV, CFTV)$$ **Equation 8.8**

This approach is proposed to give some weight to the two different types of final trust value calculation presented in Sections 8.3.1 and 8.3.2. As in the TMM, there is a proactive continuous monitoring of performance, the agent who always complies at every checkpoint might be different from the agent who does not comply at every checkpoint but delivers the full service by the end of the interaction. This approach can be mathematically expressed with the following equation:

$$\text{Trust Final} = (\alpha * \text{OFTV}) + (\beta * \text{CFTV})$$ **Equation 8.9**

Where, $\alpha\ and\ \beta$ are weighted for weighting outcome-based final trust and checkpoint-based trust value. In this case, the policy for determining α and β depends on how the trusting agent assigns an important value to both parameters. However, the aggregate number of α and β is 1. For example, some agents may place more importance on real-time trust value as incorporated in intermediate trust than on outcome-based trust. Thus, the trusting agent will give more weight to β than α. However, if the trusting agent places more emphasis on the final outcome of the interaction rather than on how the trusted agent performs during the interaction, then this trusting agent will assign more value to α than β.

In order to illustrate the operability of these three approaches, we explain their workings using a case study which is presented in the next section. In this chapter, we make use of the case study scenario described in Chapter 7 (transaction between 'Loyalty Company' and 'ABS White').

8.4 **Case Study**

In this section, we develop a simple case study to elucidate the workings of the framework for trust recalibration and how final trust can be calculated using the approaches that we have proposed in the previous section.

Let us continue using a simple example from the previous chapter which involves a business relationship between 'Loyalty Company' and 'ABS White'. 'Loyalty

Company' requests that 'ABS White' audit its 240 files of financial accounts within one month. As a result, in their Service Level Agreement (SLA), 'ABS White' agreed to audit and deliver 240 files of audited financial account over the next one month and 'Loyalty Company' agreed to pay $100 for each file audited. For simplicity, we include only one service criterion in this interaction. The details of the SLA for this interaction are as follows:

Transaction ID:	Xxx		
Time Space:	1 November 2010 – 30 November 2010		
Trusting agent ID:	Loyalty Company		
Trusted agent ID:	ABS White		
Service Context:	Auditing Service		
Time Slot:	4 (Four)		
Number of initial CP:	3 (Three) per Time Slot		
Level of Error tolerance:	0.05		
Service Descriptions	Service Criteria	Level of Importance	
		Trusting Agent (Loyalty Company)	Trusted Agent (ABS White)
S_1: Quantity	C_{11}: 240 files of financial account	1	1
S_2: Price	C_{21}: $24000	1	1

Table 8.1: Service level agreement

As we can see from Table 8.1 above, the time frame of the relationship is for one year and there are four time slots in the relationship. The details of the Time Window are as follows:

a. Time frame is the duration of the relationship to finish or to deliver service which is one month (1 November 2010 – 30 November 2010).
b. Time slot is the number of intermediate tasks that should be fulfilled or delivered. Based on the above SLA, both parties agreed that time slot would be 4 (four) during interaction. Therefore, the number of time slots is four with the duration details as follows:
   - Time Slot 1 (TS_1) : 1 November 2010 – 7 November 2010
   - Time Slot 2 (TS_2) : 8 November 2010 – 15 November 2010
   - Time Slot 3 (TS_3) : 16 November 2010 – 22 November 2010
   - Time Slot 4 (TS_4) : 23 November 2010 – 30 November 2010
c. Checkpoints are the number of points used to review the performance of service deliverability in each time slot. In this case, a third party agent determines this number of checkpoints by using equation 7.1. Let us further consider that the number of checkpoints in every time slot is 3 (three). Since the number of time slots is 4 (four), the total number of checkpoints for the whole interaction is 12 (twelve). Let us assume that the statement of intermediate agreed performance for 'Loyalty Company' and 'ABS White' at each checkpoint is as follows:

Time Slot (TS)	Date	Checkpoints	ABS White	Loyalty Company
TS_1	3 November 2010	C_1	20 files	$ 2000
	5 November 2010	C_2	20 files	$ 2000
	7 November 2010	C_3	20 files	$ 2000
TS_2	10 November 2010	C_4	20 files	$ 2000
	12 November 2010	C_5	20 files	$ 2000
	15 November 2010	C_6	20 files	$ 2000
TS_3	17 November 2010	C_7	20 files	$ 2000
	19 November 2010	C_8	20 files	$ 2000
	22 November 2010	C_9	20 files	$ 2000
TS_4	25 November 2010	C_{10}	20 files	$ 2000
	27 November 2010	C_{11}	20 files	$ 2000
	30 November 2010	C_{12}	20 files	$ 2000
Total		12 Checkpoints	240 files	$ 24000

Table 8.2: Intermediate agreed performance

After both parties have the details of the above service delivery for each checkpoint, they follow the third step of the methodology which is performance monitoring and an incentive mechanism as discussed in Chapter 7. In the performance monitoring step, both parties execute their tasks and monitor the progress of performance. This means that for every checkpoint, both parties monitor whether their interacting party performs as agreed. For example, at checkpoint 1 (C_1), 'Loyalty Company' reviews whether or not 'ABS White' delivers 20 files of audited financial accounts. Therefore, 'Loyalty Company' has information about 'ABS White's intermediate actual performance. 'Loyalty Company' needs to assign a trust value to ABS White's performance at this checkpoint (C_1). On the other hand, 'ABS White' also assigns a trust value to 'Loyalty Company' based on Loyalty Company's intermediate actual service delivery at this checkpoint.

Let us continue with the following data set of agreed performance and actual performance at each checkpoint for the whole interaction as depicted in Table 8.3. For simple illustration purposes, we provide the data set for ABS White's performance only. Therefore, 'Loyalty Company' will re-calibrate their trust value toward 'ABS White' at the end of the interaction based on the data set given in Table 8.3.

Time	Check points	Intermediate Agreed performance	Adjusted Agreed performance	Actual performance
3 November 2010	C_1	20	20	19
5 November 2010	C_2	20	21	18
7 November 2010	C_3	20	23	21
10 November 2010	C_4	20	22	22
12 November 2010	C_5	20	20	17
15 November 2010	C_6	20	23	22
17 November 2010	C_7	20	21	19
19 November 2010	C_8	20	22	22
22 November 2010	C_9	20	20	18
25 November 2010	C_{10}	20	22	21
27 November 2010	C_{11}	20	21	20
30 November 2010	C_{12}	20	21	21
Total	12	240		240

Table 8.3: Interaction performance data

At Checkpoint 1 (C_1), the agreed performance is that 'ABS White' should deliver 20 units of audited file. However, 'ABS White' delivers only 19 files. Let us further assume, that third party agent take an action to employ policy to close this performance gap. Based on our TMM, 1 files (20 - 19) are forwarded to the checkpoint 2 (C_2) agreed performance; therefore, the agreed performance in C_2 is adjusted to be 21 service units. In C_2, again 'ABS White' could not fully meet the adjusted agreed performance. As shown in Table 8.3, it only delivers 18 files. It is agreed that the 3 remaining files will be covered at checkpoint 3 (C_3). Hence, the agreed performance in C_3 is adjusted to be 23 units (20 + 3) and so on. Based on these performance data, Table 8.4 below provides intermediate trust calculation from 'Loyalty Company' to 'ABS' White using Equation 8.7.

Check points	Intermediate Agreed performance	Intermediate Adjusted Agreed performance	Intermediate Actual performance	Intermediate Trust Value
C_1	20	20	19	5.7
C_2	20	21	18	5.14
C_3	20	23	21	5.47
C_4	20	22	22	6
C_5	20	20	17	5.1
C_6	20	23	22	5.74
C_7	20	21	19	5.43
C_8	20	22	22	6
C_9	20	20	18	5.4
C_{10}	20	22	21	5.73
C_{11}	20	21	20	5.71
C_{12}	20	21	21	6

Table 8.4: Intermediate trust values

Hence, at the end of the interaction, 'Loyalty Company' has a series of performance-related data that contain intermediate agreed performance, intermediate adjusted agreed performance, intermediate actual performance and intermediate trust value. In order to determine the final trust value, the three approaches as proposed in the previous section are used. Details of the final trust calculation are given in the following sections.

8.4.1 **Outcome Based Final Trust Value (OFTV)**

The trust recalibration for this approach is based on the correlation of actual outcome performance with agreed performance in the interaction. The actual outcome performance is the total amount of actual performance. The final trust value for this approach is calculated using Equation 8.4:

$$\text{FinalTrust} = 6 * \left(\frac{\sum_{c=1}^{n} Actual\ outcome\ Performance\ Corr_{criterion\ c} * Clear_{criterion\ c} * Imp_{criterion\ c}}{\sum_{c=1}^{n} MAP\ Corr_{criterion\ c} * Clear_{criterion\ c} * Imp_{criterion\ c}}\right)$$

The criterion of this interaction is only 1 which is a service unit. The criterion is very clear (1) as both parties formalize and negotiate this criterion in the second phase of our methodology and the importance level (Imp criterion) is 1 (important). Hence, the final trust calculation is:

$$\text{FinalTrust} = 6 * \left(\frac{240 * 1 * 1}{240 * 1 * 1}\right)$$

$$\text{Final Trust} = 6$$

Hence, this final trust value corresponds to the above scenario wherein all the 240 files were delivered by 'ABS White' to 'Loyalty Company' at the end of the interaction.

8.4.2 **Checkpoint-based Final Trust Value (CFTV)**

Based on Table 8.4 above, 'Loyalty Company' has a data set for its calculation of intermediate level of trust in 'ABS White'. The Final Trust Calculation using Equations 8.6 and 8.7 is as follows:

$$\text{FinalTrust} = \left(\frac{\sum_{c=1}^{N} T\ in}{n}\right)$$

Where, T_{in} = Intermediate Trust and n denotes the total number of checkpoints during the interaction.

$$\text{FinalTrust} = \left(\frac{T_{in1} + T_{in2} + T_{in3} + T_{in4} \ldots\ldots + T_{in12}}{12}\right)$$

$$\text{FinalTrust} = \left(\frac{5.7 + 5.14 + 5.47 + 6 + \cdots + 5.71}{12}\right)$$

$$\text{Final Trust} = 5.62$$

8.4.3 **Weighted Final Trust Value (WFTV)**

As mentioned in Section 8.3.3; the weighted final trust value is determined as a function of checkpoint-based final trust value and outcome-based final trust value. It gives a predefined weight for each checkpoint-based and final trust. Let us consider that 'Loyalty Company' takes α as 0.6 and β is 0.4. Hence, in this approach, the calculation of final trust using Equation 8.9 is as follows:

$$\text{FinalTrust} \; = (\alpha * OFTV) + \; (\beta * CFTV)$$

$$\text{Final Trust} \; = (0.7 * 6) + \; (0.3 * 5.62)$$

$$\text{Final Trust} \; = (4.20) + \; (1.69)$$

$$\text{Final Trust} \; = 5.89$$

Based on the case study above, by using the three different approaches to calculate Final Trust value, 'Loyalty Company' will have a different final trust value after their interaction with 'ABS White'. The summary of the final trust values based on the three approaches is as follows:

No.	Approach	Correlation or Formula Direction	Final Trust Value
1.	Outcome-based Final Trust Value (OFTV)	agreed performance vs. actual outcome performance	6
2.	Checkpoint-based Final Trust Value (CFTV)	average of adjusted intermediate agreed performance vs. intermediate actual performance	5.62
4.	Weighted-based Final Trust Value (WFTV)	weighted combination of outcome-based and checkpoint-based	5.89

Table 8.5: Summary of final trust values

It can be seen from the above case study and simulation results that each of the above approaches result in a different final trust value. The highest final trust value is derived from the outcome-based approach which is a correlation between agreed performance and actual outcome performance at the end of the interaction, while the lowest final trust value is produced by the checkpoint-based approach. However, the checkpoint-based approach takes into account and models the dynamic nature of trust. In checkpoint-based trust, the final trust value is calculated as an average of the intermediate trust value which reflects the trust condition in an interaction due to the dynamic nature of trust. Hence, at any given point in time, real-time data regarding trust levels can be found in intermediate trust value calculation. Updated information on trust value makes it necessary to re-calibrate trust.

The outcome-based final trust value approach is based on the final outcome of an interaction. In this case, this approach produces the highest trust value. However, we argue that this final trust value does not fully represent the mutually agreed upon performance as stated in the SLA. Although by the end of the interaction the trusted agent delivers the service as agreed, this approach does not consider the way in which the trusted agent delivers the service units. The sole focus of these metrics is to compute the degree of conformance to the agreed behaviour and the actual behaviour as measured at the end of the interaction.

The third approach, the weighted-based approach, integrates both of the previous approaches. It combines both the checkpoint-based and the outcome-based approaches. We may consider this weighted approach to be the best and fairest way of calculating final trust value in trust maintenance activities. This is because the trusting agent considers giving a better reward to the trusted agent who always complies with every agreed performance at each checkpoint. However, the importance of actual service delivery as an outcome of interaction is also considered in this approach. Therefore, a weighted-based approach incorporates the final outcome of an interaction with real-time data to update trust status during an interaction.

8.5 **Trust Re-calibration for Interaction with Incentive Trust Value**

In Chapter 7, we presented the framework for incentive mechanisms in proactive continuous performance monitoring. As was discussed in Chapter 7, there is incentive provided for complying behaviour value during the interaction. As a result, the final trust calculation for interaction with incentive and without incentive would be different. In the previous section, we presented and illustrated an interaction without the inclusion of an incentive mechanism in the calculation of the trust levels. In this section, we present the mechanism for trust re-calibration if in the interaction, both parties have agreed to an incentive requirement. We propose three different approaches for final trust calculation of the interactions which are derived from metrics developed in the technique for trust re-calibration for interaction without incentive trust value.

8.5.1 **Outcome-based Incentive**

In this approach, final trust value is calculated based on the total number of service units delivered at the end of an interaction. As the interaction utilized an incentive mechanism, the net incentive is added to this approach. It can be mathematically expressed as follows:

$$
\begin{aligned}
&Trust\ Final \\
&= 6 * \left(\frac{\sum_{c=1}^{n} Actual\ outcome\ Performance\ Corr_{criterion\ c} * Clear_{criterion\ c} * Imp_{criterion\ c}}{\sum_{c=1}^{n} MAP\ Corr_{criterion\ c} * Clear_{criterion\ c} * Imp_{criterion\ c}}\right) \\
&+ Net\ Incentive
\end{aligned}
$$

Equation 8.10

Where, *net incentive* is the total incentive value that the trusted agent receives from an interaction after incentive deduction, if any. The formula for and discussion of this net incentive, can be found in Chapter 7.

8.5.2 Checkpoint-based Incentive

In this approach, similar to the mechanism for interaction without an incentive mechanism, final trust value is the sum of the average of the intermediate trust value plus net incentive. The mathematical expression for this approach is as follows:

$$\textbf{Trust Final} = \left(\frac{\sum_{c=1}^{N} T\ in}{n}\right) + \textit{Net Incentive} \qquad \textbf{Equation 8.11}$$

8.5.3 Weighted-based Incentive

Similar to the weighted-based approach for this approach to the interaction without incentive mechanism, the final trust value is calculated by adding the net incentive. Mathematically it is expressed as follows:

$$\text{Trust Final} = \{(\alpha * \text{OFTV}) + (\beta * \text{CFTV})\} + \text{Net Incentive}$$

Equation 8.12

In any case of final trust calculation, if the trust final resulting from the proposed calculation technique is greater than ‘6’, we round off this value to ‘6’. This is because we use the scale of trust value from ‘0’ to ‘6’ as we discussed in Chapter 4.

8.6 Conclusion

In this chapter, we present the framework for trust re-calibration as the last step in our TMM. As TMM means that both parties have various data that can be used to determine the final trust value, we propose three different approaches to calculate the final trust value. These three techniques, namely, outcome-based approach, checkpoint-based approach and weighted-based approach, will help trusting agents to re-calibrate their initial trust value in the trusted agent at the conclusion of the interaction. We also present three different techniques for final trust calculation if, during the interaction, both parties have agreed to utilize an incentive to facilitate service delivery. In the next chapter, we present the validation of our methodology according to various benchmarks.

8.7 **References**

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Chapter 9 - **Experimental Simulation and Validation of TMM**

9.1 **Introduction**

In the previous chapters, we presented the five frameworks as the foundation of our methodology for maintaining trust. In order to determine the effectiveness of our proposed methodology for maintaining trust, we engineered a multi-agent system. The system was engineered as a graphical user interface by making use of the following tools:

1. Java Version 1.5.0_03: Java 2 Platform Software Edition is a complete development environment which was used to code the multi-agent simulation and was later integrated with NetBeans to build the GUI for this simulation. Java was the chosen platform for the engineering the protoype because of its Object Oriented (OO) paradigm that lends itself to / allows for representation of agents and their behaviours.

2. NetBeans IDE 4.0: NetBeans is an integrated Development Environment for developers of Java applications. NetBeans was used to engineer the multi-agent simulation because of the ease with which Graphical User Interfaces (GUIs) can be built using NetBeans.

In this thesis, we propose 7 (seven) broad objectives of simulation, each of which we divide into sub-objectives. In this chapter, we present the multi-agent system that we engineered to validate our proposed methodology for maintaining trust from 3 (three) broad objectives of validity measurement. The remaining 4 (four) objectives are presented in Chapter 10. In Section 9.2, we discuss the aims and objectives of engineering this system. In Section 9.3, we give an abstract overview of each of the phases involved in running the multi-agent system. In Section 9.4, we present the parameters used in the multi-agent system. In Sections 9.5 – Section 9.7, we illustrate the workflow and the results of the simulation (which we engineered in order to determine the effectiveness of the TMM). Section 9.8 concludes the chapter. We use the terms ‘simulation’ and ‘system’ interchangeably in this chapter.

9.2 Objectives of Engineering the Prototype Systems

The aim of engineering a multi-agent system was to simulate the working of the TMM. The engineered multi-agent system is meant to reflect the transactions between entities in virtual environments and subsequently determine the effectiveness of our TMM. The interactions between the software agents in the multi-agent system are meant to reflect the transaction between entities in the virtual environments. The (software) agents in the multi-agent system carry out a finite number of transactions (specified by the end user) with other software agents. At the end of the transactions, statistics are obtained and the effectiveness of our methodology is expressed and quantified numerically using the metrics that we propose for each associated objective. The prototype simulation is available online at http://blade1.debii.curtin.edu.au:8080/trustMaintain/.

In order to enable a detailed analysis and detailed validation of the proposed methodology, in this chapter, we present its validation from three perspectives as follows:

1. **Objective 1**: The effectiveness of our methodology for maintaining trust when the behaviour of agents in each transaction is static. By this we mean that the behaviour of agents in the transactions does not change. Here, we make use of the engineered prototype and define additional benchmarks to measure the effectiveness of our TMM. We divide this objective into two sub-objectives:

   1.1 **Objective 1.1**: Compare transactions with TMM and transactions without TMM. In order to achieve this objective, we quantify the benefits of using our methodology in such transactions over transactions which do not use our methodology. In this objective, we assume the static behaviour of agents during the transactions.

   1.2 **Objective 1.2**: Determine the correlation between final trust (at completion of interaction) and initial trust (at initiation of interaction). In order to achieve this objective, we compare the level of initial trust with the final trust at each transaction. In this case, we assume the static behaviour of agents during the transactions.

2. **Objective 2**: We further investigate and present the effectiveness of our methodology for trust maintenance when the behaviour of agents / parties involved in the transactions changes dynamically during the interactions. In order to address this issue, objective 2 proposes dynamic (non-static) behaviour of agents in interactions (in contrast to objective 1). We model the behaviour changes of an agent during the transaction by proposing three

different fuzzy logic based approaches. Similar to objective 1, we divide this second objective into two sub-objectives:

2.1. **Objective 2.1**: Compare transactions with TMM and without TMM. In order to achieve this objective, we quantify the benefits of using our methodology in such transactions over transactions which do not use our methodology. In this objective, we assume the dynamic behaviour of agents during the transactions.

2.2. **Objective 2.2**: Determine the correlation between final trust (at completion of interaction) and initial trust (at initiation of interaction). Similar to the objective of simulation 1.2, in order to achieve this objective, we compare the level of initial trust with the final trust at each transaction. However, in this case, we assume that the behaviour of agents during the transactions is dynamic.

3. **Objective 3**: Ascertain the effectiveness of having an incentive mechanism in our TMM. Our objective here is to measure the effectiveness of our TMM using an incentive-based approach. We divide this third objective into two sub-objectives:

3.1 **Objective 3.1**: Compare transactions with incentive-based TMM with those transactions without incentive-based TMM. In order to achieve this, we quantify the benefits of having an incentive-based TMM compared with a non-incentive TMM.

3.2 **Objective 3.2**: Investigate the best approach for providing an incentive to facilitate successful service delivery. As we propose three different approaches for an incentive mechanism, we will compare the performance of those three approaches to determine which approach performs best in facilitating the success of service delivery.

In the next section, we present the various phases involved in the simulation.

9.3 **Phases in the Multi-agent System**

The multi-agent system comprises four different phases as listed below:

1. Initialization Phase: In this phase, the user specifies the parameters needed for the multi-agent system such as the total number of agents needed for the multi-agent simulation, number of interactions, percentage of agent in the community with each of the trustworthiness values of 1, 2, 3, 4, 5, and 6...etc.

2. Bootstrapping Phase: In this phase, the (software) agents are actually created. Subsequently, each agent is then assigned a trustworthiness value by the multi-agent system. Each trustworthiness value is associated with a unique behaviour which specifies how that agent would behave in a given circumstance. The behaviour of the agents depends upon the chosen aim of the engineered systems.

3. Interaction Phase: This phase is meant to simulate the process of an agent carrying out an interaction with another agent by making use of our TMM.

4. Results Phase: During this phase, the statistical results of simulation are gathered and presented to the user. The aim of this phase is to determine and quantify numerically the extent to which our TMM is effective in terms of maintaining the trust values between interacting parties.

In this section, we provided a snapshot of the phases involved in the simulation. In the next section, we explain the parameters used in the Multi-agent Systems.

9.4 **Parameters used in the Multi-agent System**

In this section, we present the parameters that have to be specified by the user prior to the simulation. We present the parameters for each objective presented as explained in Section 9.2. The first objective of our engineered system can be divided into two sub-objectives. Firstly, we evaluate the effectiveness of our methodology by comparing the transactions which employ our TMM with the transactions which do not employ our TMM. In this case, the behaviour of the agent is assumed to be static throughout the interaction. Table 9.1 presents the input parameters that we use for this simulation.

Parameter	**Description**	**Valid Domain Values**
Agent No.	The user can specify the total number of agents in the simulation.	$0 < x$ Where 'x' is the maximum number of agents that can be specified by the user.
Transaction No.	The user can specify the number of transactions that will be carried out by agents.	$0 < x$ Where 'x' is the maximum number of transactions that can be specified by user.
Alpha (α)	The user can specify the value of weighted for weighting outcome-based final trust.	$0 \leq \alpha \leq 1$ *)
Beta (β)	The user can specify the value of weighted for weighting checkpoint-based final trust.	$0 \leq \beta \leq 1$ *) The total value of $\alpha + \beta = 1$
Error of Tolerance	The user can specify the level of tolerance for the acceptable delivery of service unit.	$0 \leq e$ Where 'e' is the maximum error tolerance that can be specified by the user.

Algorithms	The user can specify a crisp algorithm that would be used to implement static compliance behaviour of agent.	Crisp
Percentage of TV_1 – TV_6	The user can specify the percentage of agents in the community who would behave as specified by TV_1 - TV_6.	The total value of percentage of $TV_1 + TV_2 + TV_3 + TV_4 + TV_5 + TV_6 = 1$
Running Type	The user can specify whether the interaction would be utilizing the TMM or not utilizing the TMM.	Select one option only: - With monitoring or - Without monitoring

Table 9.1: Parameters used in simulation to compare transactions with TMM and those without TMM in static behaviour of agents

The second sub-objective (objective 1.2) is to analyse the correlation between initial trust value and final trust value if the behaviours of the agents are static. Table 9.2 presents the parameters used in the simulation to achieve objective 1.2.

Parameter	Description	Valid Domain Values
Agent No.	The user can specify the total number of agents in the simulation.	$0 < x$ Where 'x' is the maximum number of agents that can be specified by the user.
Transaction No.	The user can specify the number of transactions that will be carried out by agents.	$0 < x$ Where 'x' is the maximum number of transactions that can be specified by the user.
Alpha (α)	The user can specify the value of weighted for weighting outcome-based final trust.	$0 \leq \alpha \leq 1$ *)
Beta (β)	The user can specify the value of weighted for weighting checkpoint-based final trust.	$0 \leq \beta \leq 1$ *) *) the total value of $\alpha + \beta = 1$
Error of Tolerance	The user can specify the level of tolerance for the acceptable delivery of service unit.	$0 \leq e$ Where 'e' is the maximum error tolerance that can be specifies by users
Algorithms	The user can specify a crisp	Crisp

	algorithm that would be used to implement static compliance behaviour of agent.	
Percentage of TV_1 – TV_6	The user can specify the percentage of agents in the community who would behave as specified by TV_1 - TV_6.	The total value of percentage of $TV_1 + TV_2 + TV_3 + TV_4 + TV_5 + TV_6 = 1$

Table 9.2: Parameters used in simulation to compare final trust value with initial trust value in static behaviour of agents

The second objective of the simulation is to further analyse the effectiveness of our methodology as in objective 1. However, in order to relax the static behaviour of the agent, we propose dynamic behaviour of the agent during the interaction. It is assumed that the behaviour of the trusted agent will dynamically change throughout the interaction. This is also intended to capture the changing behaviour of agents in a transaction. Similar to objective 1, we analyse the effectiveness of our methodology from two different perspectives, therefore the objective of this simulation is divided into sub-objectives 2.1 and 2.2. Tables 9.3 and 9.4 show the parameters used for the simulation to achieve this second objective.

Parameter	Description	Valid Domain Values
Agent No.	The user can specify the total number of agents in the simulation.	$0 < x$ Where 'x' is the maximum number of agents that can be specifies by users.
Transaction No.	The user can specify the number of transactions that will be carried out by agents.	$0 < x$ Where 'x' is the maximum number of transactions that can be specifies by users.
Alpha (α)	The user can specify the value of weighted for weighting outcome-based final trust.	$0 \leq \alpha \leq 1^{*)}$
Beta (β)	The user can specify the value of weighted for weighting checkpoint-based final trust.	$0 \leq \beta \leq 1^{*)}$ *) the total value of $\alpha + \beta = 1$
Error of Tolerance	The user can specify the level of tolerance for the acceptable delivery of service unit.	$0 \leq e$ Where 'e' is the maximum error tolerance that can be specifies by users
Algorithms	The user can specify an algorithm that would be used	There are three options: FL Triangular, FL

	to implement dynamic compliance behaviour of agent.	Trapezoidal and FL Hybrid
Percentage of TV_1 – TV_6	The user can specify the percentage of agents in the community who would behave as specified by TV_1 - TV_6.	The total value of percentage of $TV_1 + TV_2 + TV_3 + TV_4 + TV_5 + TV_6 = 1$
Running Type	The user can specify whether the interaction would be utilizing the TMM or not utilizing the TMM.	Select one option only: - With monitoring or - Without monitoring

Table 9.3: Parameters used in simulation to compare transactions with TMM with those without TMM in dynamic behaviour of agents

Parameter	Description	Valid Domain Values
Agent No.	The user can specify the total number of agents in the simulation.	$0 < x$ Where 'x' is the maximum number of agents that can be specified by user.
Transaction No.	The user can specify the number of transactions that will be carried out by agents.	$0 < x$ Where 'x' is the maximum number of transactions that can be specified by the user.
Alpha (α)	The user can specify the value of weighted for weighting outcome-based final trust.	$0 \leq \alpha \leq 1^{*)}$
Beta (β)	The user can specify the value of weighted for weighting checkpoint-based final trust.	$0 \leq \beta \leq 1^{*)}$ $^{*)}$ the total value of $\alpha + \beta = 1$
Error of Tolerance	The user can specify the percentage level of tolerance for the acceptable delivery of service unit.	$0 \leq e$ Where 'e' is the maximum error tolerance that can be specified by the user.
Algorithms	The user can specify an algorithm that would be used to implement the dynamic compliance behaviour of agent.	There are three options: FL Triangular FL FL Trapezoidal and FL Hybrid.
Percentage of TV_1 – TV_6	The user can specify the percentage of agents in the community who would	The total value of percentage of $TV_1 + TV_2 + TV_3 + TV_4 + TV_5 + TV_6$

	behave as specified by TV_1 - TV_6.	= 1.

Table 9.4: Parameters used in simulation to compare final trust value with initial trust value in dynamic behaviour of agents.

The third objective of the simulation is to analyse the results of the comparison of transactions which use the TMM incentive-based mechanism with those transactions which do not use an incentive mechanism (TMM non-incentive-based). The parameters used for TMM non-incentive based interactions are exactly the same as those used for the TMM simulation in Table 9.1. Moreover, as we have three different types of trust mechanism, we compare them in order to determine which is the most effective. Tables 9.5 – 9.7 show the parameters used for the simulation to achieve this third objective.

Parameter	Description	Valid Domain Values
Agent No.	The user can specify the total number of agents in the simulation.	$0 < x$ Where 'x' is the maximum number of agents that can be specified by the user
Transaction No.	The user can specify the number of transactions that will be carried out by agents.	$0 < x$ Where 'x' is the maximum number of transactions that can be specified by the user
Alpha (α)	The user can specify the value of weighted for weighting outcome-based final trust.	$0 \leq \alpha \leq 1$ *)
Beta (β)	The user can specify the value of weighted for weighting checkpoint-based final trust	$0 \leq \beta \leq 1$ *) *) the total value of $\alpha + \beta = 1$
Error of Tolerance	The user can specify the percentage level of tolerance for the acceptable delivery of service unit.	$0 \leq e$ Where 'e' is the maximum error tolerance that can be specified by the user
Algorithms	The user can specify an algorithm that would be used to implement compliance behaviour of agent.	There are four options: Crisp, FL Triangular, FL Trapezoidal and FL Hybrid.
Bonus Bias	The user can specify the value of bonus bias. This is the value to determine the level of performance increment as a response to receiving an incentive.	$0 < x < 1$ Where 'x' is the number value that can be specified by users.

Percentage of TV_1 – TV_6	The user can specify the percentage of agents in the community who would behave as specified by TV_1 - TV_6.	The total value of percentage of $TV_1 + TV_2 + TV_3 + TV_4 + TV_5 + TV_6 = 1$

Table 9.5: Parameters used in performance-driven-based incentive simulation

Parameter	Description	Valid Domain Values
Agent No.	The user can specify the total number of agents in the simulation.	$0 < x$ Where 'x' is the maximum number of agents that can be specified by the user.
Transaction No.	The user can specify the number of transactions that will be carried out by agents.	$0 < x$ Where 'x' is the maximum number of transactions that can be specified by the user.
Alpha (α)	The user can specify the value of weighted for weighting outcome-based final trust.	$0 \leq \alpha \leq 1$ *)
Beta (β)	The user can specify the value of weighted for weighting checkpoint-based final trust.	$0 \leq \beta \leq 1$ *) *) the total value of $\alpha + \beta = 1$
Error of Tolerance	The user can specify the percentage level of tolerance for the acceptable delivery of service unit.	$0 \leq e$ Where 'e' is the maximum error tolerance that can be specified by the user.
Algorithms	The user can specify an algorithm that would be used to implement compliance behaviour of agent.	There are four options: Crisp, FL Triangular, FL Trapezoidal and FL Hybrid
Incentive Ratio	The user can specify the incentive ratio over the error tolerance. This is the value to determine threshold level for receiving an incentive.	$0 < x < 1$ Where 'x' is the value that can be specified by the user
Percentage of TV_1 – TV_6	The user can specify the percentage of agents in the community who would behave as specified by TV_1 - TV_6	The total value of percentage of $TV_1 + TV_2 + TV_3 + TV_4 + TV_5 + TV_6 = 1$

Table 9.6: Parameters used in error–tolerance based incentive simulation

Parameter	Description	Valid Domain Values
Agent No.	The user can specify the total number of agents in the simulation.	0 < x Where 'x' is the maximum number of agents that can be specified by the user.
Transaction No.	The user can specify the number of transactions that will be carried out by agents.	0 < x Where 'x' is the maximum number of transactions that can be specified by the user.
Alpha (α)	The user can specify the value of weighted for weighting outcome-based final trust.	$0 \leq \alpha \leq 1$ *)
Beta (β)	The user can specify the value of weighted for weighting checkpoint-based final trust.	$0 \leq \beta \leq 1$ *) *) the total value of $\alpha + \beta = 1$
Error of Tolerance	The user can specify the percentage level of tolerance for the acceptable delivery of service unit.	0 ≤ e Where 'e' is the maximum value of error tolerance that can be specified by the user.
Algorithms	The user can specify an algorithm that would be used to implement compliance behaviour of agent.	There are four options: Crisp, FL Triangular, FL Trapezoidal and FL Hybrid.
Max Bonus To Give	The user can specify the maximum bonus to give to the agent. By default, this value is 1.	0 < x < 1 Where 'x' is the value to give incentive that can be specified by the user.
Percentage of TV_1 – TV_6	The user can specify the percentage of agents in the community who would behave as specified by TV_1 - TV_6	The total value of percentage of $TV_1 + TV_2 + TV_3 + TV_4 + TV_5 + TV_6 = 1$

Table 9.7: Parameters used in occurrence-based incentive simulation

9.5 Simulation for Objective 1: The Effectiveness of TMM with Static Behaviour of Agent

In this section, we present the results of simulation to achieve objective 1 of the System. We also present the workflow of this simulation including the screenshot to input the parameters prior to simulation. Subsequently, we discuss the results.

9.5.1 **Workflow of the Simulation for Objective 1**

The steps involved in this simulation are as follows:

a. Step 1. The user specifies all the parameter values that need to be determined as specified in Tables 9.1 – 9.2.

b. Step 2. During the bootstrapping phase, the agents are created and each of them is assigned a given behaviour to represent their level or degree of compliance. Each compliant behaviour corresponds to one trustworthiness value as presented in equations 9.1 – 9.6 below. We determine the level of compliance of agents with different trustworthiness values by dividing the compliance spectrum space into six equal parts (corresponding to the number of trustworthiness values of agents). For example, agents with trustworthiness value '1' (TV_1) would have a behaviour that would spell out the action or the way that agents have carried out a transaction. In this simulation, we assume that the behaviour of an agent is static during the interaction. We use a 'crisp compliance' approach by which each agent has a crisp level of compliance. The level of compliance also depends on the approach taken by the user to calculate the compliance level. The compliance level of agents corresponding to TV_1, TV_2, TV_3, TV_4, TV_5 and TV_6 is shown below:

TV_1 = level of compliance = 16.67% **Equation 9.1**

TV_2 = level of compliance = 33.33% **Equation 9.2**

TV_3 = level of compliance = 50% **Equation 9.3**

TV_4 = level of compliance = 66.67% **Equation 9.4**

TV_5 = level of compliance = 83.33% **Equation 9.5**

TV_6 = level of compliance = 100% **Equation 9.6**

The values above indicate that agents will comply with the mutual agreement according to the trust level that is assigned to them. For example, an agent which has TV_1 when carrying out an interaction will deliver service only at 16.67%. The reasons for this characterization are:

a. It assumes a static compliance level
b. It assumes discrete and constant increments in compliance level by 16.67% between two consecutive trust values. The reason for this constant increase is that we have divided the compliance space (between 0 – 100%) into six equal units with each unit corresponding to the compliance level of one trust value.

Therefore, an agent with TV_1 is characterized as complying at 16.67%, agent with TV_2 will always comply at 33.33%, and so on. The compliance level of an agent will determine the extent to which it will deliver on the agreed SLAs. For example, an agent with TV_4 which has a 66.67% compliance level, when carrying out a transaction, will perform only at 66.67% for the mutually agreed performance. This is represented pictorially in Figure 9.1.

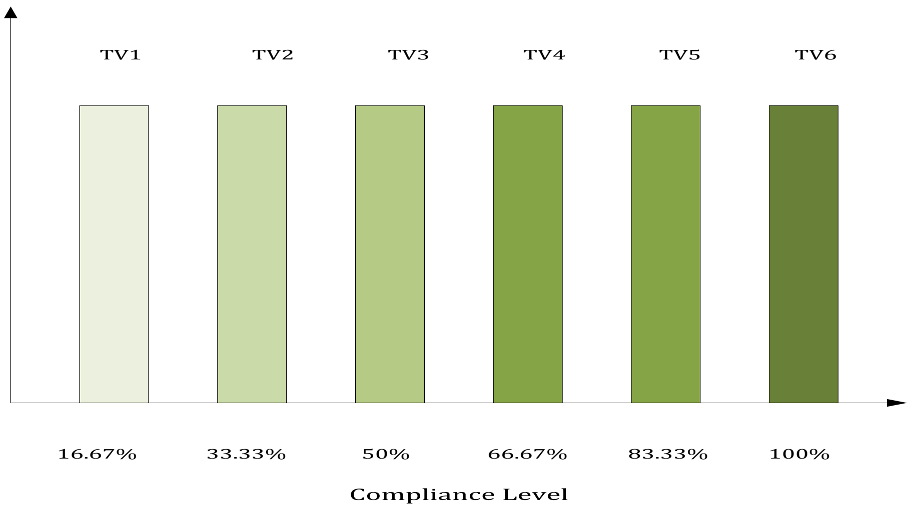

Figure 9.1: Trustworthiness values and levels of compliance

Based on this crisp approach, an agent will have a certain degree of compliance level as a crisp value.

c. Step 3. During each transaction, a trusting agent and a trusted agent are randomly chosen. The trusting agent is chosen such that it is always a compliant agent which means this trusting agent has a 100% level of compliance level. However, the compliance level of the randomly chosen trusted agent could be any trust value between TV_1 to TV_6. The agents carry out an interaction as described in our TMM.

d. Step 4. The statistical outcome regarding this simulation is gathered and presented to the user. We then analyse the results corresponding to the objective.

9.5.2 Simulation Results: Comparison of Transactions with TMM and without TMM (Static Behaviour)

This simulation is designed to achieve objective 1.1 which is to analyse the effectiveness of our TMM. The analysis is conducted by comparing the transactions which employ our TMM with those transactions which do not employ our TMM. Figure 9.2 below shows the trust maintenance tool benchmark software prompting the user to input the parameters prior running the simulation.

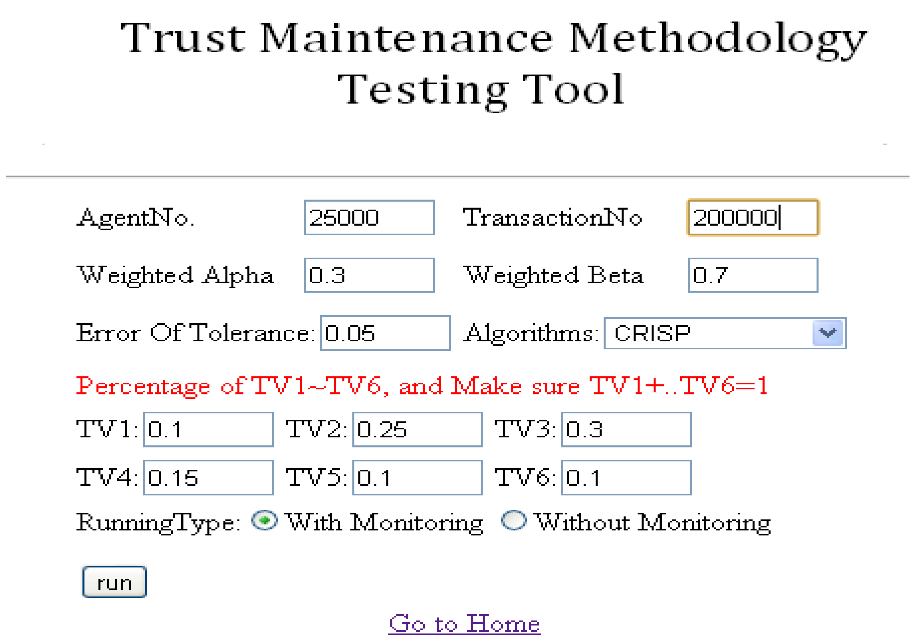

Figure 9.2: Screenshot of testing tool to compare transactions with TMM and without TMM in static behaviour of agents.

a. The simulation result with the input parameters is shown in Table 9.8 below:

Number of agents	1000
Number of transactions	1000
Error tolerance level	0.05
A	0.3
B	0.7
Algorithms	Crisp
Percentage of agents with $TV_1 – TV_6$	TV_1 = 0.1, TV_2 = 0.1, TV_3 = 0.1, TV_4 = 0.2, TV5 = 0.25, TV_6 = 0.25

Table 9.8. Input parameters for simulation to compare transactions with TMM and those without TMM in static behaviour of agents (2000 agents, 1000 transactions)

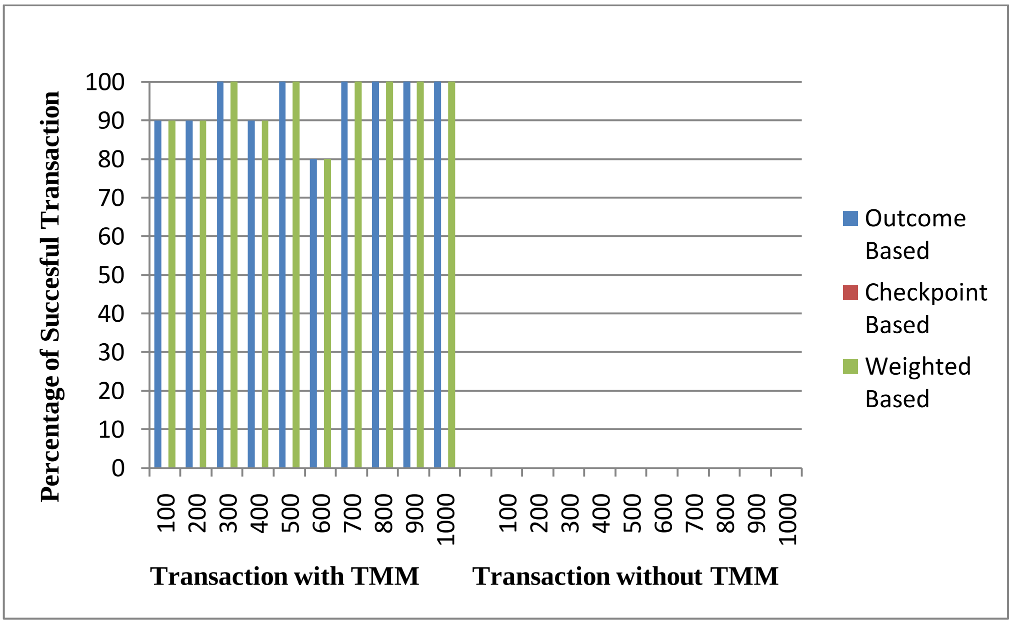

Figure 9.3: Result of simulation to compare transactions with TMM and without TMM in static behaviour of agents (1000 agents, 1000 transactions)

Figure 9.3 shows the result of the simulation and presents a comparison of the percentage of successful transactions which use our TMM with those transactions which do not employ our TMM. The input parameter for this simulation is as described at Table 9.8. As mentioned previously, in this case, the behaviour of agents is static throughout the interaction. The percentage of successful transactions is measured by comparing the final trust value with the initial trust value. If by the end of the interaction, the final trust value is greater than the initial trust, the transaction is considered to be successful. For further detailed analysis, the final trust calculation is compared using three approaches which are outcome-based, checkpoint-based, and weighted-based. The left side of the graph shows the results for transaction which use our TMM, while the bar on the right side of the graph shows the result for transactions which do not use our TMM.

In the outcome-based and weighted-based approaches, the percentage of successful transactions is the same. However, if we calculate the final trust value using the checkpoint-based approach, the percentage of successful transactions is '0'. This is because, with the checkpoint-based approach, the final trust value is calculated by computing the average of intermediate trust values at each checkpoint which produces a lower trust value compared to the outcome-based and weighted-based approaches. As was explained in Chapter 8, the outcome-based final trust calculation does not emphasize the way that a trusted agent performs during the interaction. Moreover, the weighted-based approach for final trust calculation is a hybrid measure giving weights to both the checkpoint-based approach and outcome-based approach.

Moreover, as we can see from the graph in Figure 9.4, when comparing transactions which use our TMM with transactions which do not use our TMM, none of the transactions without TMM can be considered to be successful transactions in terms of the trust level being maintained (final trust greater than initial trust). Conversely, the percentage of successful transactions which employ our TMM is more than 90% on average. It can be inferred that for every 100 transactions, an average of 90% of them have successfully maintained their trust level. For further evaluation, we run several simulations using different parameters in the next section.

b. Simulation result with the parameters as shown in Table 9.9 below:

Number of agents	2000
Number of transactions	1000
Error tolerance level	0.05
A	0.3
B	0.7
Algorithms	Crisp
Percentage of agents with $TV_1 – TV_6$	TV_1 = 0.1, TV_2 = 0.1, TV_3 = 0.1, TV_4 = 0.2, TV5 = 0.25, TV_6 = 0.25

Table 9.9: Input parameters for simulation to compare transactions with TMM and those without TMM in static behaviour of agents (2000 agents, 1000 transactions)

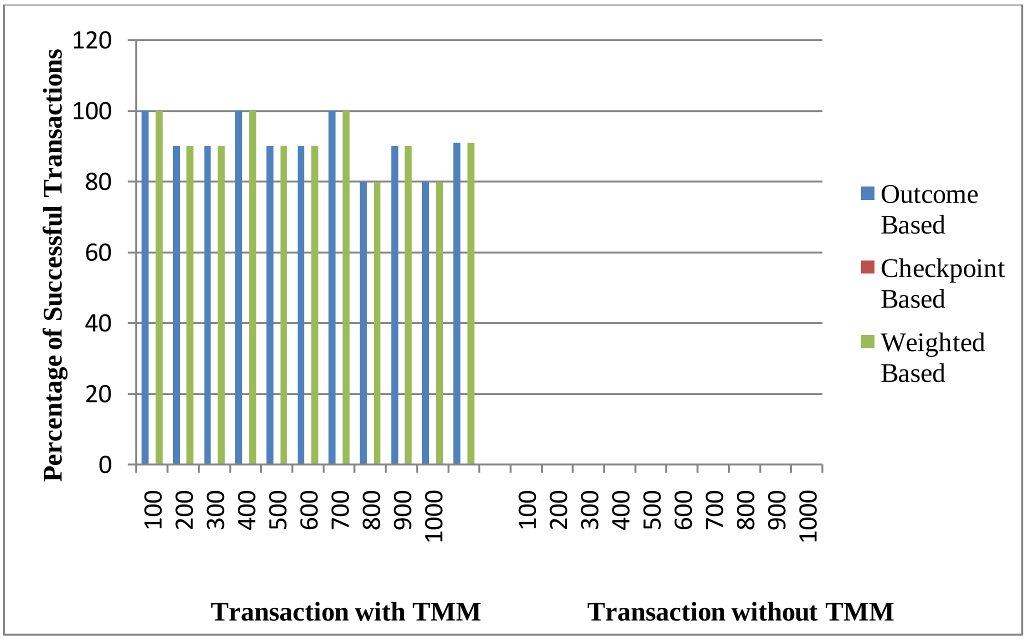

Figure 9.4: Result of simulation to compare transactions with TMM and without TMM in static behaviour of agents (2000 agents, 1000 transactions)

c. Simulation result with the parameters as shown in Table 9.10 below:

Number of agents	3000
Number of transactions	1000
Error tolerance level	0.05
α	0.3
β	0.7
Algorithms	Crisp
Percentage of agents with $TV_1 – TV_6$	TV_1 = 0.1, TV_2 = 0.1, TV_3 = 0.1, TV_4 = 0.2, TV5 = 0.25, TV_6 = 0.25

Table 9.10: Input parameters to compare transactions with TMM and those without TMM in static behaviour of agents (3000 agents, 1000 transactions)

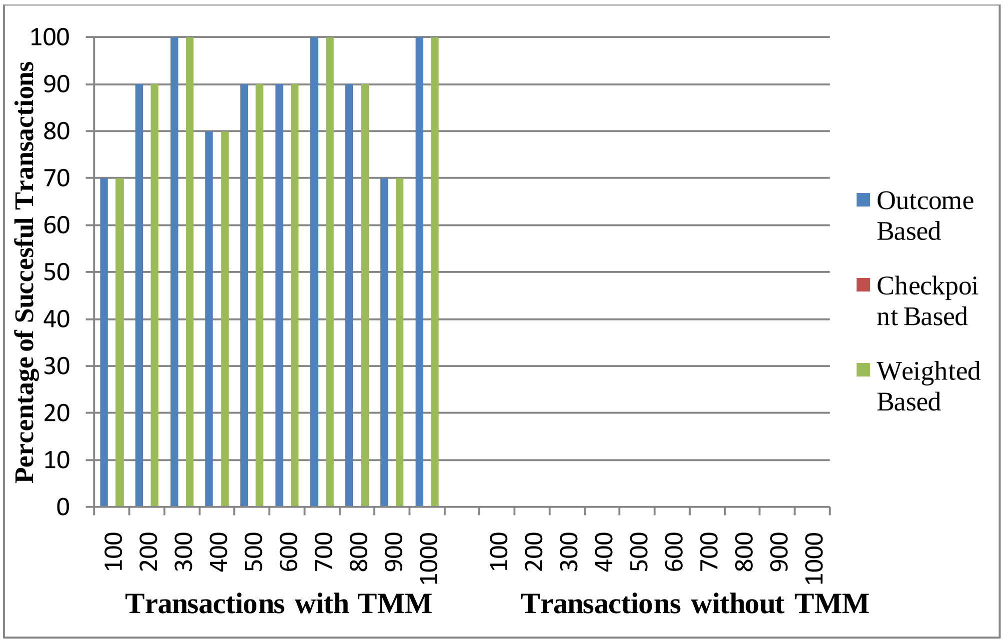

Figure 9.5: Result of simulation to compare transactions with TMM and those without TMM in static behaviour of agents (3000 agents, 1000 transactions)

We further analyse the result from point (a) by utilizing different input parameters. Figures 9.4 and 9.5 above present the comparison of simulation results from transactions which use our TMM and transactions those which do not use our TMM. As we can observe, although we increase the number of agents in the population, the results show a similar pattern. The percentage of successful transactions with TMM is far better than transactions which do not employ our TMM. There is no successful transaction from the transactions which do not use the TMM. The percentage level of transactions with TMM is more than 85%, whereas the percentage of successful transactions which do not employ the TMM is 0%. Hence, we can conclude that our TMM is effective enough to maintain the trust level between trusting agent and trusted agent. In Section 9.6.2, we further analyse this simulation by using the dynamic behaviour of agents throughout the transactions.

9.5.3 **Simulation Results: Comparison between Final Trust and Initial Trust (Static Behaviour)**

This simulation system is designed to determine the percentage of transactions in which trust has successfully been maintained. We conduct a relative comparison of the initial trust value (prior to the interaction) with the final trust value (after the interaction) to determine the effectiveness of our methodology as explained in the previous chapters. If the final trust value is greater than or equal to the initial trust value, one can conclude that our methodology has enabled trust to be maintained. Conversely, if the final trust value is lower than the initial trust value, then one can conclude that trust has not been maintained in the interaction. We propose a metric to measure the percentage of successful transactions. A successful transaction can be measured by computing the correlation between initial trust and final trust. For example, in 100 transactions, if 80 are considered successful, this is because for those 80 transactions, the final trust is greater than the initial trust. So the percentage of successful transactions is 80%. Therefore, the mathematical expression for it is:

*Percentage of successful transactions = (transactions in which the trusting agent successfully maintains the trust level / total transactions)*100.*

Equation 9.7

In this thesis, we consider two benchmarks for classifying successful transactions. Firstly, the final trust value is greater than the initial trust value ($T_{final} > T_{initial}$). We refer to this benchmark as the G-Benchmark. Secondly, the final trust value is greater than or equal to the initial trust value ($T_{final} \geq T_{initial}$). Subsequently, we refer to this benchmark as the GE-Benchmark. Figure 9.6 below shows the trust maintaining tool benchmark software prompting the user to input the parameters prior to running the simulation.

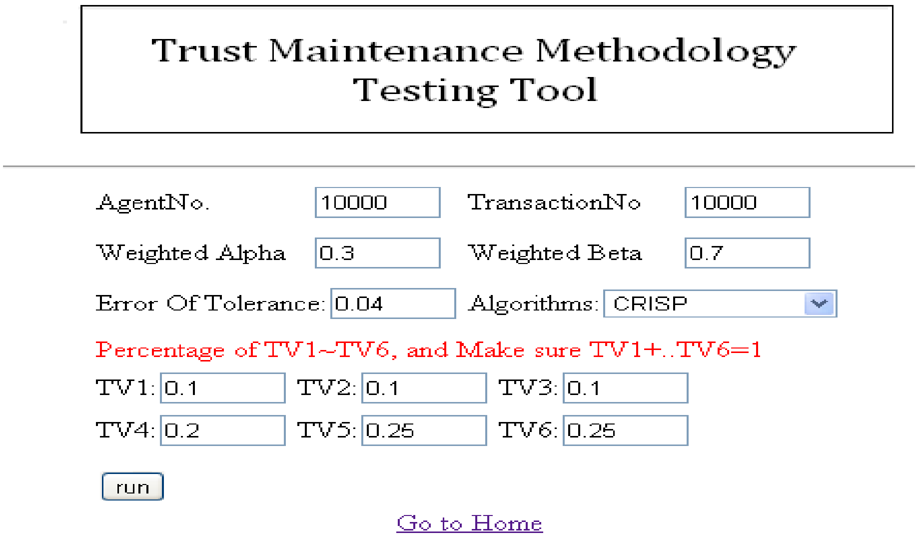

Figure 9.6: Screenshot of testing tool to compare final trust value with initial trust value in static behaviour of agents

a. Simulation results with input parameters as shown in Table 9.11

Number of agents	1000
Number of transactions	1000
Error tolerance level	0.05
α	0.3
β	0.7
Algorithm	Crisp
Percentage of agents with $TV_1 - TV_6$	TV_1 = 0.1, TV_2 = 0.1, TV_3 = 0.1, TV_4 = 0.2, TV5 = 0.25, TV_6 = 0.25

Table 9.11: Input parameters for simulation to compare final trust value and initial trust value in static behaviour of agents (1000 agents, 1000 transactions)

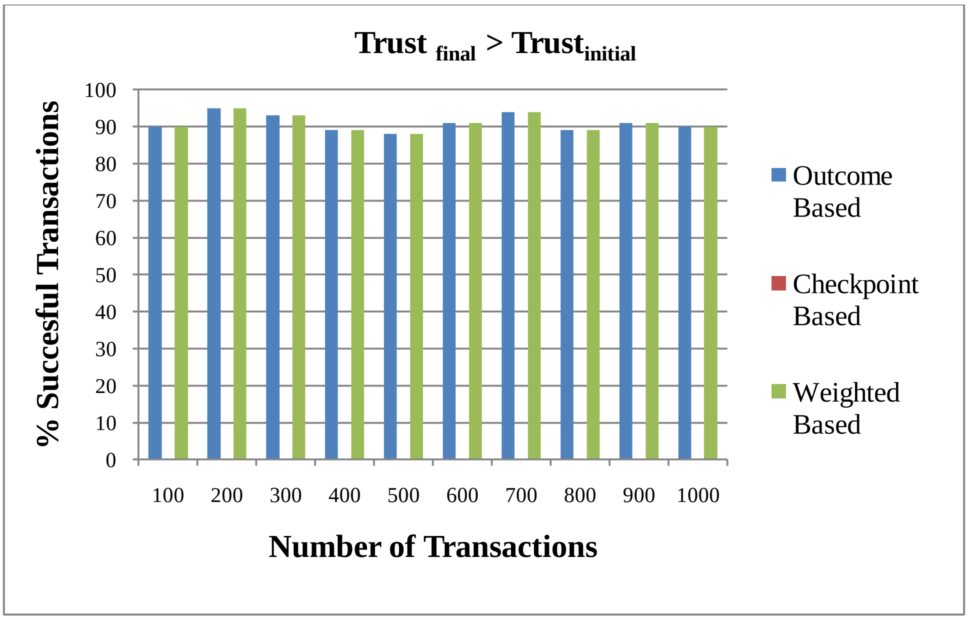

Figure 9.7: Results of simulation to compare final trust value with initial trust value in static behaviour of agents (1000 agents, 1000 transactions) (G-Benchmark)

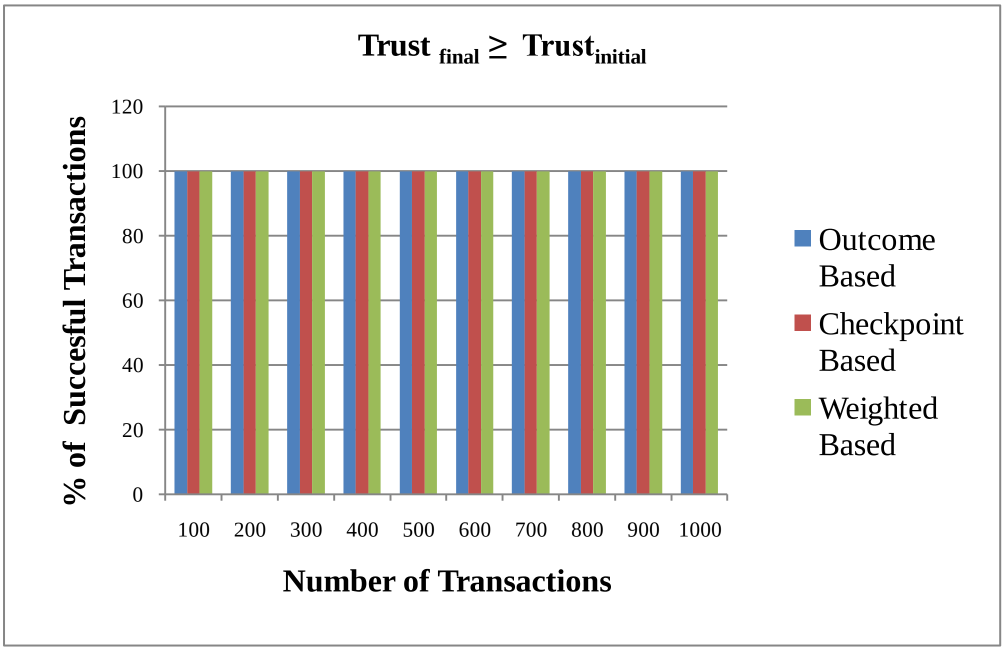

Figure 9.8: Results of simulation to compare final trust value with initial trust value in static behaviour of agents (1000 agents, 1000 transactions) (GE-Benchmark)

At the crisp compliance level, the degree of compliance of the chosen agent is constant throughout the interaction. Figure 9.7 above shows that, based on outcome-based and weighted-based approaches for trust recalibration, if we use the G-Benchmark, for every 100 transactions, more than 90% of them are successful. However, if we compute the final trust value using the checkpoint-based approach, no transaction appears to be successful. This is because, as the compliance level is constant throughout the interaction, at every checkpoint an agent will always comply at that compliance level. Therefore, the initial trust will always be the same as the final trust. Further, if the metrics for measuring successful transactions is the G-Benchmark, then no transactions can be considered to be successful. However, if we use the second benchmark scenario which is the GE-Benchmark, the number of successful interactions using the checkpoint-based approach to calculate final trust is 100% as shown in Figure 9.8. Similar results are obtained for final trust calculation based on the outcome-based approach and the weighted-based approach. By using those approaches, the percentage of successful interactions is 100%. This is because the trusted agent demonstrates the same degree of trustworthiness throughout the interaction. This results in the final trust being equal to the initial trust. Table 9.12 below shows the analysis of the differences between the success ratios of the G-Benchmark and GE-Benchmark for each trust value.

	G-Benchmark						
	Successful Transactions	TV_1	TV_2	TV_3	TV_4	TV_5	TV_6
OB	910	103	174	236	302	90	0
CP	0	0	0	0	0	0	0
WB	910	103	174	236	302	90	0
	GE-Benchmark						
	Successful Transactions	TV_1	TV_2	TV_3	TV_4	TV_5	TV_6
OB	1000	103	174	236	302	95	90
CP	1000	103	174	236	302	95	90
WB	1000	103	174	236	302	95	90

Table 9.12: Differences in success ratios in simulation to compare final trust value with initial trust value in static behaviour of agents

As clearly evident from Table 9.12, the difference in the success ratios using the G-Benchmark and GE-Benchmark measurements comes from an agent that has an initial trust value of ‘6’. Since the possible highest trust value is 6, in G-Benchmark there will no successful transactions for the agent with an initial trust value of ‘6’. However, if we determine a successful transaction by using the GE-Benchmark, a given agent with an initial trust value of ‘6’ would be counted as a successful transaction if the final trust value calculation is ‘6’.

b. Simulation results with parameters as shown in Table 9.13

Number of agents	5000
Number of transactions	3000
Error tolerance level	0.04
α	0.3
β	0.7
Algorithm	Crisp
Percentage of agent with TV_1 – TV_6	TV_1 = 0.1, TV_2 = 0.1, TV_3 = 0.1, TV_4 = 0.2, TV5 = 0.25, TV_6 = 0.25

Table 9.13: Input parameters for simulation to compare final trust value with initial trust value in static behaviour of agents (5000 agents, 3000 transactions)

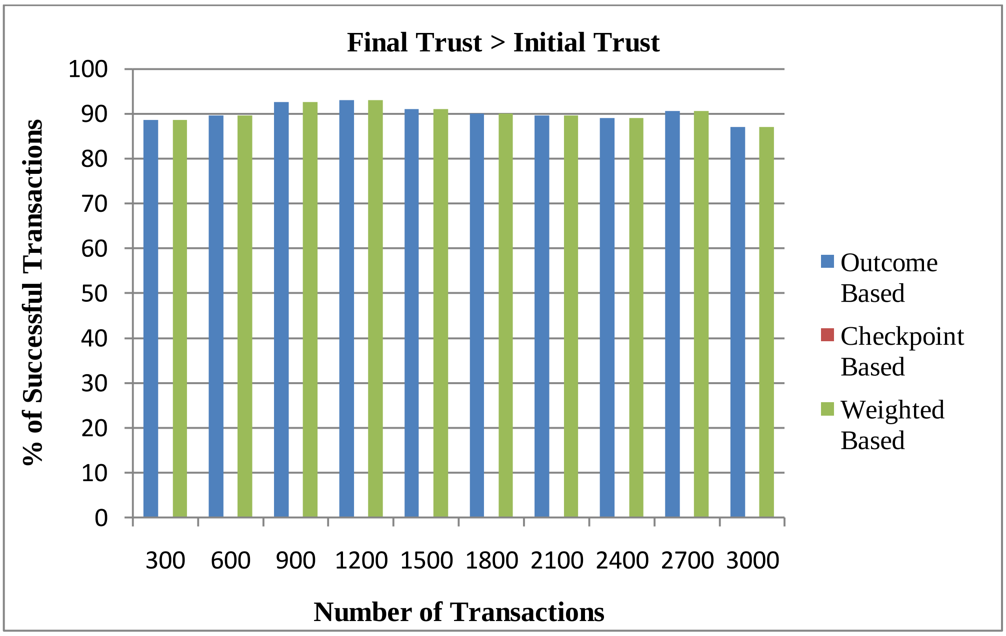

Figure 9.9: Result of simulation to compare final trust value with initial trust value in static behaviour of agents (5000 agents, 3000 transactions) (GE-Benchmark)

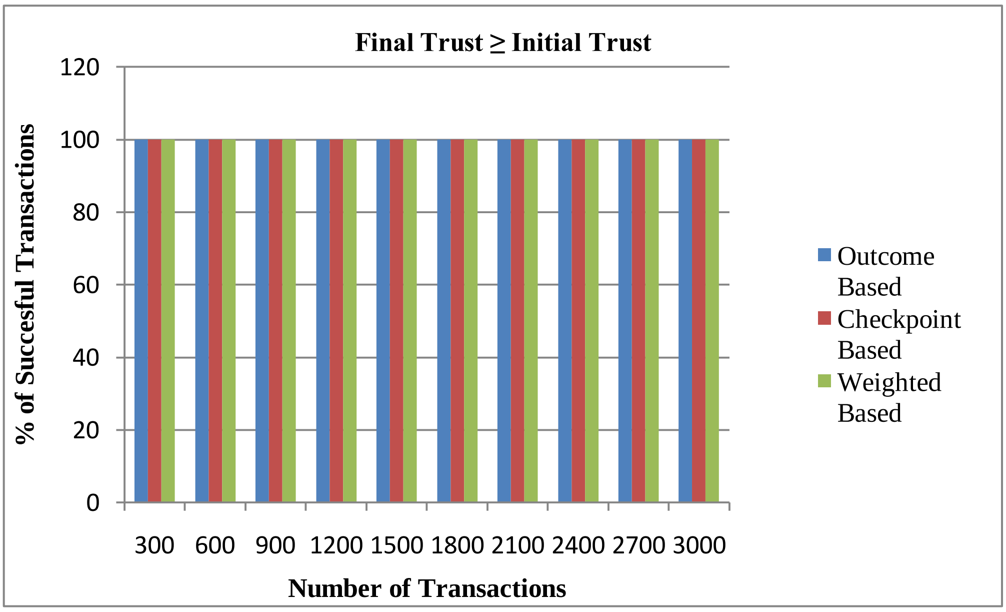

Figure 9.10: Result of simulation to compare final trust value with initial trust value in static behaviour of agents (5000 agents, 3000 transactions) (GE-Benchmark)

c. Simulation results with the parameters as shown in Table 9.14 below:

Number of agents	10000
Number of transactions	10000
Error tolerance level	0.05
A	0.3
B	0.7
Algorithm	Crisp
Percentage of agents with $TV_1 - TV_6$	TV_1 = 0.1, TV_2 = 0.1, TV_3 = 0.1, TV_4 = 0.2, TV5 = 0.25, TV_6 = 0.25

Table 9.14: Input parameters for simulation to compare final trust value with initial trust value in static behaviour of agents (10000 agents, 10000 transactions)

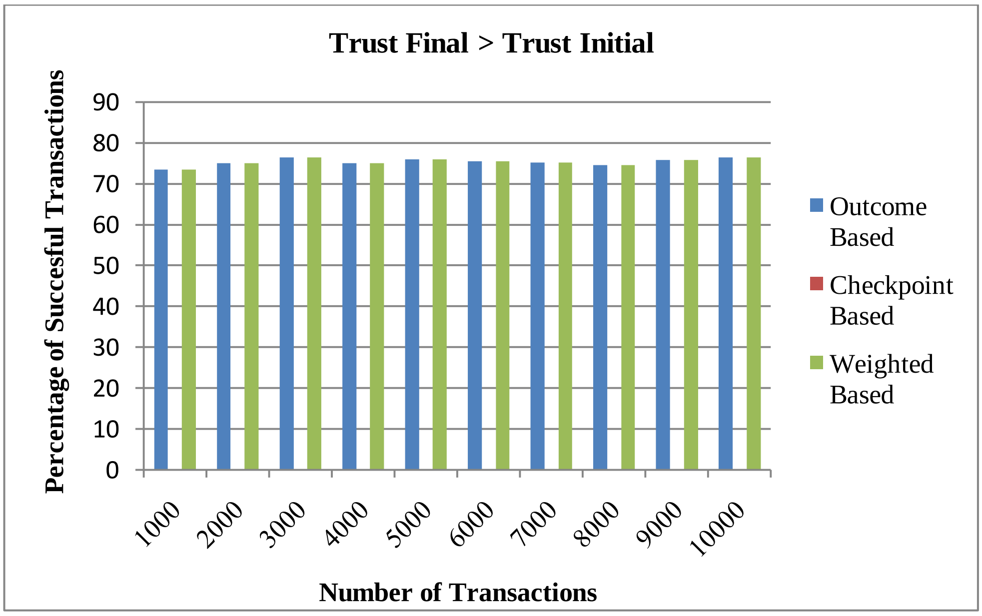

Figure 9.11: Result of simulation to compare final trust value with initial trust value in static behaviour of agents (10000 agents, 10000 transactions) with G - Benchmark

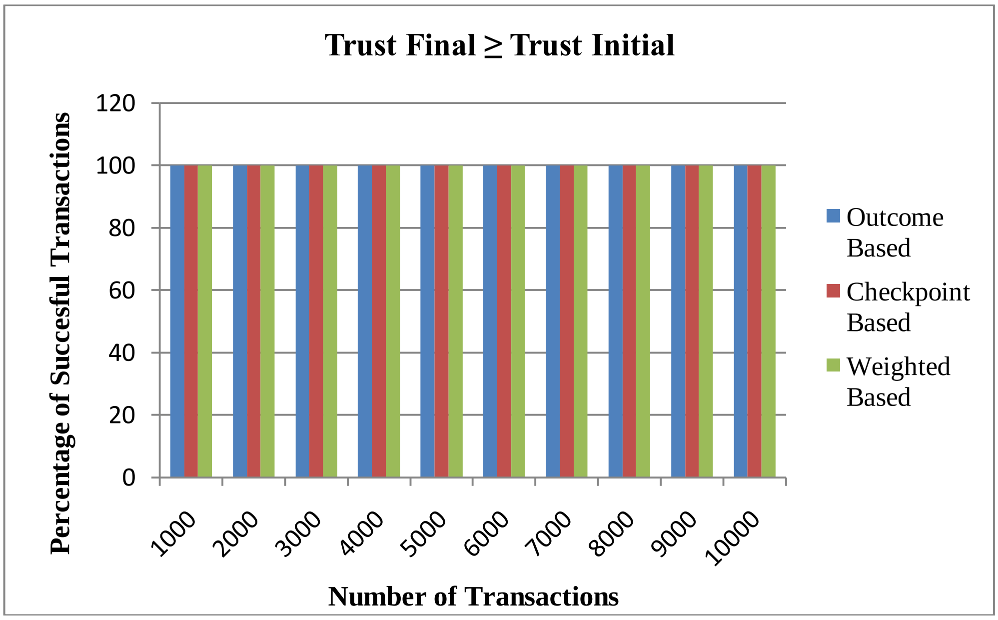

Figure 9.12: Result of simulation to compare final trust value with initial trust value in static behaviour of agents (10000 agents, 10000 transactions) with GE-Benchmark

Figures 9.9 – 9.12 present the result of simulation conducted to compare final trust value with initial trust value using various input parameters. In this case, the behaviour of agents throughout the interaction is static. As observed, the percentage of successful transactions where the final trust value is higher than the initial trust value is more than 90 % if we use G-Benchmark and 100 % if we use GE-Benchmark. Moreover, with the G-Benchmark no transactions are considered to be successful if we calculate the final trust value using the checkpoint-based approach. We found this similar condition in the other simulation results. The main reason is because in the checkpoint-based approach, the trust final is calculated by computing the average of intermediate checkpoints, while in the outcome-based approach, the final trust value is calculated based on the actual delivery of service at the end of the interaction (or for the entire interactions). Further discussion regarding results of simulation for objective 1 is presented in the next section.

9.5.4 **Discussion of Results Obtained for Objective 1**

Based on simulation results with various input parameters as presented in several figures in the previous section, we can infer the following:

a. Objective 1.1: Transaction with TMM and without TMM in static behaviour of agents

   As indicated by Figures 9.3 – 9.5, the average successful ratio of interactions with TMM is higher than for transactions without TMM. Our investigation was done from the perspective of the various parameters and it can be concluded that for agents with static behaviour, the successful transactions using TMM is approximately 91.3%, whereas in transactions without TMM, it is around 0%. For elucidation purposes, Table 9.15 below presents the summary of average simulation results.

Trust Final Calculation	G - Benchmark	
	Transaction with TMM	Transactions without-TMM
Outcome Based	91.3%	0%
Checkpoint Based	0%	0%
Weighted Based	91.3%	0%

Table 9.15: Summary of simulation result to compare the transactions with TMM and without TMM

b. Objective 1.2: Trust final and trust initial for agents with static behaviour

As explained in Section 9.5.3, the successful ratio of transactions (using the TMM) determined by comparing final trust with initial trust using both the G and GE-Benchmark, is acceptably high. If we use the G-Benchmark, the successful ratio is 81%; whereas if we use the GE-Benchmark, it is 100%. It can be inferred that for any number of transactions using our TMM, the number of successful transactions deduced by comparing final trust with initial trust is greater than 80%. By using our TMM, the level of trust at the end of the transaction is higher than initial trust at the initial transaction. Hence, we can conclude that our TMM very significantly assists the trusted agent to maintain the trust of the trusting agent. Table 9.16 presents the summary of simulation results on average.

Benchmark / Trust Final Calculation	**G–Benchmark**	**GE–Benchmark**
Outcome Based	81.25%	100%
Checkpoint Based	0	100%
Weighted Based	84%	100%

Table 9.16: Summary of simulation result to compare final trust value with initial trust value in static behaviour of agents

9.6 Simulation for Objective 2: The Effectiveness of TMM with Dynamic Behaviour of Agent

The objective of this simulation is to further analyse the effectiveness of our TMM similar to objective 1. However, in this case, the behaviour of agents is not static because it is not always possible for the compliance level of an agent to be static during the interaction. The compliance level of an agent could be dynamic. In order to model this scenario, we discuss modelling the behaviour of agents using a fuzzy logic approach membership function, and in the next section we examine the results. In this section, we present the workflow of the simulation which accommodates the three different approaches to modelling the dynamic behaviour; we also present and discuss the simulation result.

9.6.1 Workflow of the Simulation for Objective 2

The steps involved in this simulation are:

a. Step 1. The user specifies all the parameters' values that need to be determined by the user prior to initiating the simulation as specified in Table 9.3 and Table 9.4.

b. Step 2. During the bootstrapping phase, the agents are created and each of them is assigned a given behaviour to represent their level of compliance. In this approach, the behaviour of each agent corresponding to a trustworthiness value is represented using a membership function as shown in Table 9.17. The degree of compliant behaviour of an agent for each trust value is determined with the help of a statistical graph which corresponds proportionally to the measurement of 100 scale intervals. The number '0%' denotes the lowest level of compliance, meaning that the agent is totally non-compliant, and '100%' denotes the perfect performance or full compliance. A fuzzy trust grade set will be defined as the fuzzy measurement result, which is denoted by Trust Value (TV) = [1, 2, 3, 4, 5, 6]. These six grades TV_1, TV_2, TV_3, TV_4, TV_5, and TV_6 denote the gradational measurement results ranging from the fully compliant to fully non-compliant as depicted in Figure 9.13 below.

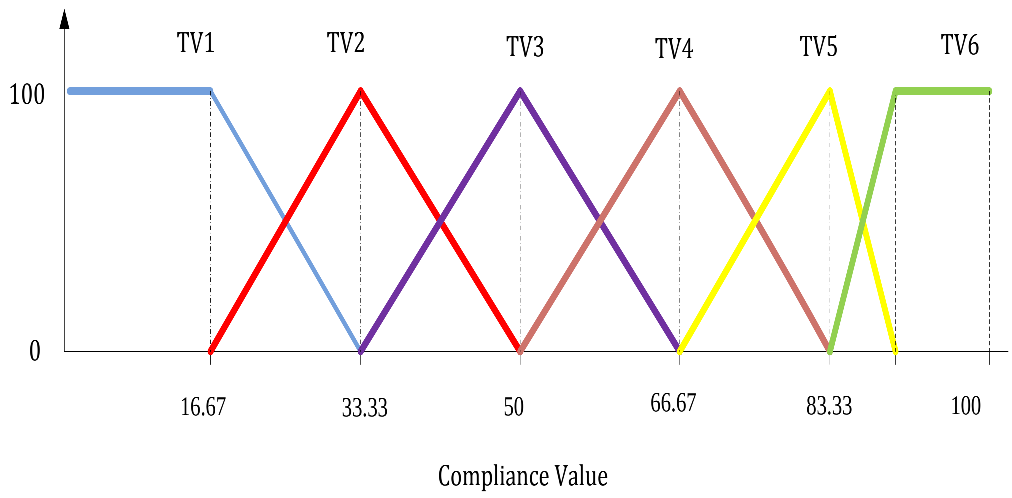

Figure 9.13: Triangular membership degree and compliance values corresponding to various trust levels.

The graph above shows the degree of membership and value of compliance for every agent for each trust value. It can be seen that the nature of membership functions is primarily triangular; hence, we term this type of compliance '*fuzzy triangular compliance*'. An agent with a certain level of compliance will have a certain trust value. Membership degree *(y)* which ranges from 0 to 1 is a mapping called the membership function of the fuzzy set TV, and level of compliance *(x)* indicates the degree of belongingness or membership value of *'x'* in any Trust Value. Therefore, a certain compliance level acquires two trustworthiness (membership) characteristics.

During simulation, the user randomly selects an agent with the probability of having a compliance value ranging from 0% to 100%. There are six grades of TV_1, TV_2, TV_3, TV_4, TV_5, and TV_6. Each compliance value will correspond to a certain degree of trust value membership. For example, if a user chooses an agent with a 28%, level of compliance, their behaviour will exhibit some degree similarity to the TV_1 and TV_2 characteristics as this point has a certain degree of membership in TV_1 and TV_2. However, the total degree of membership is always 1. The equations representing fuzzy triangular compliance corresponding to TV_1, TV_2, TV_3, TV_4, TV_5, and TV_6 are shown below:

TV	Membership Degree	$(x\ value)$
TV_1	0	$x \geq 33.33$
	$\frac{33.33 - x}{33.33 - 16.67}$	16.68< x < 33.33
	1	$0 \leq x \leq 16.67$
TV_2	0	$x \leq 16.67$
	$\frac{x - 16.67}{33.33 - 16.67}$	$16.67 < x < 33.33$
	$\frac{50 - x}{50 - 33.33}$	$33.33 < x < 50$
	1	$x = 33.33$
TV_3	0	$0 \leq x \leq 33.33$
	$\frac{x - 33.33}{50 - 33.33}$	$33 < x < 50$
	$\frac{66.67 - x}{66.67 - 50}$	$50 < x < 66.67$
	1	$x = 66.67$
TV_4	0	$0 \leq x \leq 50$
	$\frac{x - 50}{66.67 - 50}$	$50 < x < 66.67$
	$\frac{83.33 - x}{83.33 - 66.67}$	$66.67 < x < 83.33$
	1	$x = 83.33$
TV_5	0	$0 \leq x \leq 66.67$
	$\frac{x - 66.67}{83.33 - 66.67}$	$66.67 < x < 83.33$
	$\frac{90 - x}{90 - 83.33}$	$83.33 < x < 90$
	1	$x = 90$
TV_6	0	$0 \leq x \leq 83$
	$\frac{x - 83.33}{90 - 83.33}$	$83.33 < x < 90$
	1	$90 < x \leq 100$

Table 9.17: Fuzzy triangular compliance rules

In this approach, consider for example that we have an agent with a compliance level of 85%. This agent will exhibit behaviour to some degree of TV_5 and to some extent of TV_6. Therefore, the calculation of compliance behaviour is as follows:

$$Compliance\ Behaviour = (membership\ degree * TV_{5char}) + (membership\ degree * TV_{6char})$$

Equation 9.8

Membership degree is the level of membership based on calculation using the fuzzy rule above, whereas $TV_{n\ char}$ is a characteristic of trust value as derived from the crisp compliance level. Based on the above rule, the compliance level of this agent is 87.5% as a result of the following calculation shown in Table 9.18.

TV	$(x\ value)$	Membership Degree	Compliance Behaviour
TV_5	$83.33 < x < 90$	$\frac{90-85}{90-83.33} = 0.75$	$0.75 * 83.33 = 62.5$
TV_6	$83.33 < x < 90$	$\frac{85-83.33}{90-83.33} = 0.25$	$0.25 * 100 = 25$
Total		$0.75 + 0.25 = 1$	$62.5 + 25 = 87.5$

Table 9.18: Triangular compliance behaviour calculation

The second approach that we propose for modelling the dynamic behaviour of an agent is to use a fuzzy trapezoidal compliance level. This approach is an extension of the fuzzy triangular approach. However, the membership functions corresponding to TV_2 to TV_5 are trapezoidal; hence, we call this type of compliance '*fuzzy trapezoidal compliance*'. This is depicted in Figure 9.14 below.

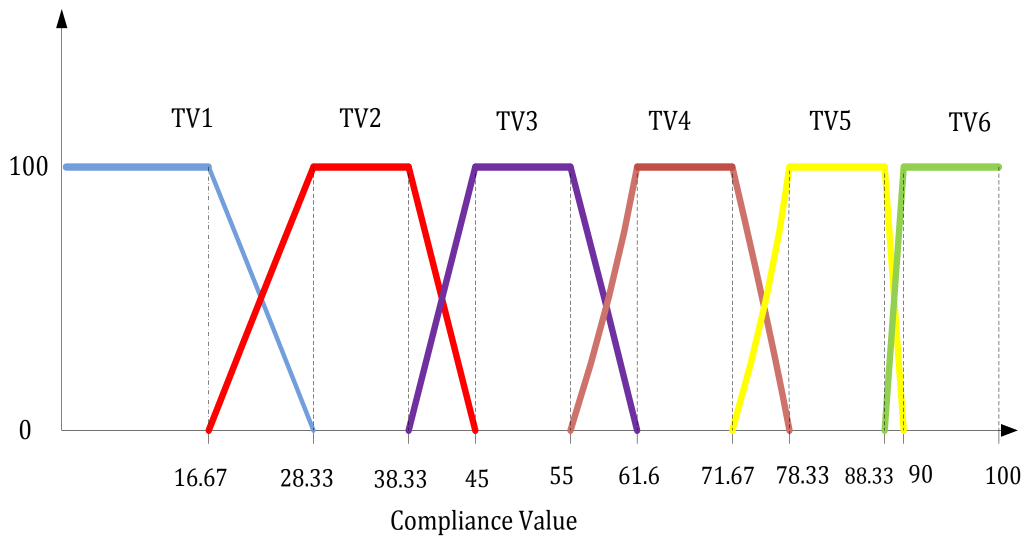

Figure 9.14: Trapezoidal membership degree and compliance values

The membership functions are shown below in Table 9.19.

TV	Membership Degree	$(x\ value)$
TV_1	0	$x \geq 28.33$
	$\frac{28.33 - x}{28.33 - 16.67}$	$16.67 < x < 28.33$
	1	$0 \leq x \leq 16.67$
TV_2	0	$x < 16.67$
	$\frac{16.67 - x}{28.33 - 16.67}$	$16.67 < x < 28.33$
	1	$28.33 \leq x \leq 38.33$
	$\frac{45 - x}{45 - 38.33}$	$38.33 < x < 45$
TV_3	0	$0 \leq x \leq 38.33$

	$\frac{x-38.33}{45-38.33}$	$38.33 < x < 45$
	1	$45 \leq x \leq 55$
	$\frac{61.67-x}{61.67-55}$	$55 < x < 61.67$
TV_4	0	$0 \leq x \leq 55$
	$\frac{x-55}{61.67-55}$	$55 < x < 61.67$
	1	$61.6 \leq x \leq 71.67$
	$\frac{78.33-x}{78.33-71.67}$	$71.68 < x < 78.33$
TV_5	0	$0 \leq x \leq 71.67$
	$\frac{x-71.67}{78.33-71.67}$	$71.67 < x < 78.33$
	1	$78.33 \leq x \leq 88.33$
	$\frac{90-x}{90-88.33}$	$88.33 < x < 90$
TV_6	0	$0 \leq x \leq 88.33$
	$\frac{x-88.33}{90-88.33}$	$88.33 < x < 90$
	1	$90 < x \leq 100$

Table 9.19: Fuzzy trapezoidal compliance rules

In order to show the difference between compliance level calculation by using this approach and the previous approach, consider for example, that we have an agent with a compliance level of 85%. This compliance value has a full degree of membership in TV_5. Therefore, this agent will categorize in characteristic of TV_5 with compliance behaviour 83.33%. Consider another example where we randomly have an agent with a compliance value of 89%. This compliance behaviour will categorize to some extent the degree of TV_5 and TV_6. The compliance behaviour of this agent is 90.16 as a result of the calculation of compliance behaviour as illustrated in Table 9.20 below:

TV	$(x\ value)$	Membership Degree	Compliance Behaviour
TV_5	$88.33 < x < 90$	$\frac{90-89}{90-88.33} = 0.41$	$0.59 * 83.33 = 49.16$
TV_6	$88.33 < x < 90$	$\frac{89-88.33}{90-88.33} = 0.41$	$0.41 * 100 = 41$
Total		$0.59 + 0.41 = 1$	$49.16 + 41 = 90.16$

Table 9.20: Trapezoidal compliance calculation

The third method that we propose for modeling the dynamic behaviour of an agent is by determining the behaviour of agents with the help of a graph which combines the triangular approach and trapezoidal approach. Hence, we term this approach '*fuzzy hybrid compliance*'. This is represented pictorially in Figure 9.15 below.

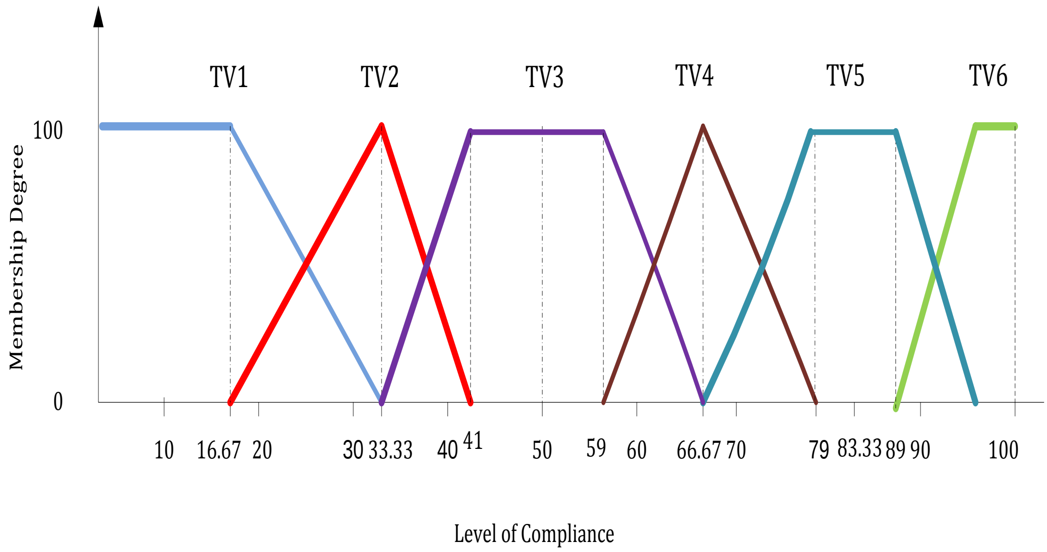

Figure 9.15: Hybrid membership degree and compliance values

The membership functions are shown below in Table 9.21

TV	Membership Degree	$(x\ value)$
TV_1	0	$x \geq 33.33$
	$\frac{33.33 - x}{33.33 - 16.67}$	$16.68 < x < 33.33$
	1	$0 \leq x \leq 16.67$
TV_2	0	$x \leq 16.67$
	$\frac{x - 16.67}{33.33 - 16.67}$	$16.67 < x < 33.33$
	$\frac{41 - x}{41 - 33.33}$	$33.33 < x < 41$
	1	$x = 33.33$
TV_3	0	$0 \leq x \leq 33.33$
	$\frac{x - 33.33}{41 - 33.33}$	$33 < x < 41$
	1	$41 < x < 59$
	$\frac{66.67 - x}{66.67 - 59}$	$59 < x < 66.67$
TV_4	0	$0 \leq x \leq 50$
	$\frac{x - 50}{66.67 - 50}$	$50 < x < 66.67$

	$\frac{79 - x}{79 - 66.67}$	$66.67 < x < 79$
	1	$x = 66.67$
TV_5	0	$0 \leq x \leq 66.67$
	$\frac{x - 66.67}{79 - 66.67}$	$66.67 < x < 79$
	1	$79 < x < 89$
	$\frac{95 - x}{95 - 89}$	$89 < x < 95$
TV_6	0	$0 \leq x \leq 89$
	$\frac{x - 89}{95 - 89}$	$89 < x < 95$
	1	$95 < x \leq 100$

Table 9.21: Fuzzy hybrid compliance rules

In order to show how to calculate the compliance behaviour of an agent with a certain trust value using this approach, let us consider for example that we have an agent with a compliance level of 70%. According to the fuzzy hybrid compliance rules in Table 9.21, this compliance level exhibits elements of compliance of both agents with TV_4 and TV_5. The compliance behaviour of this agent is 71.16 as a result of the calculation of compliance behaviour as illustrated in Table 9.22 below:

TV	$(x\ value)$	**Membership Degree**	**Compliance Behaviour**
TV_4	$66.67 < x < 79$	$\frac{79 - 70}{79 - 66.67} = 0.73$	$0.73 * 66.67 = 48.67$
TV_5	$66.67 < x < 79$	$\frac{70 - 66.67}{79 - 66.67} = 0.27$	$0.27 * 83.33 = 22.49$
Total		$0.73 + 0.27 = 1$	$48.67 + 22.49 = 71.16$

Table 9.22: Hybrid compliance behaviour calculation

c. Step 3. During each transaction, a trusting agent and a trusted agent are randomly chosen. The trusting agent is chosen so that it is always a compliant agent which means this trusting agent has a 100% level of compliance. However, the compliance level of the randomly chosen trusted agent could be any trust value between TV_1 to TV_6. Both agents then carry out the interaction guided by our trust maintenance methodology.

d. Step 4. The statistical outcome corresponding to the results produced by the simulation.

Once we retrieve all these statistical results, we then analyse them in order to determine the effectiveness of our methodology.

9.6.2 **Simulation Results: Comparison of Transactions with TMM and without TMM (Dynamic Behaviour)**

This simulation is designed to achieve objective 2.1 which is to analyse the effectiveness of our TMM in terms of the dynamic behaviours of agents. The analysis is conducted in order to compare transactions which employ our TMM with those which do not employ our TMM. Figure 9.16 below shows the trust maintaining tool benchmark software prompting the user to input the parameters as described in Table 9.3.

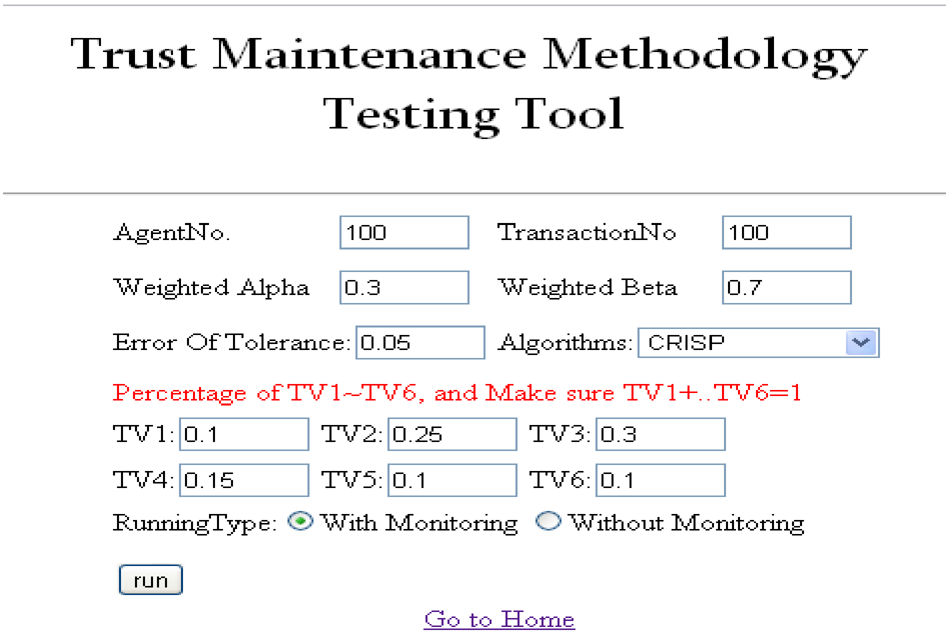

Figure 9.16: Screenshot of testing tool to compare transactions with TMM and without TMM in dynamic behaviour of agents

a. Simulation result with the input parameters as shown in Table 9.23 below:

Number of agents	1000
Number of transactions	1000
Error tolerance level	0.05
α	0.7
β	0.3
Algorithms	FL Triangular
Percentage of agents with $TV_1 – TV_6$	TV_1 = 0.1, TV_2 = 0.1, TV_3 = 0.1, TV_4 = 0.2, TV5 = 0.25, TV_6 = 0.25

Table 9.23: Input parameters for simulation to compare transactions with TMM and without TMM in dynamic behaviour of agents (FL Triangular)

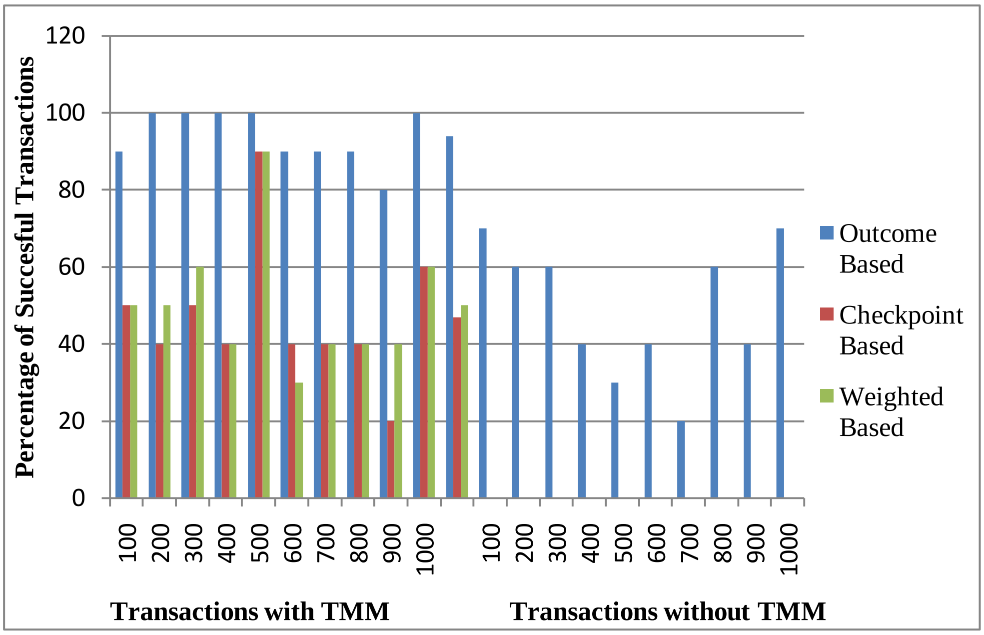

Figure 9.17: Result of simulation to compare transactions with TMM and without TMM in dynamic behaviour of agents (FL Triangular)

Figure 9.17 presents results of simulations using the parameters given in Table 9.23. In this case, the dynamic behaviour of agents is represented with the help of FL Triangle. As we can observe from the figure, for agents who use our TMM in their transactions, by the end of transactions, the trust level between trusting agent and trusted agent has been successfully maintained. If we calculate final trust using outcome-based, after 200 transactions, 100% of them have successfully maintained their trust level. Conversely, if we investigate those transactions which do not use our TMM, the percentage of successful transactions is lower than 70% on average. Additionally, if we calculate the trust final using checkpoint-based and weighted-based, the percentage of successful transactions is 0%. This is because, without having our TMM in the transactions, there will be no intermediate checkpoint by which trusting agent can assign an intermediate value of trust. Checkpoint-based final trust is the average value of intermediate trust values during interaction. This situation also occurs if we calculate final trust using weighted-based. Weighted-based final trust value is calculated by giving a weight alpha for outcome-based and checkpoint-based. As in the transactions without TMM there is no checkpoint value, hence the final trust value based on weighted based is ‘0’. Thus, we can infer from the comparison, by using outcome-based, the transaction which used our TMM give a better result in terms of maintaining trust compare with the transactions which do not use our TMM. In contrast, in the simulation using the static behaviour of agent, in comparison with the dynamic behaviour of agent, the successful transactions are slightly lower in transactions with TMM. This is because with dynamic behaviour, the performance of the agent throughout the interaction is dynamically changing. In the next section, we further investigate the simulation using other approaches for dynamic behaviour modelling.

b. Simulation result with the parameters as shown in Table 9.24 below:

Number of Agents	1000
Number of transactions	1000
Error tolerance level	0.05
α	0.3
β	0.7
Algorithms	FL Trapezoidal
Percentage of agents with $TV_1 – TV_6$	TV_1 = 0.1, TV_2 = 0.1, TV_3 = 0.1, TV_4 = 0.2, TV5 = 0.25, TV_6 = 0.25

Table 9.24: Input parameters to compare transactions with TMM and without TMM in dynamic behaviour of agents (FL Trapezoidal)

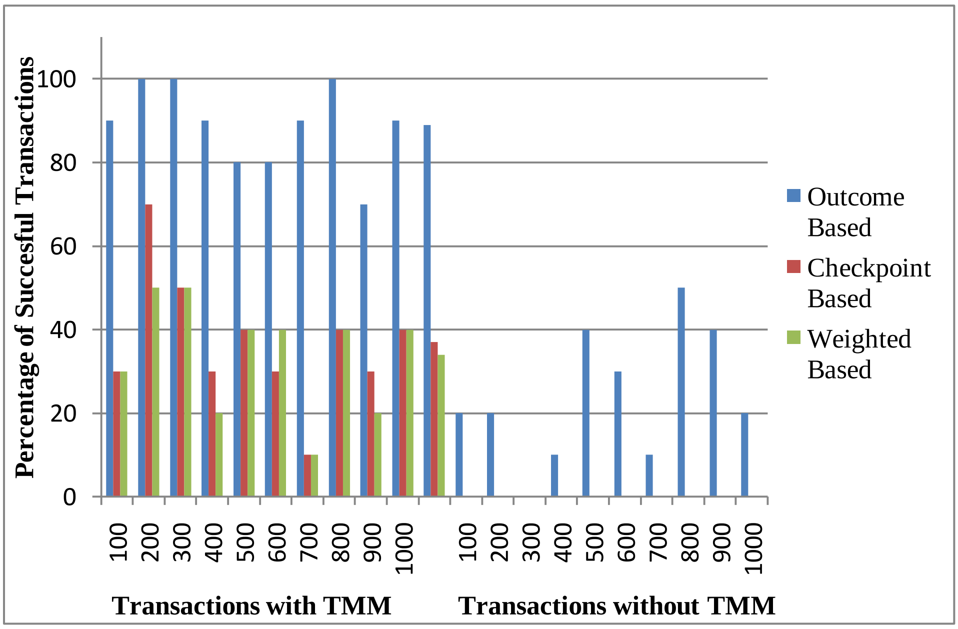

Figure 9.18: Result of simulation to compare transactions with TMM and without TMM in dynamic behaviour of agents (FL Trapezoidal)

Figure 9.18 gives a similar result as that depicted in Figure 9.17. However, the modelling of dynamic behaviour of agents in this simulation is represented by using the FL trapezoidal. It can be clearly seen that across the board, irrespective of the approach used to model the dynamic behaviour of agents, by using our TMM, the percentage of successful transactions with TMM is always higher than for the transactions without TMM. Similar to the previous cases in simulation without TMM, there is no value for final trust calculation using checkpoint-based and weighted-based. In transactions without TMM, there is no performance continuous monitoring. Hence, there is no intermediate trust value based on the intermediate monitoring.

c. Simulation result with the parameters as shown in Table 9.25 below:

Number of agents	125000
Number of transactions	100000
Error tolerance level	0.03
α	0.4
β	0.6
Algorithms	FL Hybrid
Percentage of agents with $TV_1 – TV_6$	TV_1 = 0.1, TV_2 = 0.1, TV_3 = 0.1, TV_4 = 0.2, TV5 = 0.25, TV_6 = 0.25

Table 9.25: Input parameters for simulation to compare transactions with TMM and without TMM in dynamic behaviour of agents (FL Hybrid)

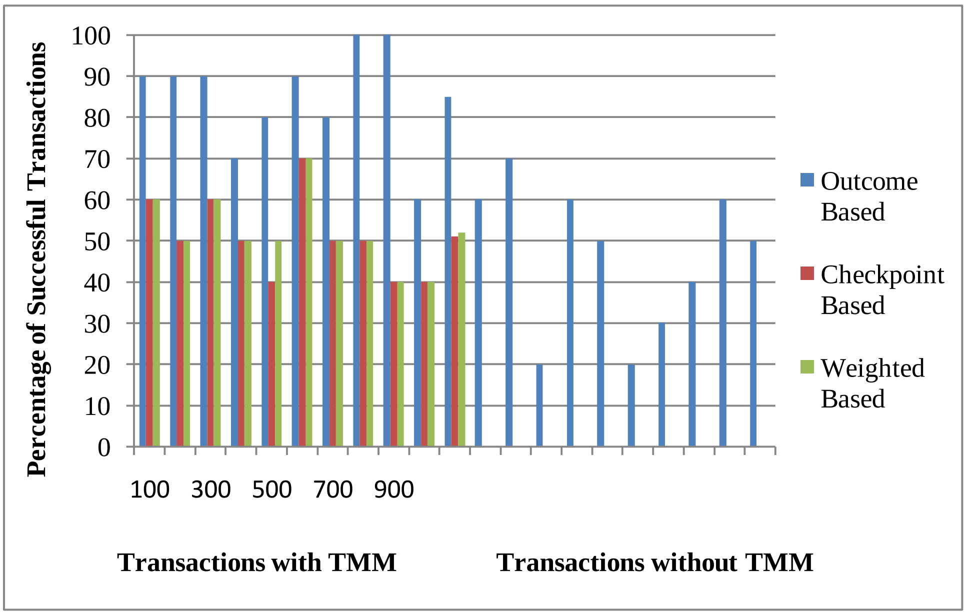

Figure 9.19: Result of simulation to compare transactions with TMM and without TMM in dynamic behaviour of agents (FL Hybrid)

Figure 9.19 presents results for simulation with the input parameters as described in Table 9.25. The modeling of agent behaviour in this simulation is determined with the help of FL Hybrid. As can be seen from the figure 9.20, the percentage of successful transactions with TMM is higher than transactions without TMM. Hence, it can be concluded that even though the behaviour of agent is dynamic throughout the transactions, based on all the three modeling approaches, our TMM is effective in helping the trusting agent to maintain its trust value in the trusted agent. Further analysis and discussion can be found in Section 9.6.4.

9.6.3 Simulation Results: Comparison between Final Trust and Initial Trust (Dynamic Behaviour)

Figure 9.20 below shows the screenshot of the trust maintenance tool benchmark software prompting the user to input the parameters for simulation with the objective to analyse the effectiveness of our TMM by making a comparison between final trust value and initial trust value.

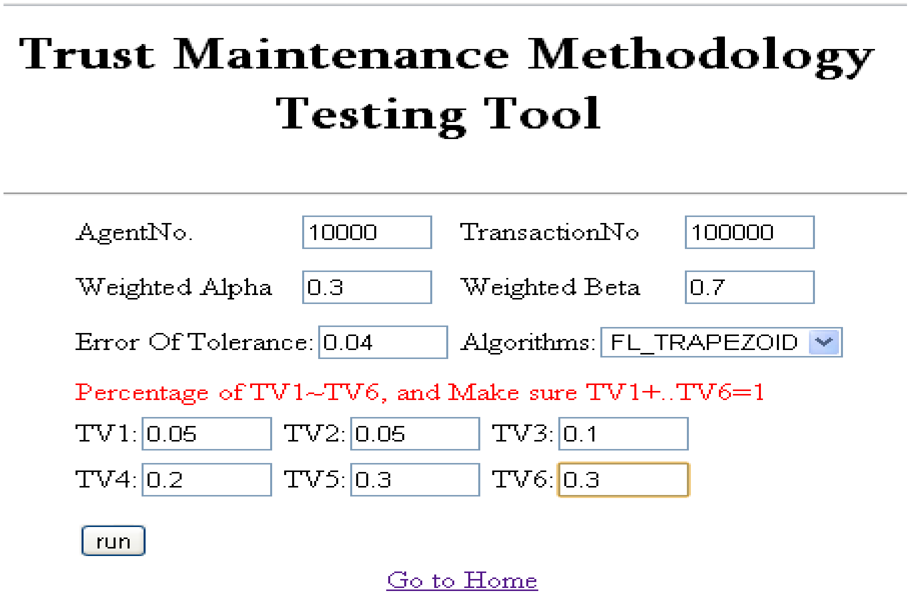

Figure 9.20: Screenshot of testing tool to compare final trust value with initial trust value in dynamic behaviour of agents

a. Simulation results using the input parameters as shown in Table 9.26 below:

Number of Agents	5000
Number of Transactions	1000
A	0.3
B	0.7
Error Tolerance	0.05
Algorithm	FL Triangular
Percentage of $TV_1 – TV_6$	TV_1= 0.1; TV_2= 0.1; TV_3= 0.1; TV_4=0.2; TV_5=0.25; TV_6=0.25

Table 9.26: Input parameters for simulation to compare final trust value and initial trust value in dynamic behaviour (FL Triangular)

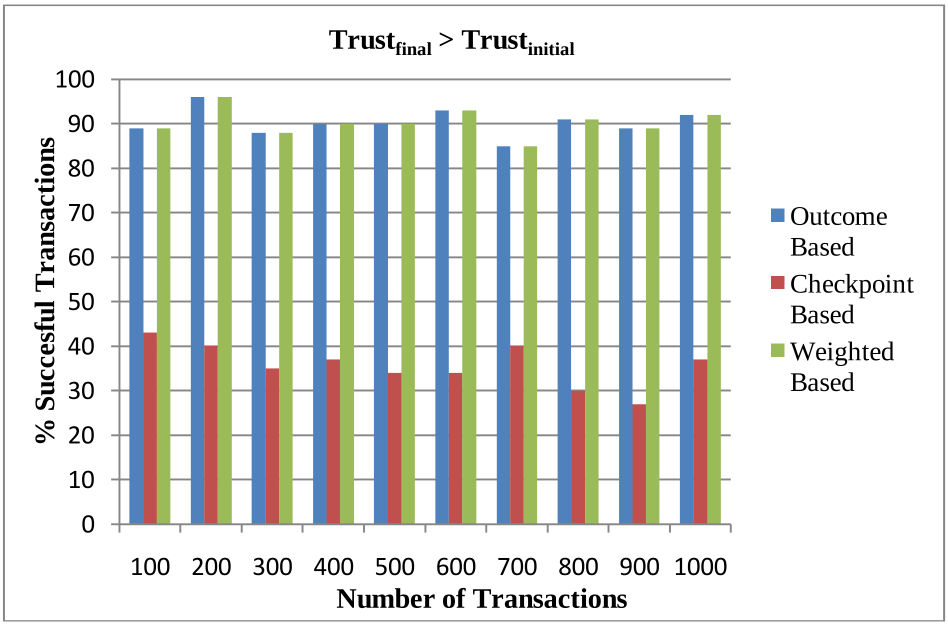

Figure 9.21: Result of simulation to compare final trust value with initial trust value in dynamic behaviour of agents (FL Triangular) (G-Benchmark)

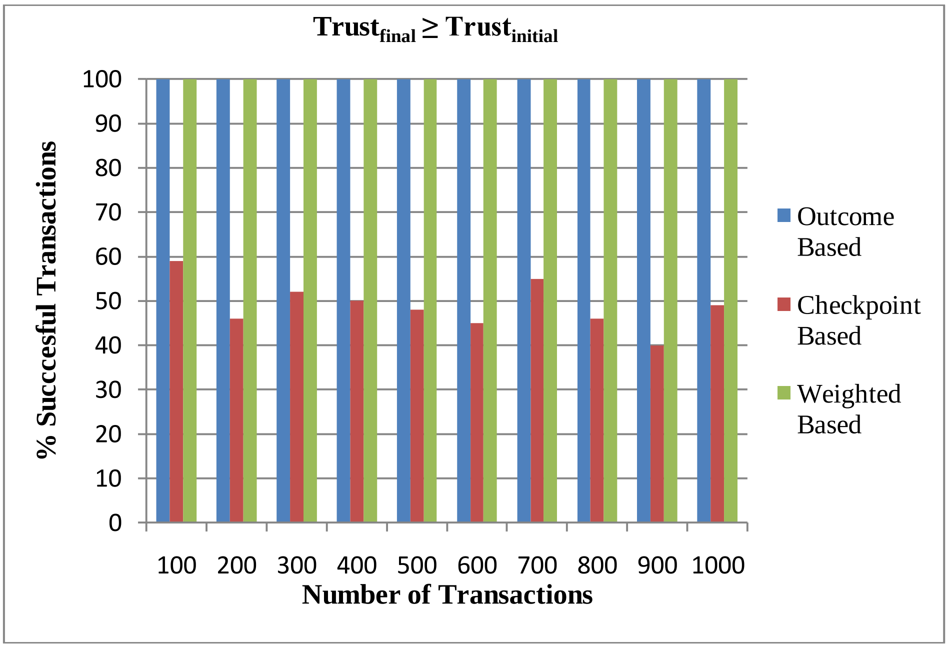

Figure 9.22: Result of simulation to compare final trust value with initial trust value in dynamic behaviour of agents (FL Triangular) (GE-Benchmark)

Figures 9.21 and 9.22 above depict the results of the simulation using the input parameters shown in Table 9.26. The number of agents in this simulation is 5000 and they carried out 1000 transactions. Figure 9.21 describes the results when the effectiveness of methodology is measured by using the G Benchmark (final trust greater than initial trust), while Figure

9.22 depicts the results when the effectiveness of methodology is measured by using the GE Benchmark (final trust greater than or equal to initial trust). The final trust calculation is measured using three approaches which are: outcome-based, checkpoint-based and weighted-based.

As we can observe from Figures 9.21 and 9.22, in every 100 transactions, by using outcome-based and weighted-based approaches for final trust calculation and the G-Benchmark, on average, the number of successful interactions is around 90%. This is because, with the outcome-based approach, final trust is determined by the final outcome of the interaction without considering how this agent behaves at every checkpoint. Based on the methodology of proactive continuous performance monitoring, once a performance discrepancy occurs, it needs to be resolved in a timely manner. Hence, by the end of the interaction, the actual performance will correspond as closely as possible to the mutually agreed performance (assuming that both parties intend to maintain trust). With the large weight given to outcome-based trust (70%) relative to checkpoint-based trust (30%) when computing the final trust value using the weighted-based approach, we can observe a pattern of success similar to that of the outcome-based approach. However, if we employ the GE-Benchmark, then we can see that all the transactions (by using the outcome-based approach and weighted-based approach) can be regarded as successful. In order to understand the difference in the success ratio, using these benchmarks, we carried out an analysis of the percentage of successful transactions as a function of the trustworthiness value of the trusted entity. The analysis is presented in Table 9.27 below:

	G-Benchmark						
	Successful Transactions	TV_1	TV_2	TV_3	TV_4	TV_5	TV_6
OB	903	90	137	258	324	94	0
CP	357	90	0	123	142	2	0
WB	903	90	137	258	324	94	0
	GE-Benchmark						
	Successful Transactions	TV_1	TV_2	TV_3	TV_4	TV_5	TV_6
OB	1000	90	137	258	324	94	97
CP	490	90	0	138	161	4	97
WB	1000	90	137	258	324	94	97

Table 9.27: The differences in success ratios when comparing final trust value with initial trust value in dynamic behaviour of agents (FL Triangular)

As we can clearly observe from Table 9.27, the difference in the success ratio using both the G- and GE-Benchmarks occurs when the trust initial value of the trusted entity is ‘6’. Since the trust initial value of the trusted entity is ‘6’, the final trust value at best could be 6. In this case, by using the G-benchmark, this transaction would be considered unsuccessful. However, by using the GE-Benchmark, this transaction would be regarded as successful.

On the other hand, if we computed final trust using the checkpoint-based approach, the number of successful interactions is around 36% on average for the G-Benchmark and around 49% for the GE-Benchmark scenario. This difference occurs because we use different scenarios to determine successful transactions. The lower number of successful interactions using the checkpoint-based approach compared with the outcome-based and weighted-based approaches occurs due to the manner in which the final trust value in the checkpoint-based approach is computed using average of intermediate behaviour. The methodology helps the trusted agent to close the performance gap at every checkpoint; however, the checkpoint-based approach does not consider the final outcome. In contrast to the outcome-based approach, the checkpoint-based approach calculates the final trust value by averaging all the trust values for the checkpoints in the interaction. The final calculated trust value does not particularly focus on whether the final service delivery (in the final checkpoint correspond with agreed service delivery, but rather the degree of compliance at all checkpoints in the interaction).

b. Simulation results using the input parameters are shown in Table 9.28 below:

Number of Agents	1000
Number of Transactions	100000
α	0.3
β	0.7
Error Tolerance	0.05
Algorithm	FL Hybrid
Percentage of $TV_1 – TV_6$	TV_1= 0.1; TV_2= 0.1; TV_3= 0.1; TV_4=0.2; TV_5=0.25; TV_6=0.25

Table 9.28: Input parameters to compare final trust value with initial trust value in dynamic behaviour of agents (FL Hybrid)

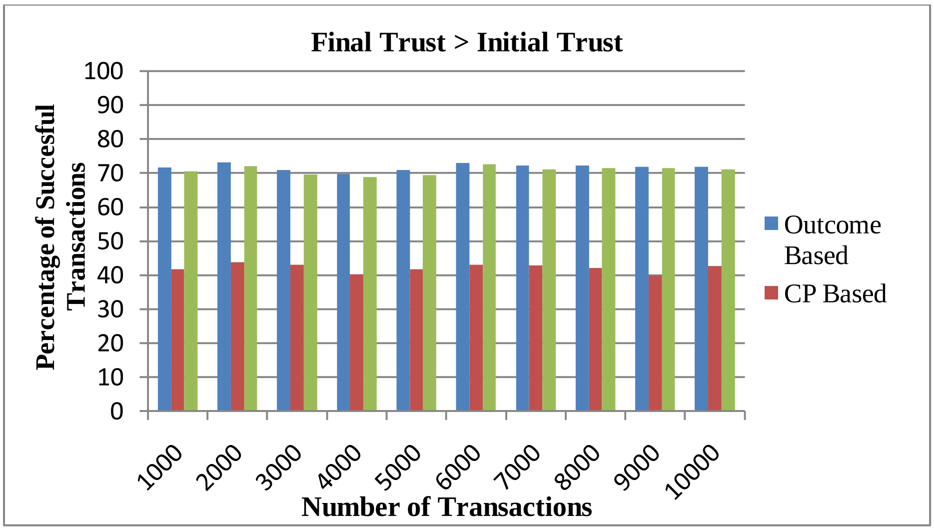

Figure 9.23: Result of simulation to compare final trust value with initial trust value in dynamic behaviour of agents (FL Hybrid) (G-Benchmark)

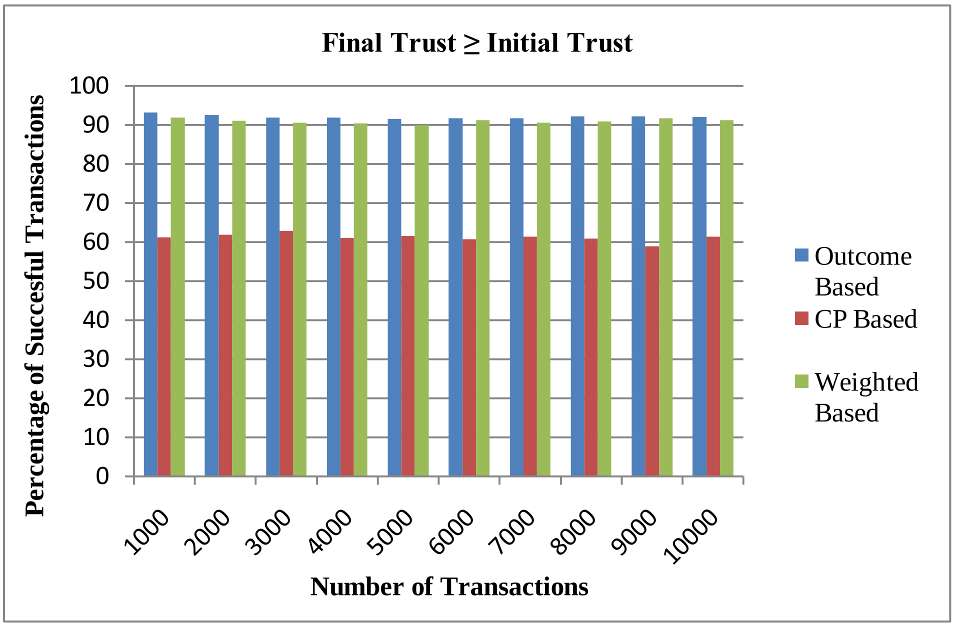

Figure 9.24: Result of simulation to compare final trust value with initial trust value in dynamic behaviour of agents (FL Hybrid) (GE-Benchmark)

Figure 9.23 and Figure 9.24 above present the analytical results for the effectiveness of our TMM after comparing final trust with initial trust. The input parameters are those described in Table 9.28. It is evident that by using the GE-Benchmark, the average number of successful transactions, that is, those where final trust is greater than initial trust, is about 70%, if we calculate final trust using outcome-based and weighted-based approaches. However, if final trust is calculated using the checkpoint-based (CP based) method, the percentage of successful transactions is around 40% on average. This is because the trust final calculation in checkpoint based approach considers only the performance of service delivery during the intermediate performance. It does not pay any particular significance or importance the final delivery outcome by end of the interaction.

Nonetheless, if we use the GE-Benchmark, the percentage of successful transactions is greater than for those where the G-Benchmark was used. As our analysis with the triangular FL dynamic behaviour in section (a) above shows, the difference in the success ratio using both the G and GE-Benchmarks occurs when the trust initial value of the trusted entity is ‘6’. Since the initial trust value of the trusted entity is ‘6’, the final trust value at best could be 6. In this case, by using the G-benchmark, this transaction would be considered unsuccessful. However, by using the GE-Benchmark, this transaction would be regarded as successful.

c. Simulation results using the input parameters as shown in Table 9.29 below:

Number of Agents	5000
Number of Transactions	1000
α	0.3
β	0.7

Error Tolerance	0.05
Algorithm	FL Trapezoidal
Percentage of $TV_1 – TV_6$	TV_1= 0.1; TV_2= 0.1; TV_3= 0.1; TV_4=0.2; TV_5=0.25; TV_6=0.25

Table 9.29: Input parameters for simulation to compare final trust value with initial trust value in dynamic behaviour of agents (FL Trapezoidal)

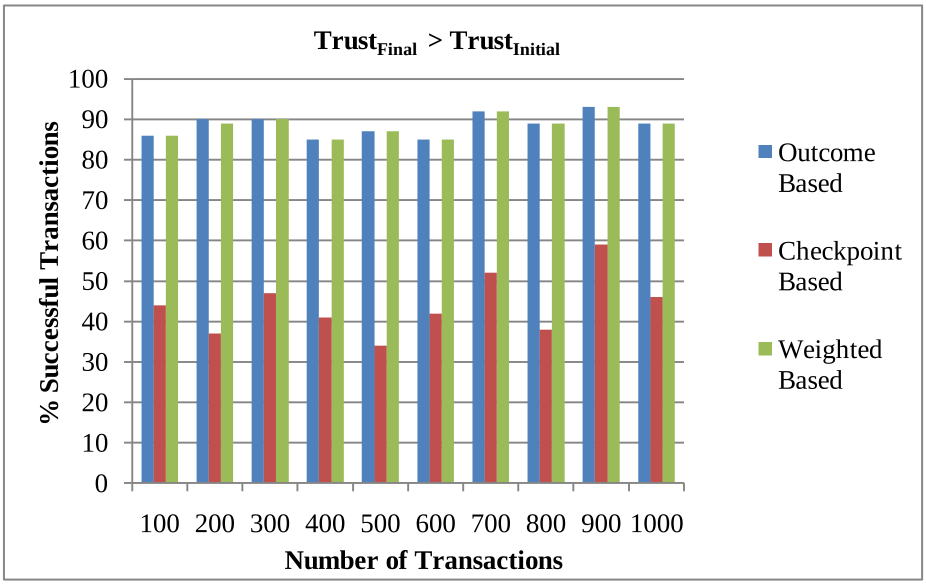

Figure 9.25: Result of simulation to compare final trust value with initial trust value in dynamic behaviour of agents (FL Trapezoidal) (G-Benchmark)

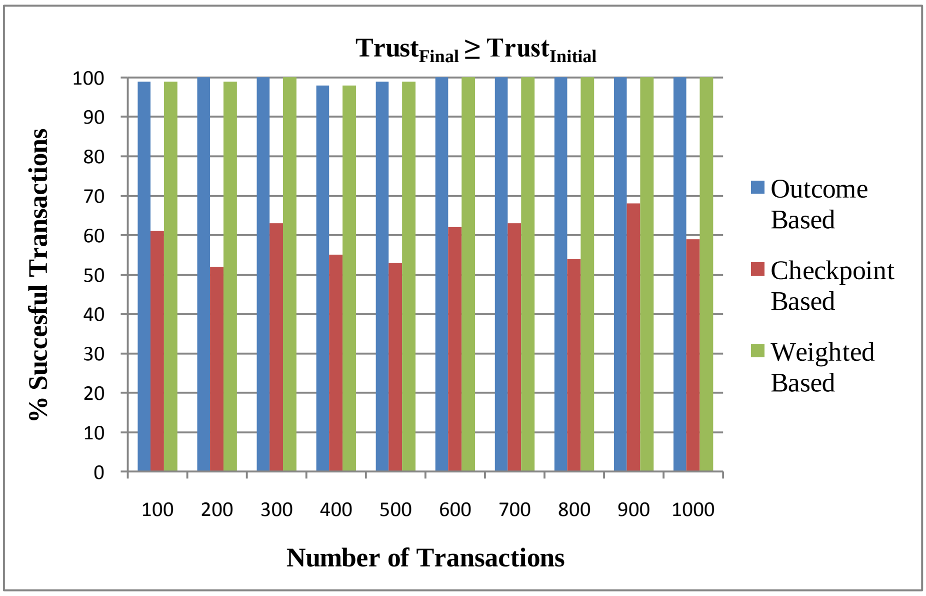

Figure 9.26: Result of simulation to compare final trust value with initial trust value in dynamic behaviour of agents (FL Trapezoidal) (GE-Benchmark)

As we can see from Figures 9.26 and 9.27, in every 100 transactions, by using outcome-based and weighted-based trust recalibration, the number of successful interactions is around 85% for the G-Benchmark and 99% for the GE-Benchmark.

This result is quite different from the result of triangular compliance level. This is because we employed the trapezoidal compliance level so that the behaviour of the chosen trusted agent is different from that of the chosen agent at the triangular compliance level. An in-depth analysis of the difference between the success ratio using both G and GE-Benchmarks is provided in Table 9.30 below:

	G-Benchmark						
	Successful Transactions	TV_1	TV_2	TV_3	TV_4	TV_5	TV_6
OB	886	109	132	275	274	96	0
CP	440	109	48	141	141	1	0
WB	885	109	132	275	274	95	0
	GE-Benchmark						
	Successful Transactions	TV_1	TV_2	TV_3	TV_4	TV_5	TV_6
OB	996	109	132	275	274	96	110
CP	590	109	69	150	151	1	0
WB	995	109	132	275	274	95	110

Table 9.30: The difference in success ratios when comparing final trust value with initial trust value in dynamic behaviour of agents (FL Trapezoidal)

Table 9.30 above shows that the differences between the G and GE- Benchmarks occur in the agent with an initial trust value of '6'. Moreover, if we compute the final trust using the checkpoint-based approach, the number of successful interactions by using G-Benchmark is 44% and 59% if we utilize the GE-Benchmark. As mentioned previously, this is due to the manner in which the checkpoint-based approach arrives at an aggregate value from intermediate trust values during the transaction. It may be the case that the number of low performances is greater than the number of high performances for the whole checkpoint. Even though the trusted agent delivers service fully by the end of the transaction, this checkpoint-based approach does not give a weighting to the service delivery at a particular checkpoint; instead, it considers only how the trusted agent complies at every checkpoint. In order to elucidate this further, let us consider a simple example where the trusted agent does not comply at several checkpoints, but this agent delivers a service in total by the end of the transaction. This would result in a lower number of intermediate trust values which influences the final trust calculation. Therefore, it produces a lower number of successful interactions than do the outcome-based and weighted-based approaches.

9.6.4 **Discussion of Results Obtained for Objective 2**

Based on results from various input parameters as presented in several figures in the previous section, we can draw the following conclusions:

a. Objective 2.1: Comparison between transaction with TMM and without TMM in dynamic behaviour of agents

   We have three different approaches to modeling the dynamic behaviour of agents in carrying out an interaction. Hence, the discussion will be based on the three different dynamic behaviours of agents. As we can see from Figures

9.17 – 9.18, the average successful ratio of interaction with TMM is higher than for transactions without TMM. We carried out our investigation from the perspective of the various parameters and it can be concluded that where an agent displays dynamic behaviour, the percentage of successful transactions with TMM is more than 85%; whereas, in transactions without TMM the success rate is lower than 50%. For elucidation purposes, Table 9.31 below presents the summary of the average of simulation results both with and without TMM.

	Transaction with TMM			Transaction without TMM		
	FL Triangular	FL Trapezoidal	FL Hybrid	FL Triangular	FL Trapezoidal	FL Hybrid
OFTV	94%	89%	85%	49%	0%	46%
CFTV	47%	37%	51%	0%	0%	0%
WFTV	50%	34%	52%	0%	0%	0%

Table 9.31: Summary of simulation result to compare transactions with TMM and without TMM in dynamic behaviour of agents

b. Objective 2.2: Comparison between final trust value and initial trust value in dynamic behavior of agents

As explained in Section 9.6.3, the ratio of successful transactions ascertained by comparing final trust and initial trust using both G and GE-Benchmark is satisfactorily high. In modeling agent behaviours using fuzzy logic triangular, the successful ratio is 90.3% if we calculate this using the outcome-based and weighted-based approaches (G-Benchmark). However, if we use the GE-Benchmark, the success ratio is 100%. The checkpoint-based approach resulted in a lower number of successful transactions because in this case, the final trust calculation considers only the intermediate performance without paying attention to final delivery. With the help of the fuzzy logic trapezoidal to model the dynamic behaviour of the agent, the number of successful transactions is much lower than when using the triangular approach for both, using the G and GE-Benchmarks. However, the number of successful transactions is greater than 88% when using the G-Benchmark and 99.5% for the GE-Benchmark.

The last approach for modelling the dynamic behaviour of an agent is by using a hybrid fuzzy logic compliance level. With this approach, the percentage of successful transactions using our TMM is greater than 90% based on both the G and GE-Benchmarks. Hence, it can be inferred from this discussion that using our TMM, for any number of transactions and any number of agents, with the hybrid fuzzy logic of dynamic behaviour of agents, the number of successful transactions when the final trust is greater than the trust initial, is close to 100%. Moreover, the successful ratio using the GE-Benchmark using weighted-based calculation is 100%. Table 9.32 below presents the summary of average results of this particular simulation.

Benchmark / FTC	G-Benchmark			GE–Benchmark		
	OFTV	CFTV	WFTV	OFTV	CFTV	WFTV
FL Triangular	90.3%	35%	90.3%	100%	49%	100%
FL Trapezoid	88.6%	44%	88.5%	99.6%	59%	99.5%
FL Hybrid	92%	50%	87%	98%	58%	100%

N.B.: FTC = Final Trust Calculation, OFTV = Outcome-based Final Trust Value, CFTV = Checkpoint-based Final Trust Value, WFTV = Weighted-based Final Trust Value.

Table 9.32: Summary of simulation result for comparison between final trust value and initial trust value in dynamic behaviour of agents

We can also additionally infer from Table 9.32 above that by using FL triangular, the successful ratio is the highest compared with other approaches of dynamic behaviour model, based on the GE-Benchmark. A similar pattern of results can be found if we examine them from the G-Benchmark perspective.

Finally, we can conclude that for transactions in a virtual environment which employ our TMM, the level of trust at the end of the transaction is higher than the initial trust at the initial transaction. The success ratio is higher than 88%. In this case, we may ignore the final trust calculation from the checkpoint-based approach. As was discussed by (Fachrunnisa and Hussain 2011), the weighted-based approach to calculate final trust at the end of the interaction using the TMM is the most effective and reasonable method. The weighted approach takes into account the dynamic nature of trust information during the interaction and the final outcome that has been delivered by the trusted agent at the end of the interaction which the checkpoint based approach and outcome based approach do not. Hence, we can conclude that our TMM is effective in helping the trusted agent to maintain trust in the trusting agent.

9.7 Simulation for Objective 3: The Effectiveness of Incentive-based TMM

The objectives of the simulation are to analyse the effectiveness of using/employing incentive mechanisms in our TMM. In this simulation, we employ three different incentive mechanisms in our TMM. We carried out an analysis to evaluate the performance of a TMM with an incentive mechanism compared with a TMM without an incentive mechanism. Moreover, as we have three different approaches to providing an incentive in such transactions, we also investigate which of these approaches best facilitates the trust maintenance effort and service deliverability. In the next section, we explain the workflow and simulation results, discuss each incentive mechanism approach in detail, and compare the performance of these three mechanisms (with each other) to maintain trust and without any incentive-based approach in TMM.

9.7.1 Workflow of Simulation for Objective 3.1

In order to achieve this objective, we run simulations for TMM non-incentive-based approaches similar to the simulation for objective 1. Using the same input parameters, we also run simulation for TMM incentive-based. The steps involved in the TMM incentive-based simulation are as follows:

a. Step 1. The user specifies all the parameter values that need to be determined as stated in Table 9.5 – Table 9.7.

b. Step 2. During the bootstrapping phase, the agents are created and each of them is assigned a given behaviour, to represent their level of compliance.

c. Step 3. During each transaction, a trusting agent and a trusted agent are randomly chosen. The trusting agent is chosen such that it is always a compliant agent which means this trusting agent has a 100% level of compliance. However, the compliance level of the randomly chosen trusted agent could be any trust value between TV_1 to TV_6. Both agents then carry out the interaction following all the framework steps that we proposed in our trust maintenance incentive-based methodology.

d. Step 4. The outcome statistics are gathered and presented.

In this case, we compare the results of transactions which utilize our TMM incentive-based approach with the results from transactions which did not utilize our TMM incentive-based approach.

9.7.2 Simulation Results: Comparison of TMM with Incentive and TMM without Incentive.

This simulation is designed to compare TMM without incentive and TMM with incentive. We propose three different approaches for the incentive mechanisms: (a) TMM performance-driven-based incentive, (b) TMM occurrence-based incentive, and (c) TMM error-tolerance-based incentive. Figure 9.27 below shows the screenshot of trust maintaining tool benchmark software for a performance-driven incentive-based mechanism prompting the user to input the parameters.

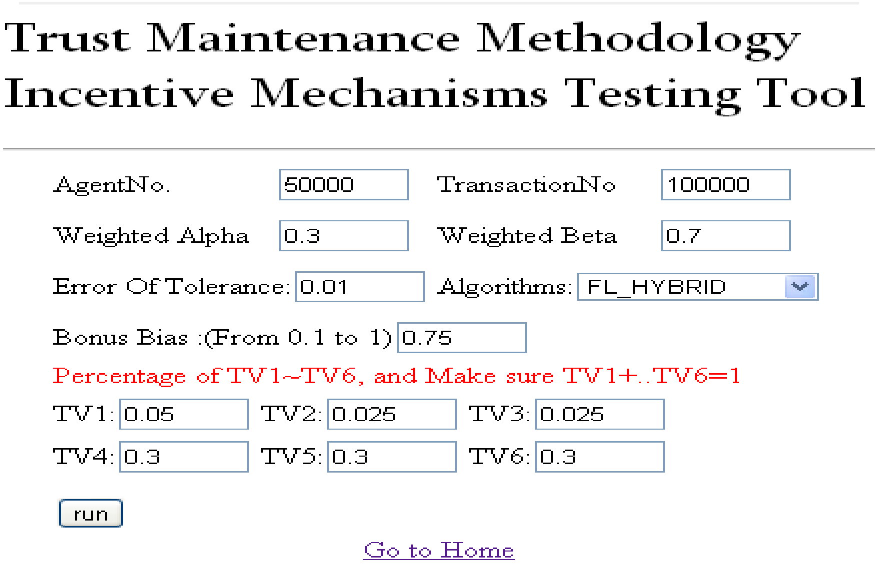

Figure 9.27: Screenshot of testing tool for performance-driven-based incentive mechanism

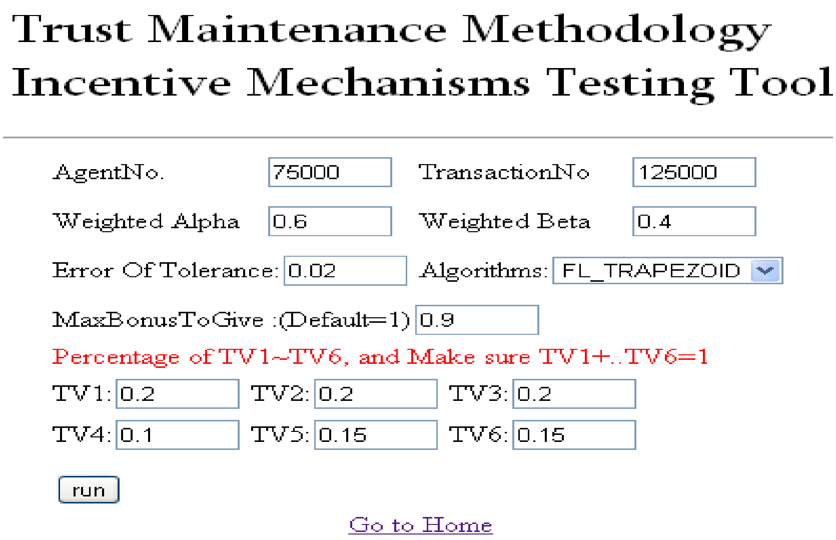

Figure 9.28: Screenshot of testing tool for occurrence-based incentive mechanism

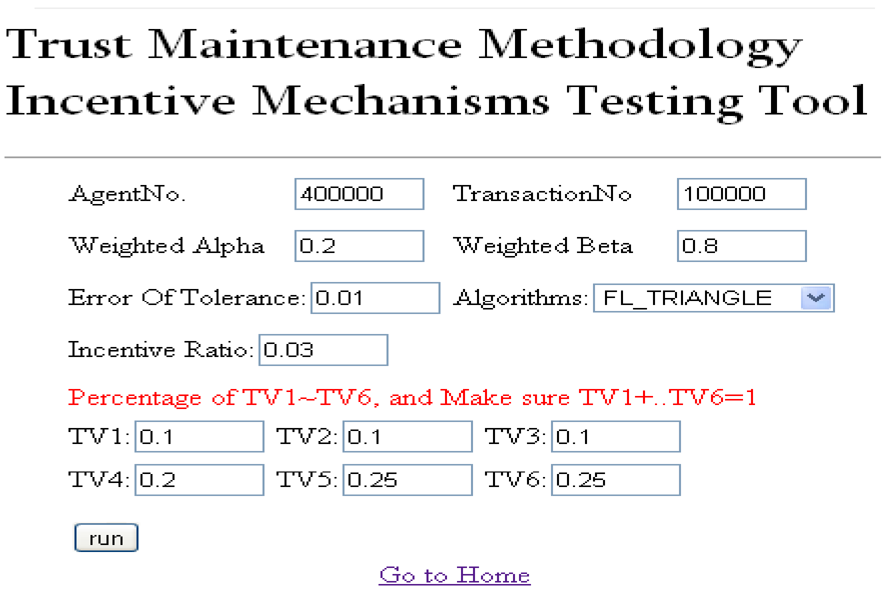

Figure 9.29: Screenshot of testing tool for error-tolerance-based incentive mechanism

a. Simulation results using the input parameters shown in Table 9.33.

Number of Agents	1000
Number of Transactions	1000
α	0.3
β	0.7
Error Tolerance	0.05
Algorithm	FL Triangular
Brake option (performance-driven)	0.1
Incentive ratio (error-tolerance-based)	0.02
Max bonus (occurrence-based)	1
Percentage of TV_1 – TV_6	TV_1= 0.1; TV_2= 0.1; TV_3= 0.1; TV_4=0.2; TV_5=0.25; TV_6=0.25

Table 9.33: Input parameters for testing incentive mechanism (FL Triangular)

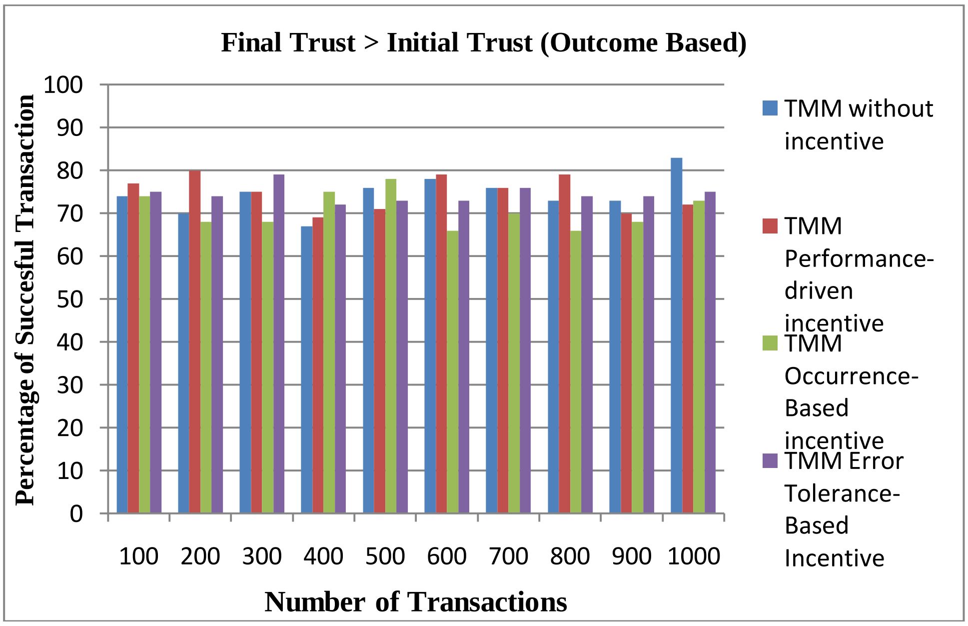

Figure 9.30: Result of testing the effectiveness of incentive based TMM with FL Triangular (Outcome-based: G-Benchmark)

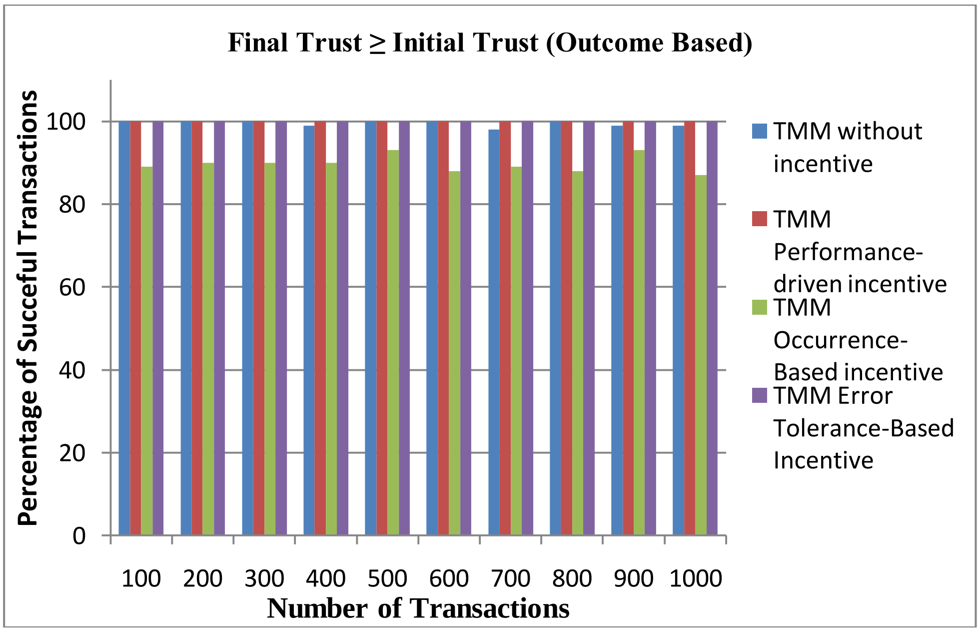

Figure 9.31: Result of testing the the effectiveness of incentive based TMM with FL Triangular (Outcome-based: GE-Benchmark)

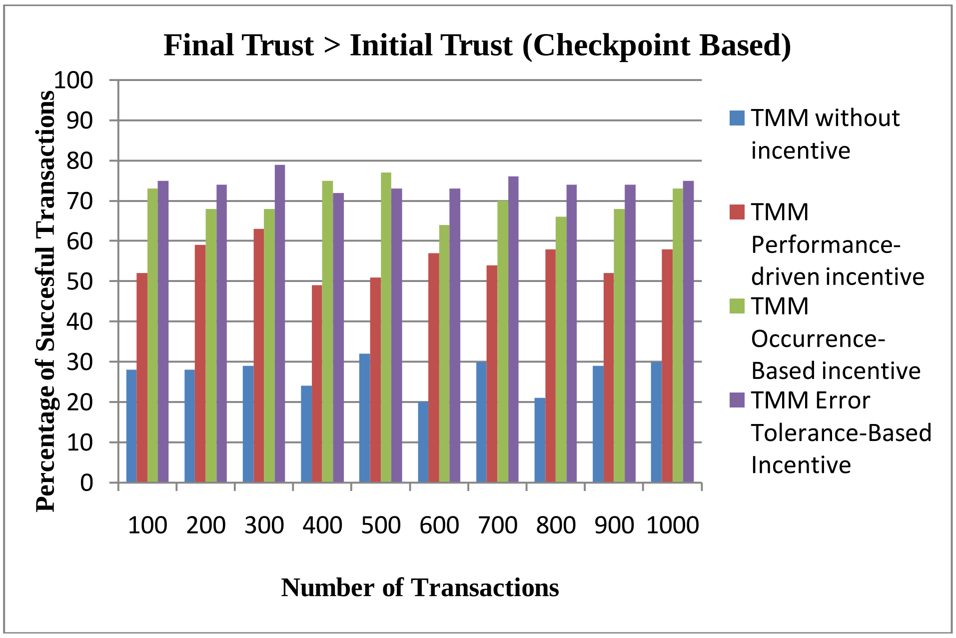

Figure 9.32: Result of testing the effectiveness of incentive based TMM with FL Triangular (Checkpoint-based G-Benchmark)

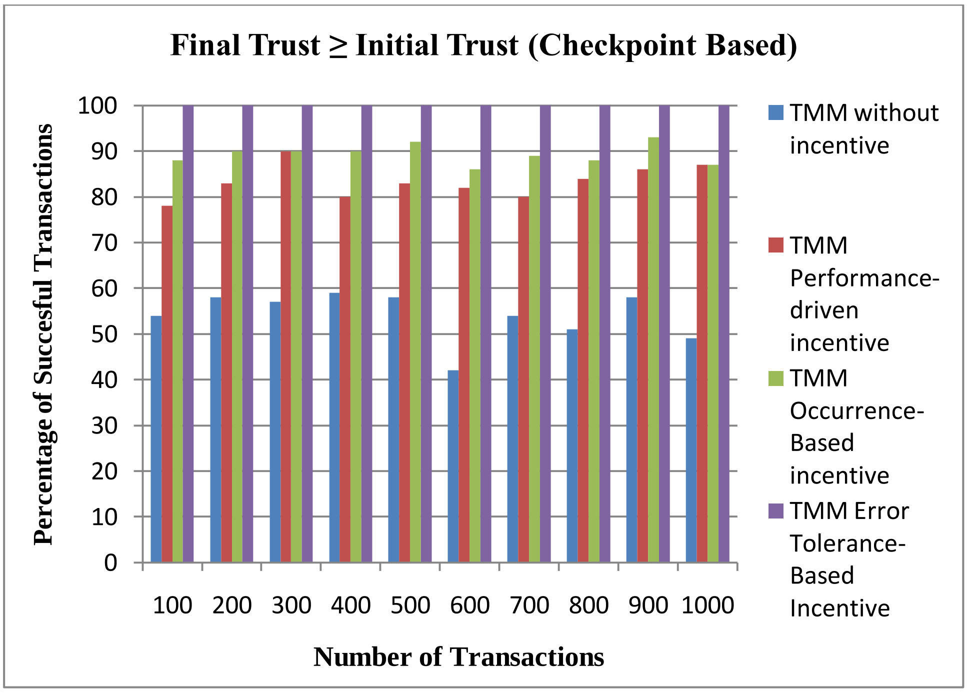

Figure 9.33: Result of testing the effectiveness of incentive based TMM with FL Triangular (Checkpoint-based GE-Benchmark)

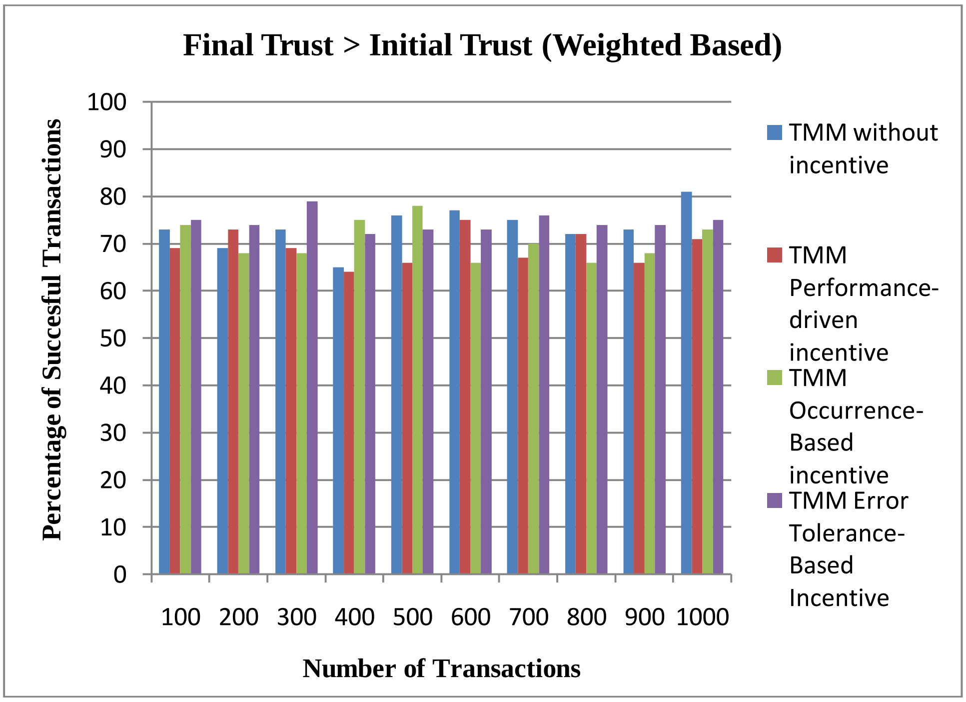

Figure 9.34: Result of testing the effectiveness of incentive based TMM with FL Triangular (Weighted-based G-Benchmark)

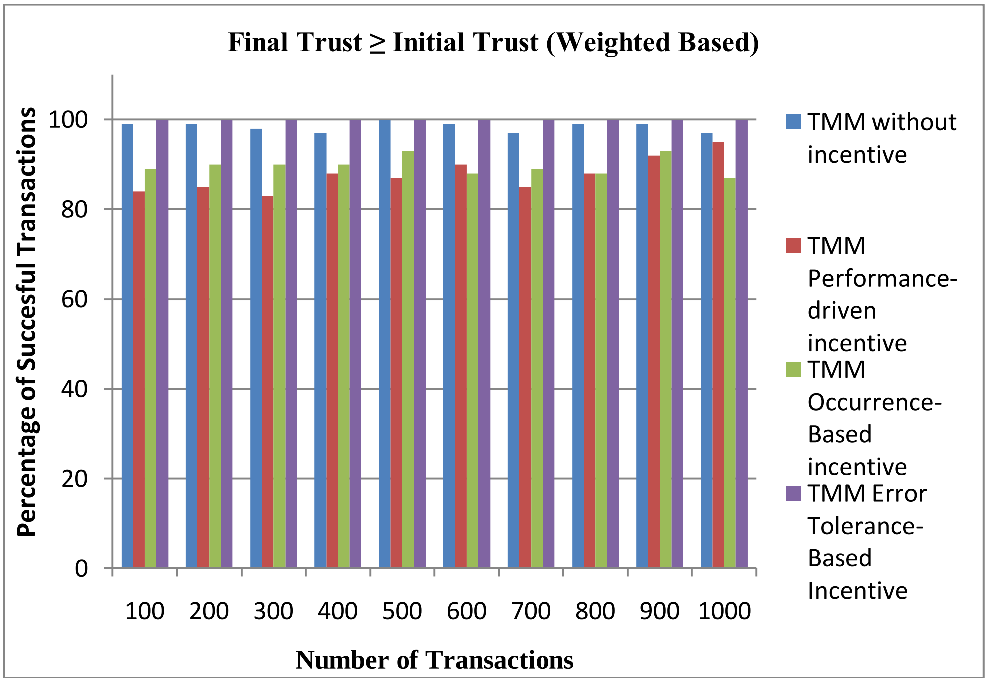

Figure 9.35: Result of testing the effectiveness of incentive based TMM with FL Triangular (Weighted-based GE-Benchmark)

Figures 9.30 to 9.35 above show a comparison of the numbers of successful transactions using the TMM incentive-based approach and the TMM without incentive-based in which the dynamic behaviour of agents is determined with the help of the FL Triangular. We measure the success of transactions by comparing initial trust value (prior to the transaction) with final trust value (at the end of the transaction). Moreover, the final trust value is calculated using three different approaches: outcome-based, checkpoint-based and weighted-based. We present the details of each of these using both G and GE-Benchmark. If the final trust value is greater than or equal to the initial trust, this indicates that the trusted agent in that particular transaction has maintained its level of trust in the trusting agent. It does not mean that the service has been delivered at a full compliance level (100%); rather, this depends on the initial compliance level as a representation of the trustworthiness value of the agent and the level of error tolerance taken into account.

As observed from the figures above, in interactions with our incentive-based TMM, using the outcome-based GE-Benchmark, the successful service delivery remains at 100% throughout the interaction. If we calculate the final trust using the checkpoint-based approach GE-Benchmark, the TMM error-tolerance-based incentive shows the highest ratio of success. It means that all agents have shown either an increase or the same initial trust as a result of the incentive. In contrast, for interactions without incentive, the performance of TMM without incentive is considered as good only if we calculate the final trust using the weighed-based GE-Benchmark. For the other approaches of final trust calculation for the successful service delivery for interactions without incentive TMM, the performance of successful transactions is less than 80% on average. This means that during transactions, only 80% of agents have shown an improved trust level by the end of the interaction. In the next sub-section, we present the results of simulations conducted using various parameters. Further discussion of this result is provided in Section 9.7.5.

b. Simulation results using the input parameters shown in Table 9.34 below.

Number of Agents	1000
Number of Transactions	1000
α	0.6
β	0.4
Error Tolerance	0.01
Algorithm	FL Trapezoidal
Brake option (performance-driven)	0.9
Incentive ratio (error tolerance-based)	0.02
Max bonus (occurrence-based)	1
Percentage of TV_1 – TV_6	TV_1= 0.2; TV_2= 0.2; TV_3= 0.2; TV_4=0.1; TV_5=0.15; TV_6=0.15

Table 9.34: Input parameters for testing incentive mechanism (FL Trapezoidal)

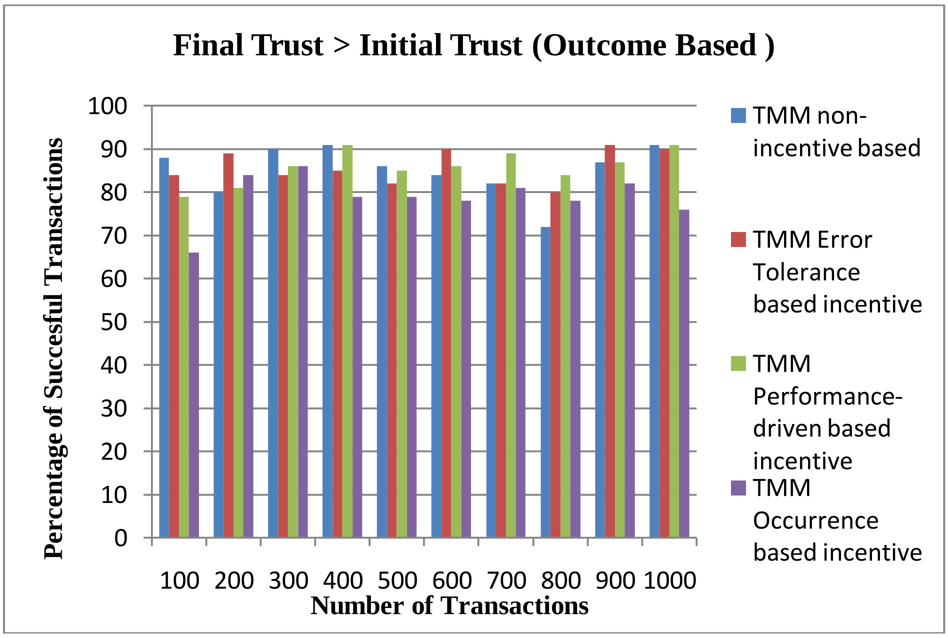

Figure 9.36: Result of testing the effectiveness of incentive based TMM with FL Trapezoidal (Outcome-based G-Benchmark)

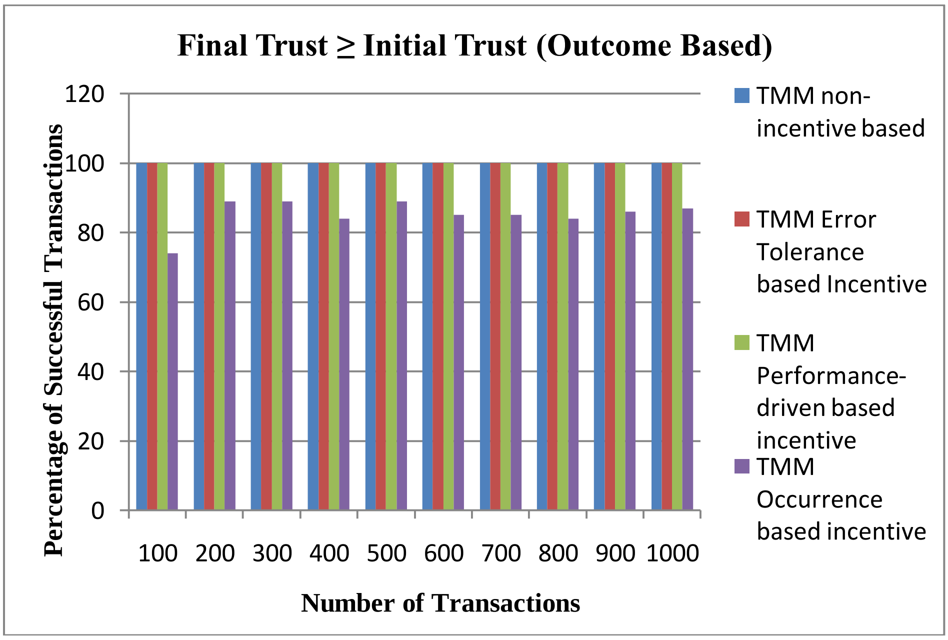

Figure 9.37 Result of testing the effectiveness of incentive based TMM with FL Trapezoidal (Outcome-based GE-Benchmark)

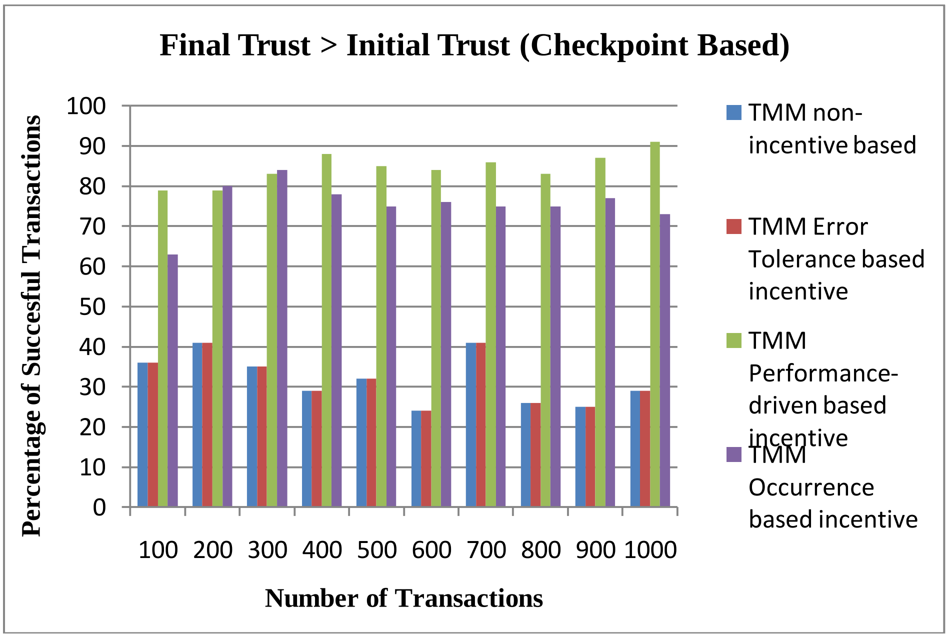

Figure 9.38 Result of testing the effectiveness of incentive based TMM with FL Trapezoidal (Checkpoint-based G-Benchmark)

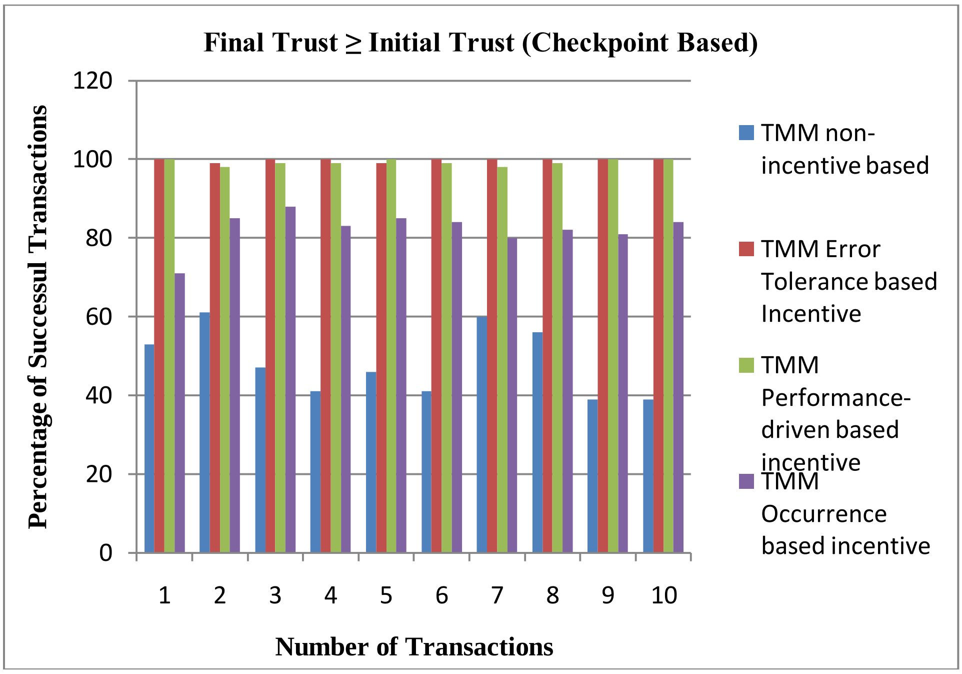

Figure 9.39 Result of testing the effectiveness of incentive based TMM with FL Trapezoidal (Checkpoint-based GE-Benchmark)

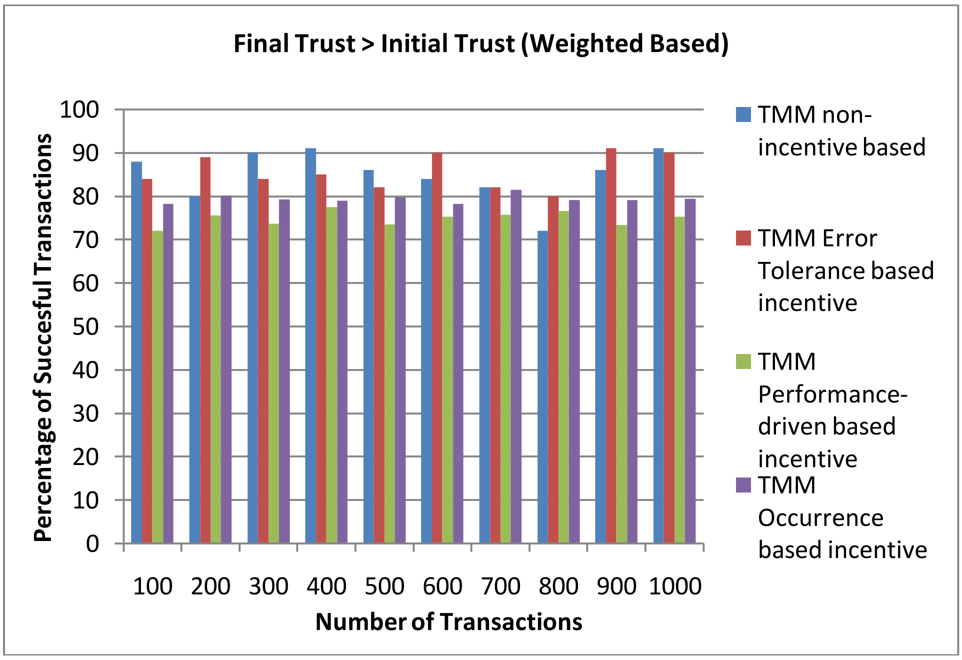

Figure 9.40 Result of testing the effectiveness of incentive based TMM with FL Trapezoidal (Weighted-based G-Benchmark)

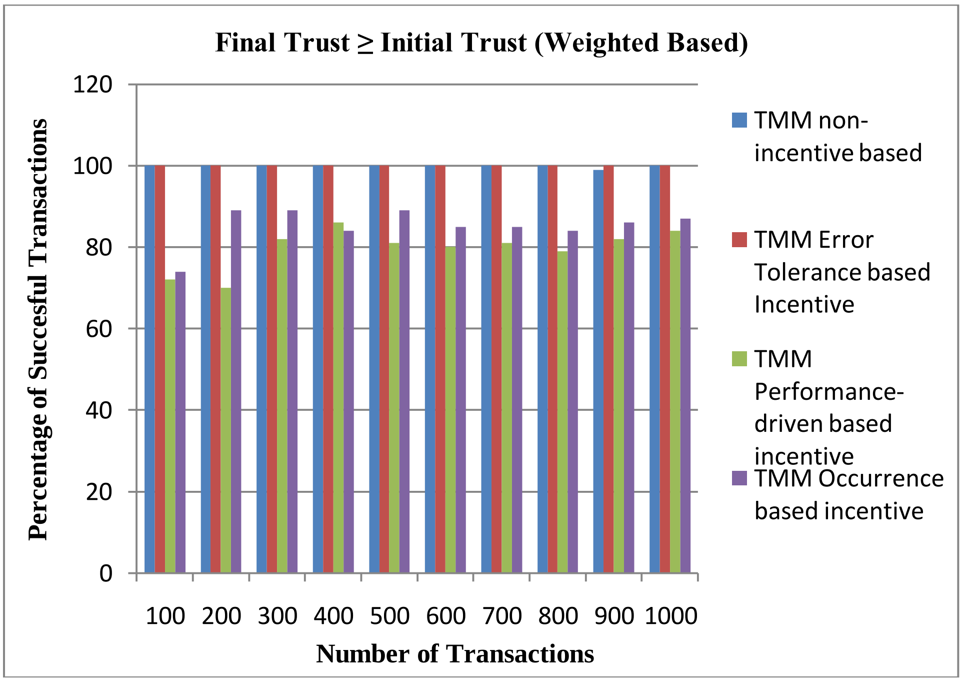

Figure 9.41 Result of testing the effectiveness of incentive based TMM with FL Trapezoidal (Weighted-based GE-Benchmark)

Figures 9.36 to 9.41 above present the simulation results for the parameters shown in Table 9.34. This is done in order to make a comparison between TMM without incentive and TMM with incentive based on the three incentive mechanisms. In this case, the dynamic behaviour of agents is determined with the help of the FL trapezoid. As we can observe from the graphs, by using the outcome-based G-Benchmark, only in three cases out of ten cases is the performance of TMM without incentive better than the TMM with incentive. In the outcome-based GE-Benchmark, the performance of TMM without incentive is the same as that for TMM with incentive in error-tolerance-based incentive and performance-driven incentive-based. Moreover, in the checkpoint-based approach, by using G – Benchmark, the performance of TMM non-incentive based is lower than TMM incentive based. A similar result is produced if we use the GE-Benchmark in the checkpoint-based final trust value-based approach. In the other case, if we calculate the final trust value using the weighted-based approach, the performance of TMM non-incentive based is higher in five out of ten blocks of transactions. However, if we use the GE-Benchmark, the performance of TMM non-incentive based is the same for the TMM Error-tolerance-based incentive mechanism which performs the best of the three mechanisms.

c. Simulation results using the input parameters shown in Table 9.35 below.

999	1000
Number of Transactions	1000
α	0.6
β	0.4
Error Tolerance	0.01
Algorithm	FL Hybrid
Brake option (performance-driven)	0.9
Incentive ratio (error tolerance-based)	0.02
Maximum bonus (occurrence-based)	1
Percentage of $TV_1 – TV_6$	TV_1= 0.2; TV_2= 0.2; TV_3= 0.2; TV_4=0.1; TV_5=0.15; TV_6=0.15

Table 9.35: Input parameters for testing the incentive mechanism (FL Hybrid)

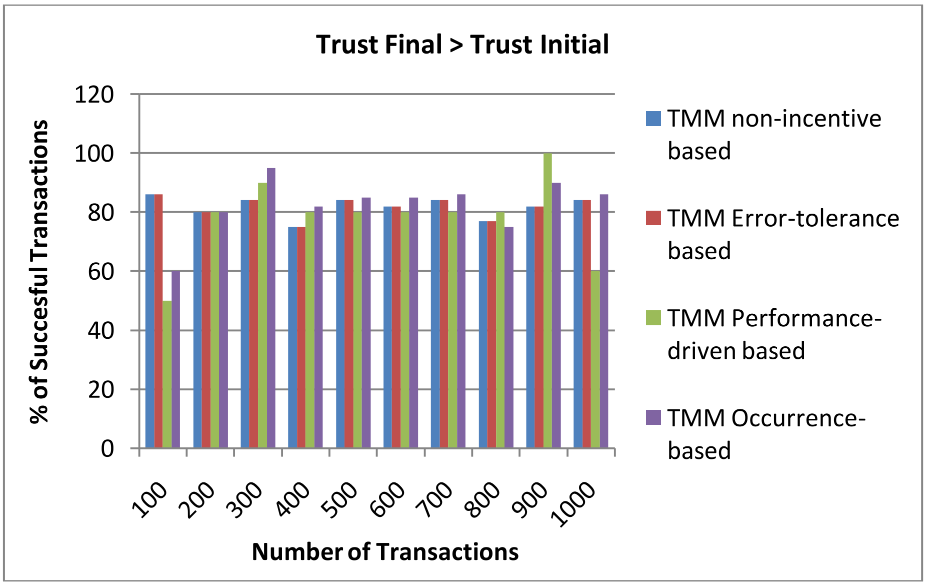

Figure 9.42: Result of testing the effectiveness of incentive based TMM with FL Hybrid (Outcome-based G-Benchmark)

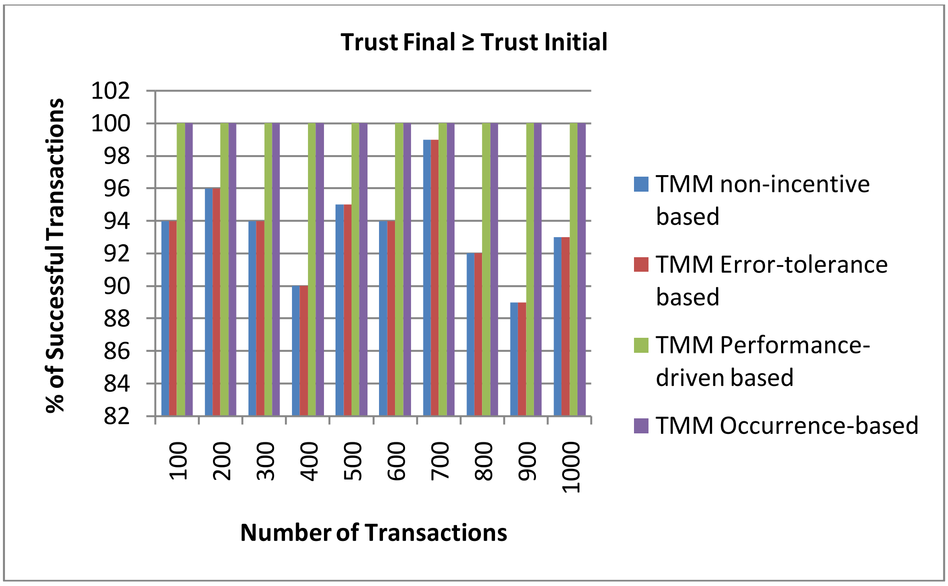

Figure 9.43: Result of testing the effectiveness of incentive based TMM mechanism with FL Hybrid (Outcome-based GE-Benchmark)

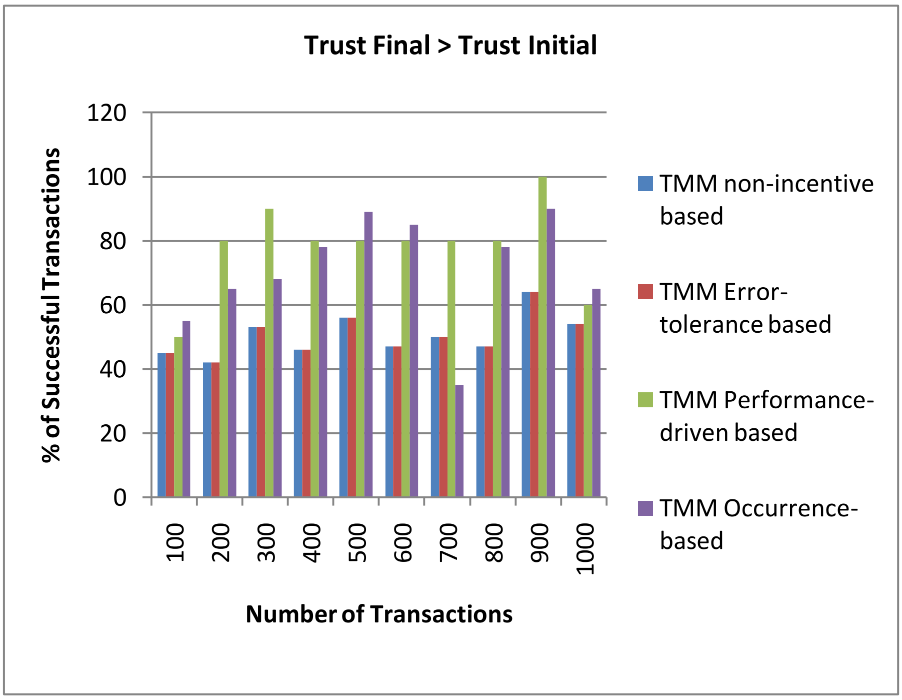

Figure 9.44: Result of testing the effectiveness of incentive based TMM mechanism with FL Hybrid (Checkpoint-based G-Benchmark)

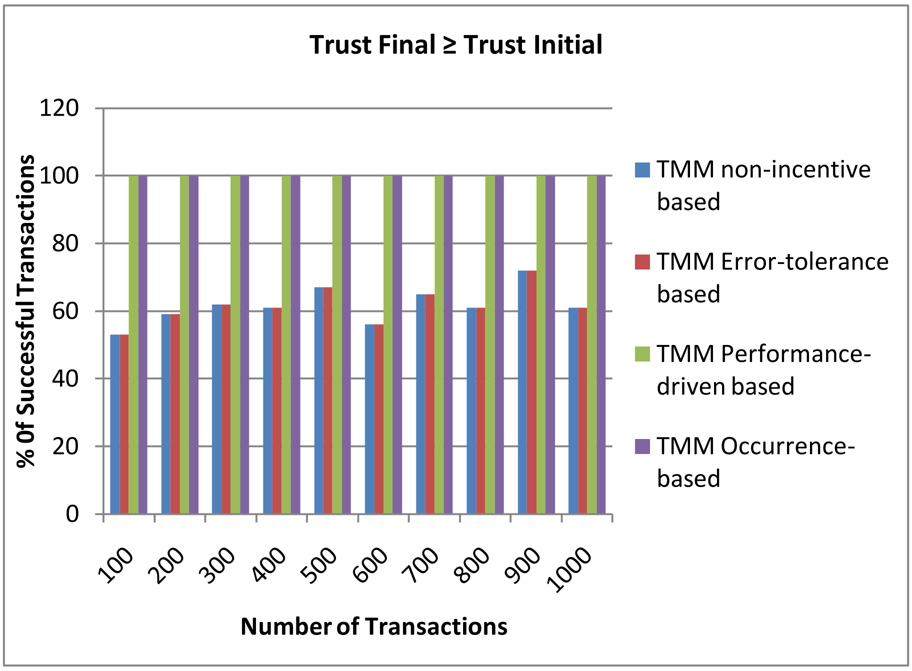

Figure 9.45: Result of testing the performance-driven-based incentive mechanism with FL Hybrid (Checkpoint-based GE-Benchmark)

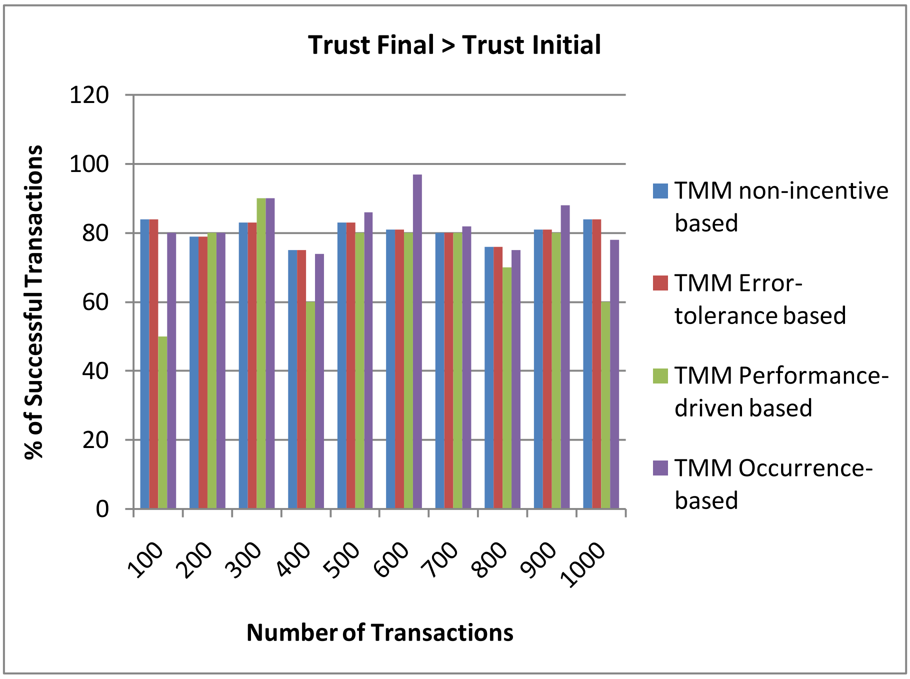

Figure 9.46: Result of testing the effectiveness of incentive based TMM mechanism with FL Hybrid (Weighted-based G-Benchmark)

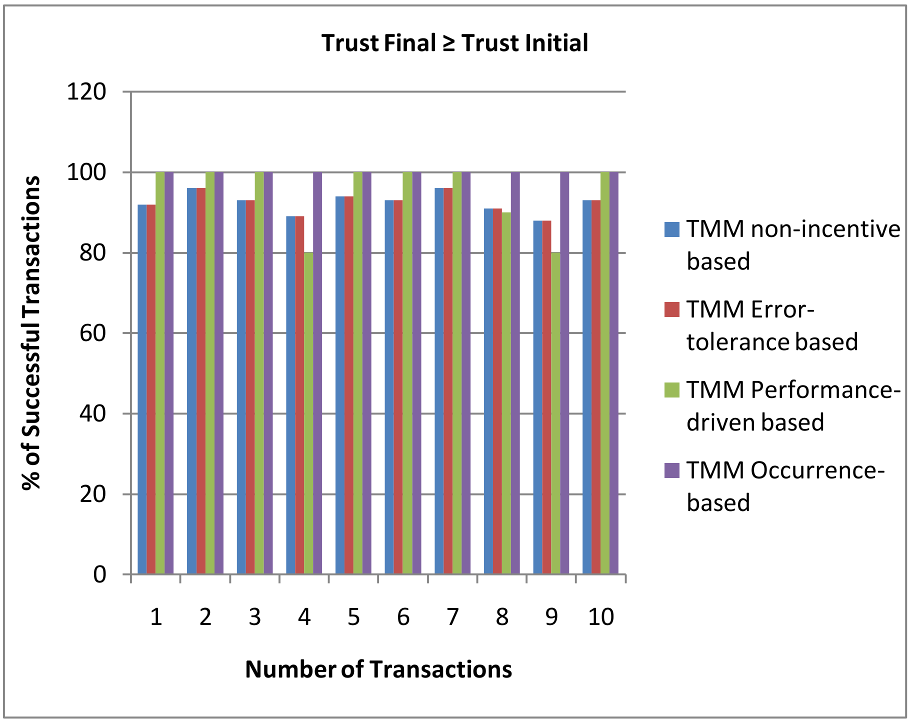

Figure 9.47: Result of testing the effectiveness of incentive based TMM mechanism with FL Hybrid (Weighted-based GE-Benchmark)

Figures 9.42 – 9.47 present results from simulation with the objective to make a comparison between TMM non-incentive-based with TMM incentive-based on three approaches. In this case, the dynamic behaviour of agents throughout the interaction is determined with the help of FL Hybrid. The percentage of successful transactions is measured by comparing final trust values with initial trust values. For simulations using other approaches in the dynamic modelling of agents' behaviour, we use two benchmarks, G-Benchmark and GE-Benchmark, in order to compare final trust with initial trust. Additionally, the trust final is calculated using three different approaches: outcome-based, checkpoint-based and weighted-based. Figures 9.42 and 9.43 are the result of simulation when the trust final is calculated using outcome-based. As we can observe in G-Benchmark (Figure 9.42), the performance of TMM non-incentive-based is the same as that of the TMM error-tolerance-based-incentive. However, if we use the GE-Benchmark, the performance of TMM non-incentive-based is lower than the TMM performance-driven-based incentive and TMM occurrence-based incentive. The performance of TMM non-incentive-based is always the same as the TMM error-tolerance-based. In the checkpoint-based approach to calculate the trust final, both using G and GE-Benchmark, the performance of TMM non-incentive-based is lower than TMM incentive-based. In addition, by using a weighted-based approach in final trust calculation, for both the G- and GE-Benchmarks, the performance of TMM non-incentive is always the same as that of TMM error-tolerance-based. However, it is always lower than TMM performance-driven-based and TMM occurrence-based incentive. Further evaluation is discussed in Section 9.7.5.

9.7.3 Workflow of Simulation for Objective 3.2: Comparison between Three Approaches of Incentive Mechanisms

This simulation is designed to evaluate the performance of three types of incentive mechanism for successful delivery of service. We compare three of them and determine which one has the best performance in facilitating successful delivery of service. The workflow of this simulation is as follows:

a. Step 1. The user specifies all the parameter values that need to be determined as presented in Tables 9.5 – Table 9.7.

b. Step 2. During the bootstrapping phase, the agents are created and each of them is assigned a given behaviour, to represent their level of compliance.

c. Step 3. During each transaction, a trusting agent and a trusted agent are randomly chosen. The trusting agent is chosen such that it is always a compliant agent which means this trusting agent has a 100% level of compliance level. However, the compliance level of the randomly chosen trusted agent could be any trust value between TV_1 to TV_6. Both agents then carry out the interaction following all the framework steps that we proposed in our TMM with the chosen incentive–based approach.

d. Step 4. The statistical outcome is gathered and presented to the user.

9.7.4 Simulation Results for Objective 3.2: Investigate the Best Incentive Mechanism Approach.

a. Comparison between TMM performance-driven-based and TMM occurrence-based. The simulation was carried out using the input parameters shown in Table 9.36 below:

Number of Agents	1000
Number of Transactions	1000
α	0.7
β	0.3
Error Tolerance	0.02
Algorithm	FL Triangle
Brake option (performance-driven-based)	0.9
Maximum bonus (occurrence based)	1
Percentage of TV_1 – TV_6	TV_1= 0.1; TV_2= 0.1; TV_3= 0.1; TV_4=0.2; TV_5=0.25; TV_6=0.25

Table 9.36: Input parameters for simulation to compare TMM performance-driven-based and TMM occurrence-based (1000 agents, 1000 transactions)

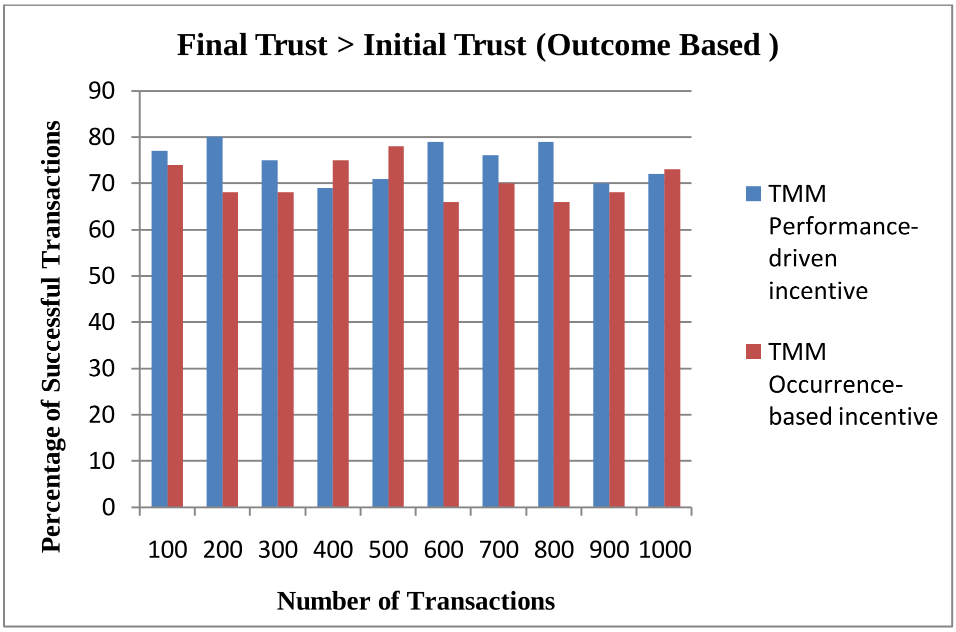

Figure 9.48: Result of simulation to compare TMM performance-driven-based with TMM occurrence-based in 1000 agents carrying out 1000 transactions (Outcome-based G-Benchmark)

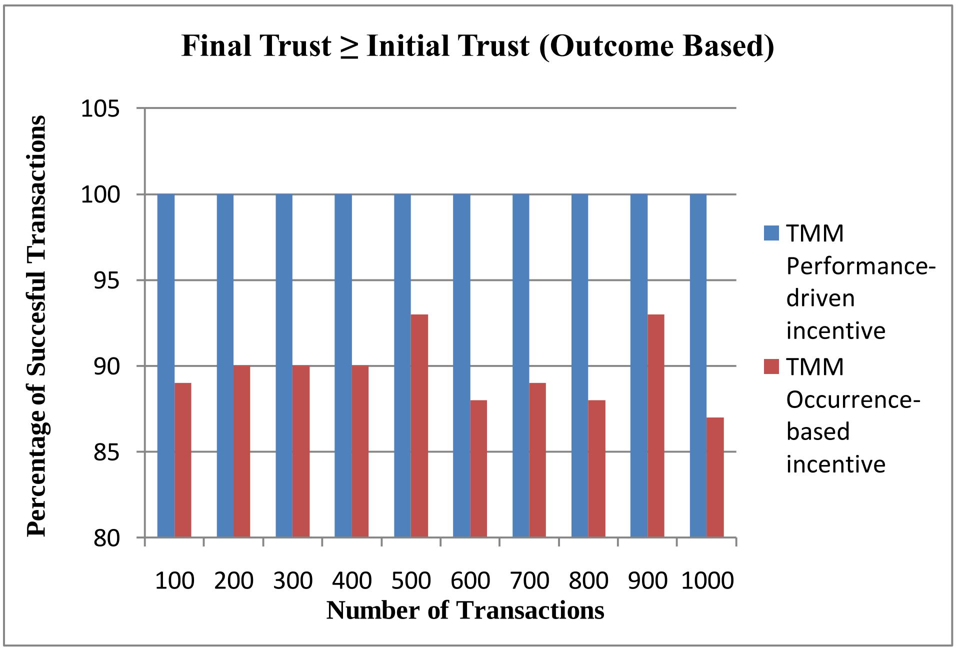

Figure 9.49: Result of simulation to compare TMM performance-driven-based with TMM occurrence-based in 1000 agents carrying out 1000 transactions (Outcome-based GE-Benchmark)

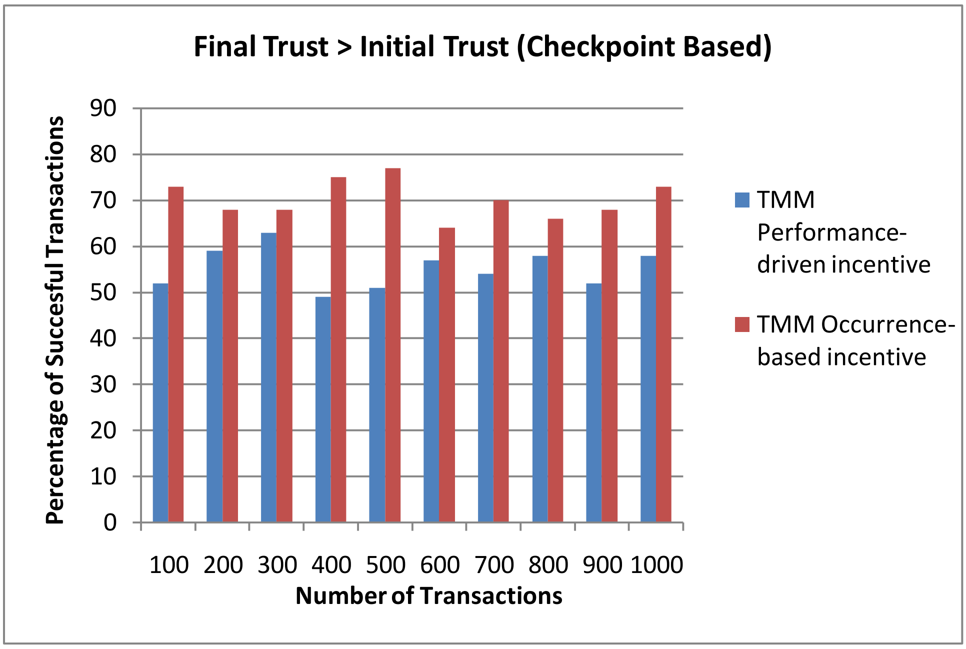

Figure 9.50: Result of simulation to compare TMM performance-driven-based with TMM occurrence-based in 1000 agents carrying out 1000 transactions (Checkpoint-based G-Benchmark)

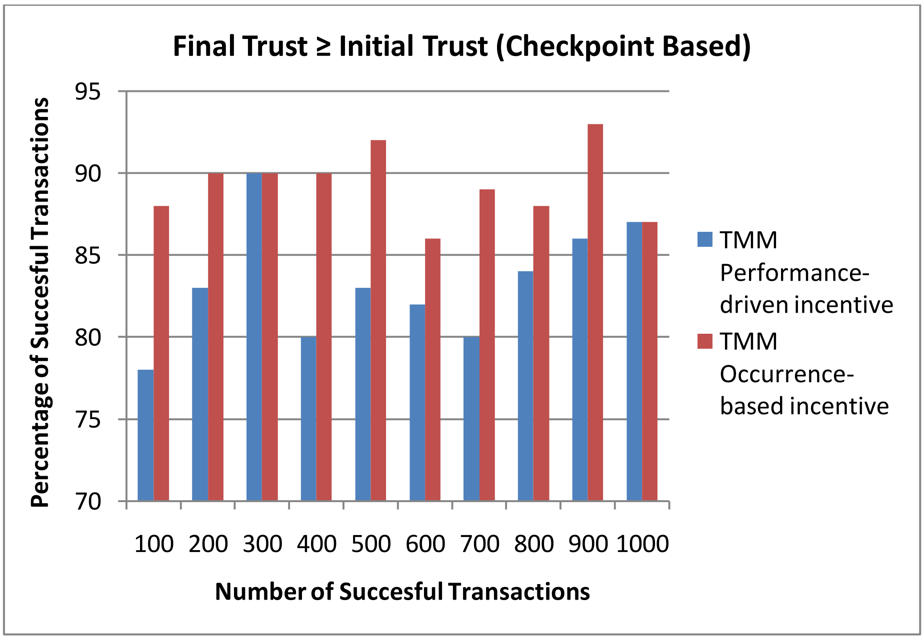

Figure 9.51: Result of simulation to compare TMM performance-driven-based with TMM occurrence-based in 1000 agents carrying out 1000 transactions (Checkpoint-based GE-Benchmark)

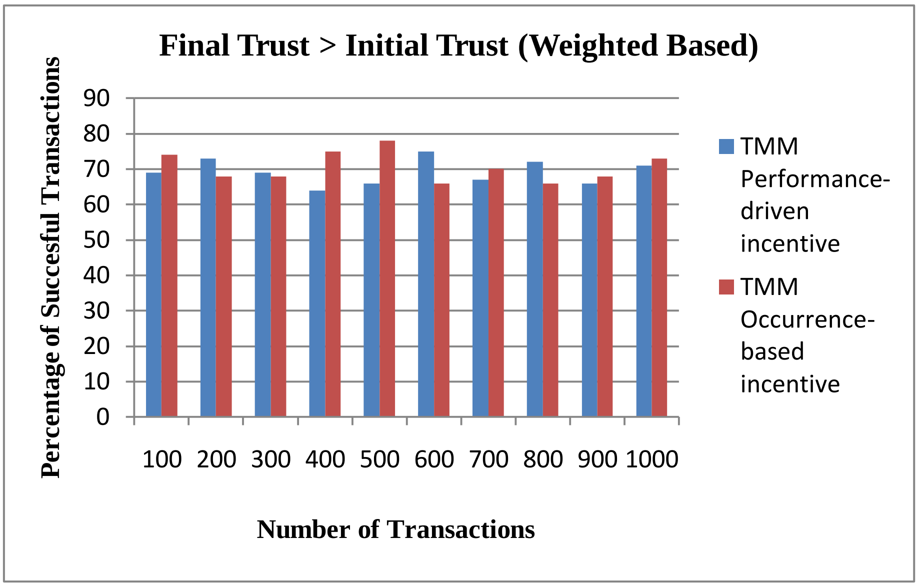

Figure 9.52: Result of simulation to compare TMM performance-driven-based with TMM occurrence-based in 1000 agents carrying out 1000 transactions (Weighted-based G-Benchmark)

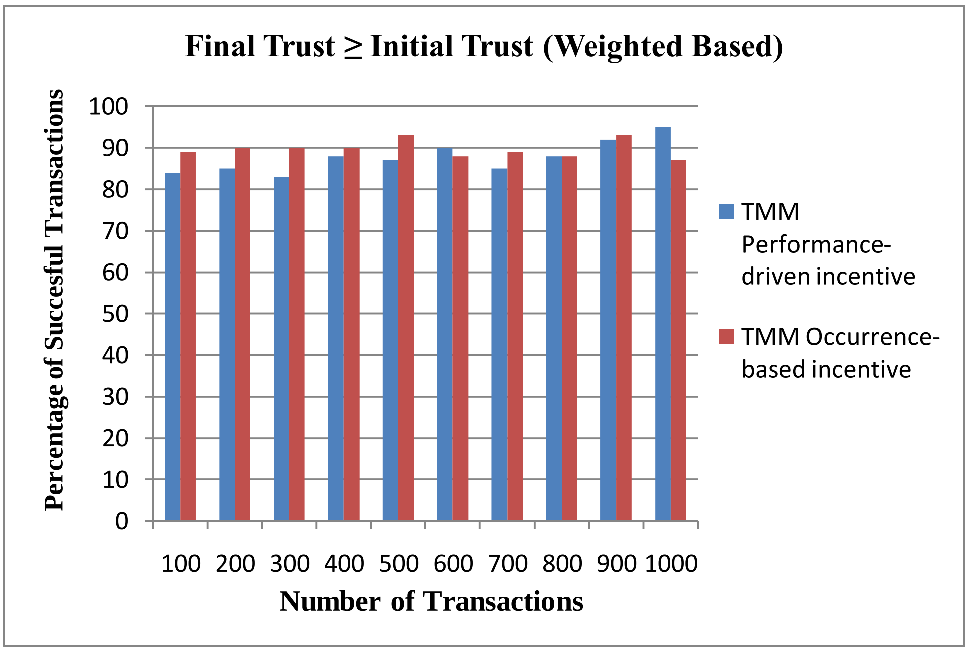

Figure 9.53: Result of simulation to compare TMM performance-driven-based with TMM occurrence-based in 1000 agents carrying out 1000 transactions (Weighted-based GE-Benchmark)

Figures 9.48 – 9.53 present the results of simulation to achieve objective 3.2 which are the comparison between the performances of TMM performance-driven incentive-based with TMM occurrence-based incentive by which the dynamic behaviour of an agent is determined with the help of the FL trapezoidal. By 'performance of TMM' we mean the ratio of successful transactions for which trust has been maintained. As explained in the previous section, we use two benchmarks, the G and GE-benchmark to indicate whether trust has been maintained during the interaction. Moreover, we calculated the trust final using three different approaches, outcome-based, checkpoint-based and weighted-based. We present each of the results of these three approaches. For example, Figure 9.48 presents the results of a simulation which compares the TMM performance-driven-based incentive with the TMM occurrence-based incentive. In this case, we calculate the final trust using the weighted-based approach, and we compare final trust with initial trust using the GE-Benchmark. It can be observed from the graph that in an agent population of 1000 who carry out 1000 transactions, for each continuing 100 transactions, the performance of TMM occurrence-based is slightly higher than TMM performance-driven- incentive-based approach. As we can observe, the performance of the TMM occurrence-based incentive is higher in seven out of ten blocks of transactions.

Let us consider another result from Figure 9.49. In this case, the trust final calculation is done by using the outcome-based approach and the GE-Benchmark. We simulate 1000 agents who have carried out 1000 transactions and present the result at every 100 transactions consecutively. As we can observe from Figure 9.49, the TMM performance-driven-based incentive has a higher success rate than does the TMM occurrence-based incentive. This result is different if we use the weighted-based approach to calculate the final trust. Further discussion of this variation of results is presented in Section 9.7.5.

b. Comparison between TMM performance-driven-based and TMM error-tolerance-based. The simulation carried out using the input parameters shown in Table 9.37 below:

Number of Agents	50000
Number of Transactions	100000
α	0.7
β	0.3
Error Tolerance	0.02
Algorithm	FL Hybrid
Brake option (performance-driven-based)	0.9
Error tolerance (error-tolerance based)	0.03
Percentage of TV_1 – TV_6	TV_1= 0.05; TV_2= 0.05; TV_3= 0.1; TV_4=0.3; TV_5=0.25; TV_6=0.25

Table 9.37: Input parameters to compare TMM performance-driven-based with TMM error-tolerance-based (50000 agents, 100000 transactions)

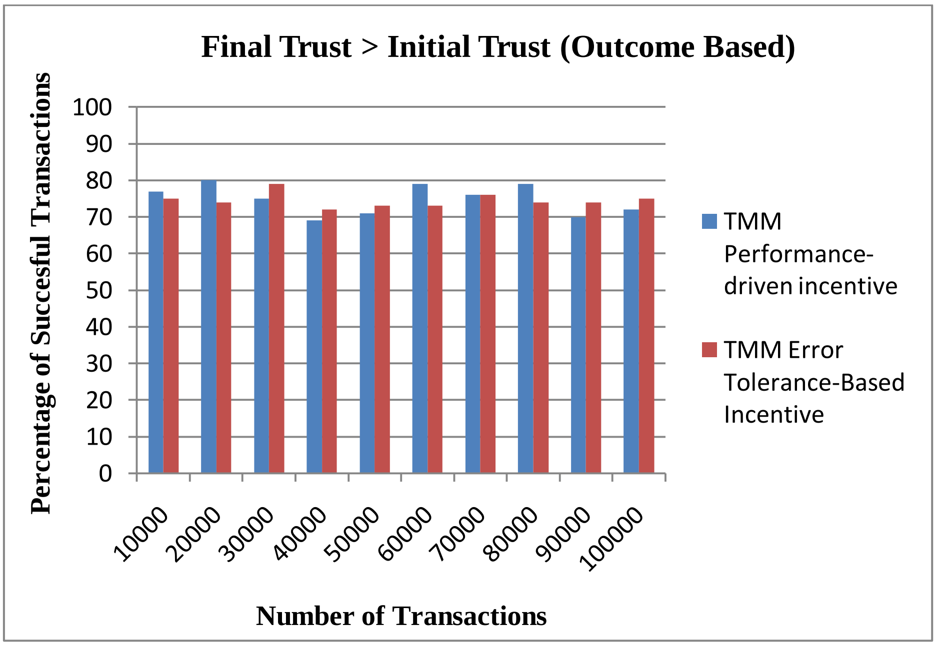

Figure 9.54: Result of simulation to compare TMM performance-driven-based with TMM error-tolerance-based in 50000 agents carrying out 100000 transactions (Outcome-based G-Benchmark)

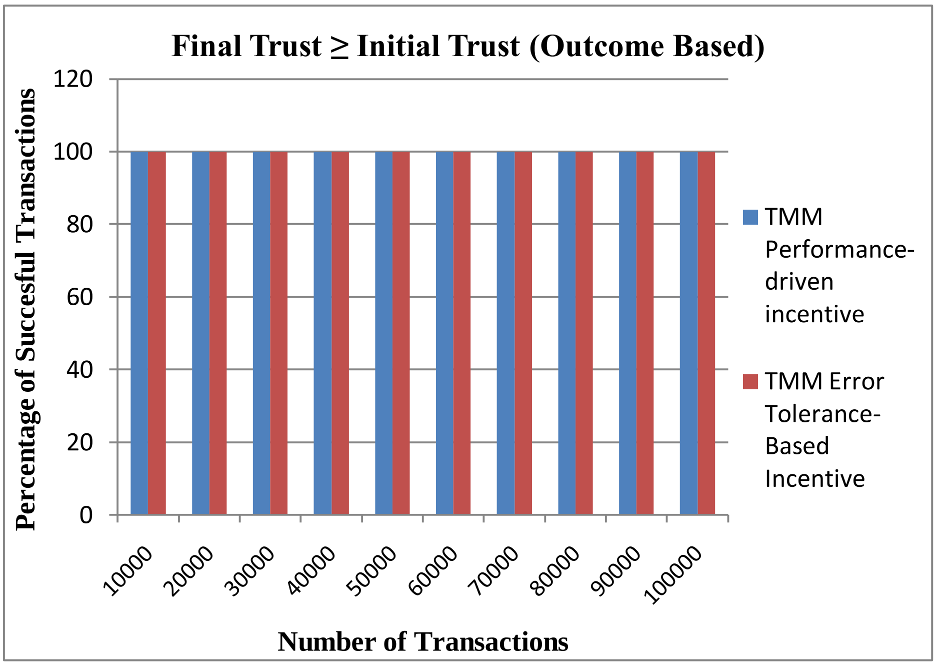

Figure 9.55: Result of simulation to compare TMM performance-driven-based with TMM error-tolerance-based in 50000 agents carrying out 100000 transactions (Outcome-based GE-Benchmark)

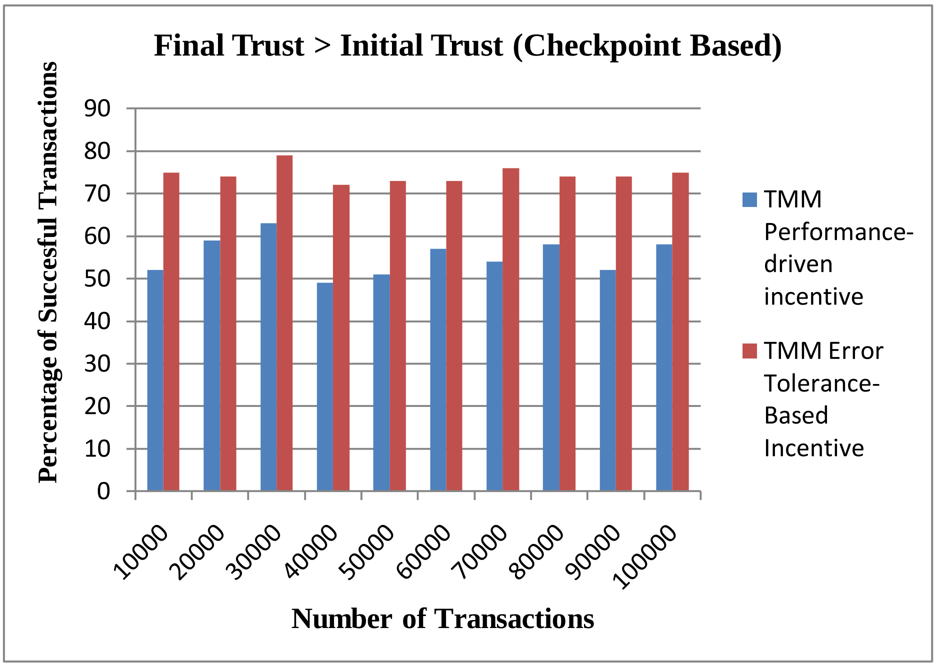

Figure 9.56: Result of simulation to compare TMM performance-driven-based with TMM error-tolerance-based in 50000 agents carrying out 100000 transactions (Checkpoint-based G-Benchmark)

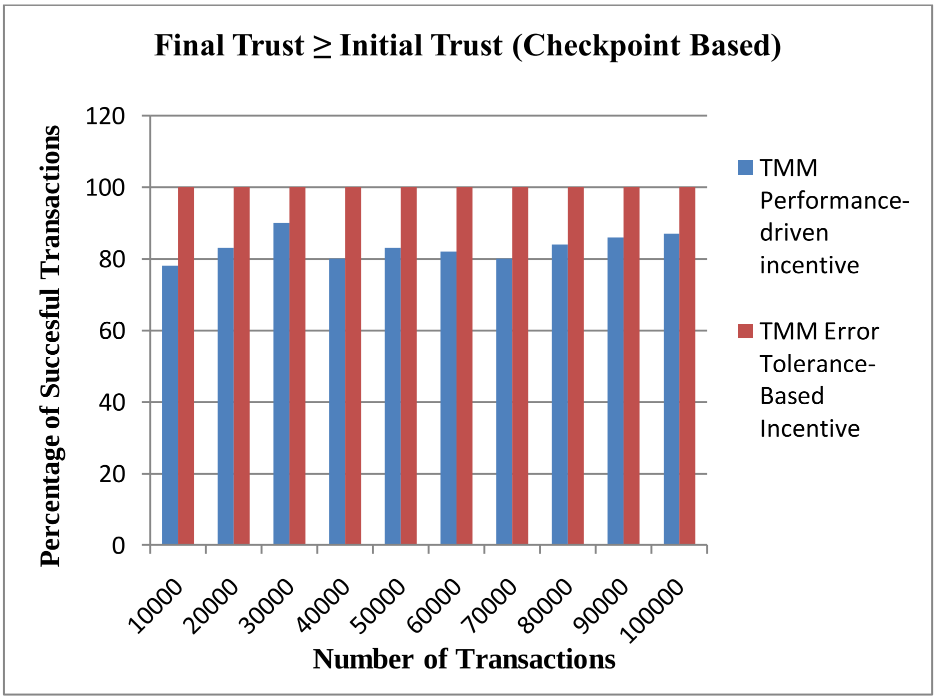

Figure 9.57: Result of simulation to compare TMM performance-driven-based with TMM error-tolerance-based in 50000 agents carrying out 100000 transactions (Checkpoint-based GE-Benchmark)

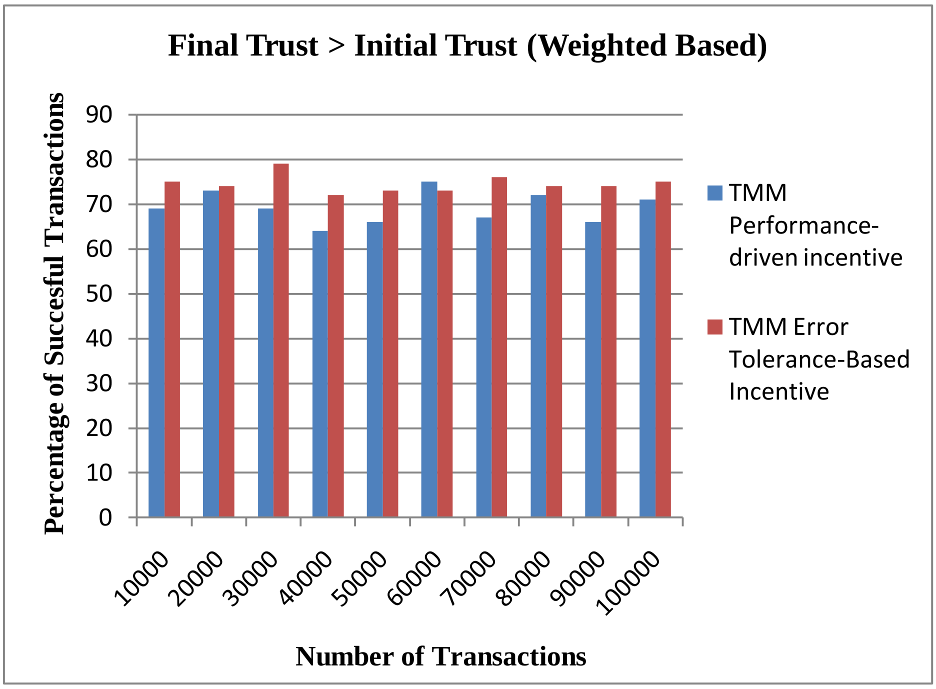

Figure 9.58: Result of simulation to compare TMM performance-driven-based with TMM error-tolerance-based in 50000 agents carrying out 100000 transactions (Weighted-based G-Benchmark)

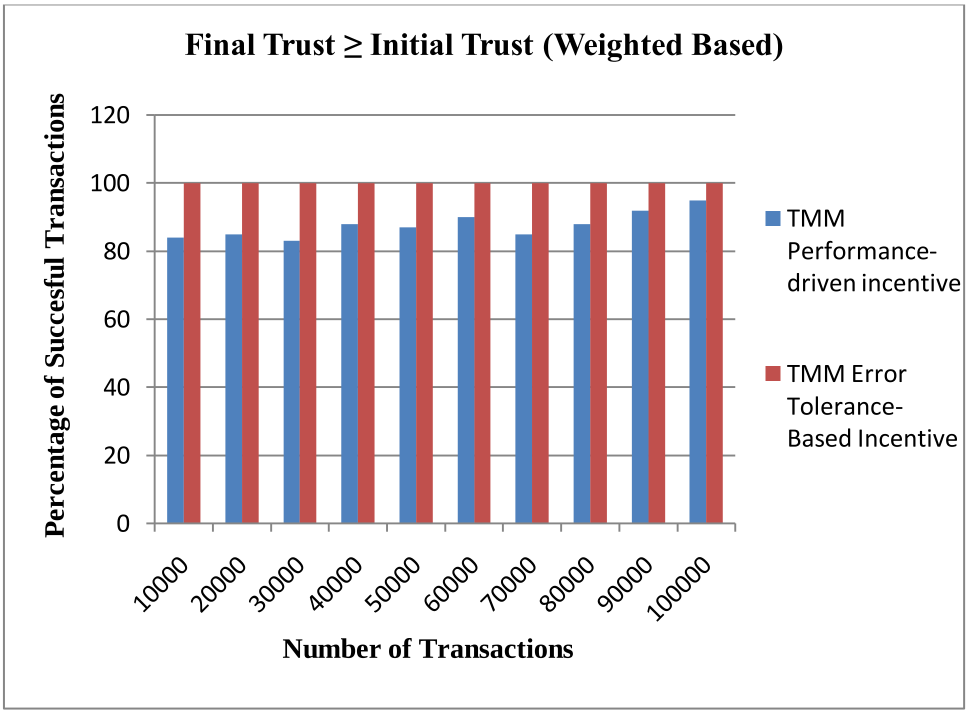

Figure 9.59: Result of simulation to compare TMM performance-driven-based with TMM error-tolerance-based in 50000 agents carrying out 100000 transactions (Weighted-based GE-Benchmark)

Figures 9.54 – 9.59 present the results of simulation which compare TMM performance driven incentive with TMM error-tolerance-based. As we can observe, by using outcome based approach in trust final calculation with G-Benchmark, the TMM performance-driven-based incentive has a higher percentage than TMM error-based incentive in four blocks of transaction. Moreover, their percentage of successful transaction is in the same at one block of transactions (occurs in 7000 transactions). The TMM error-tolerance based incentive performs better than TMM performance-driven-based incentive for five blocks of transactions. However, by using GE-Benchmark, the TMM performance-driven-based incentive has the same percentage of successful transactions which is 100%. This means that both incentive mechanisms are able to effectively support the deliverability of service and the trust maintenance.

On the other hand, if we calculate final trust value by using checkpoint-based approach, in both G and GE-Benchmark, the TMM error-tolerance-based incentive has higher performance compared to the TMM performance-driven. A similar pattern also occurs if we calculate the final trust value using weighted-based. In both G and GE-Benchmark, the percentage of successful transactions which employ TMM error-tolerance based is higher than TMM performance-driven incentive. From this observation, in comparison between TMM performance-driven-based incentive with TMM error-tolerance based, for transactions which employ the TMM error-tolerance based, the successful percentage is higher than TMM performance-driven-based incentive. Comparison between TMM occurrence-based and TMM error-tolerance-based. The simulation carried out using the input parameters is shown in Table 9.38 below:

Number of Agents	50000
Number of Transactions	100000
α	0.7
β	0.3
Error Tolerance	0.02
Algorithm	FL Hybrid
Brake option (performance-driven-based)	0.9
Error tolerance (error-tolerance based)	0.03
Percentage of TV_1 – TV_6	TV_1= 0.05; TV_2= 0.05; TV_3= 0.1; TV_4=0.3; TV_5=0.25; TV_6=0.25

Table 9.38: Input parameters for simulation to compare TMM occurrence-based with TMM error-tolerance-based

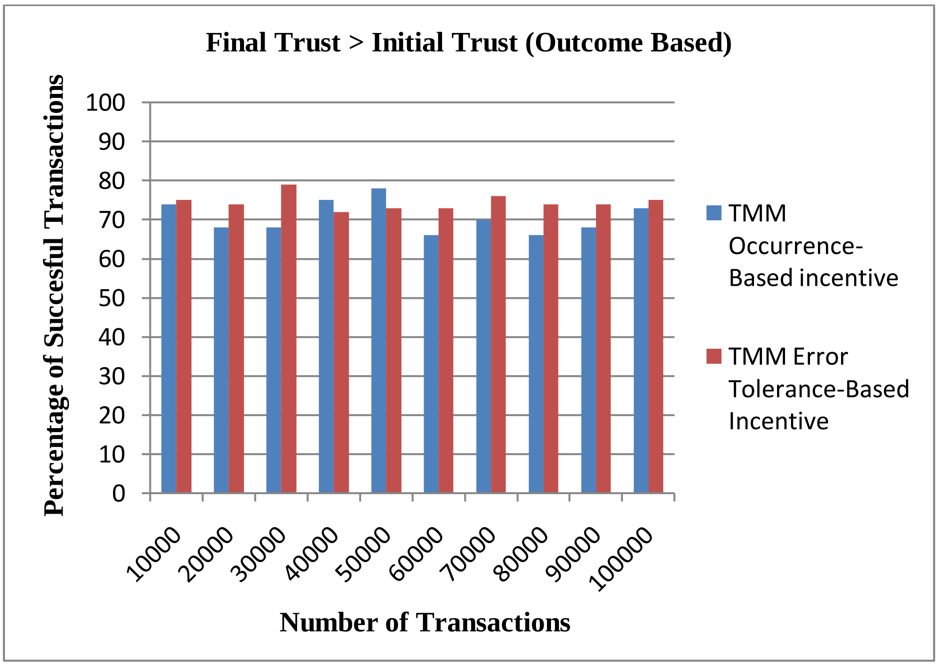

Figure 9.60: Result of simulation to compare TMM occurrence-based with TMM error-tolerance-based (Outcome-based G-Benchmark)

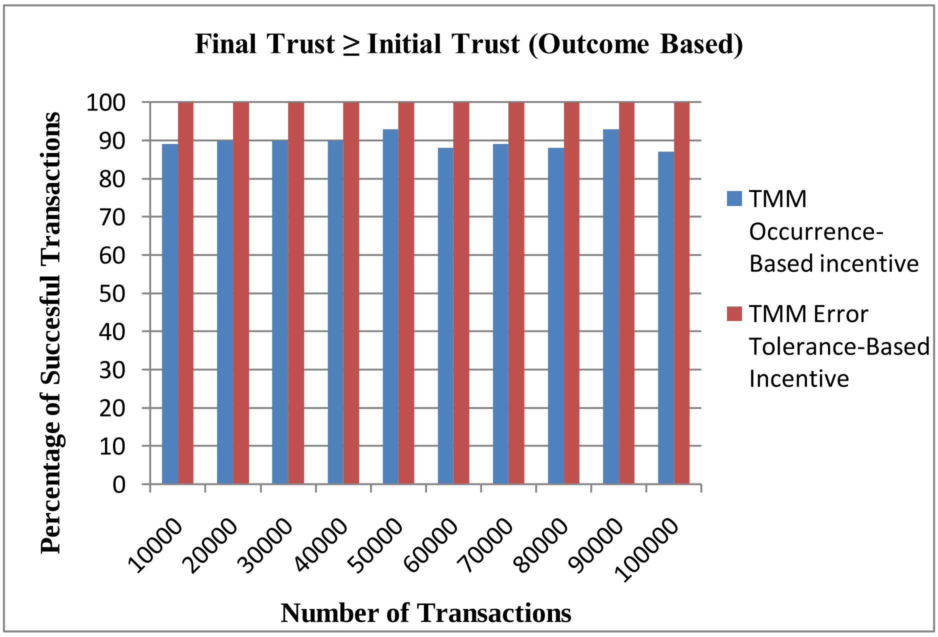

Figure 9.61: Result of simulation to compare TMM Occurrence-based with TMM error-tolerance-based (Outcome-based GE-Benchmark)

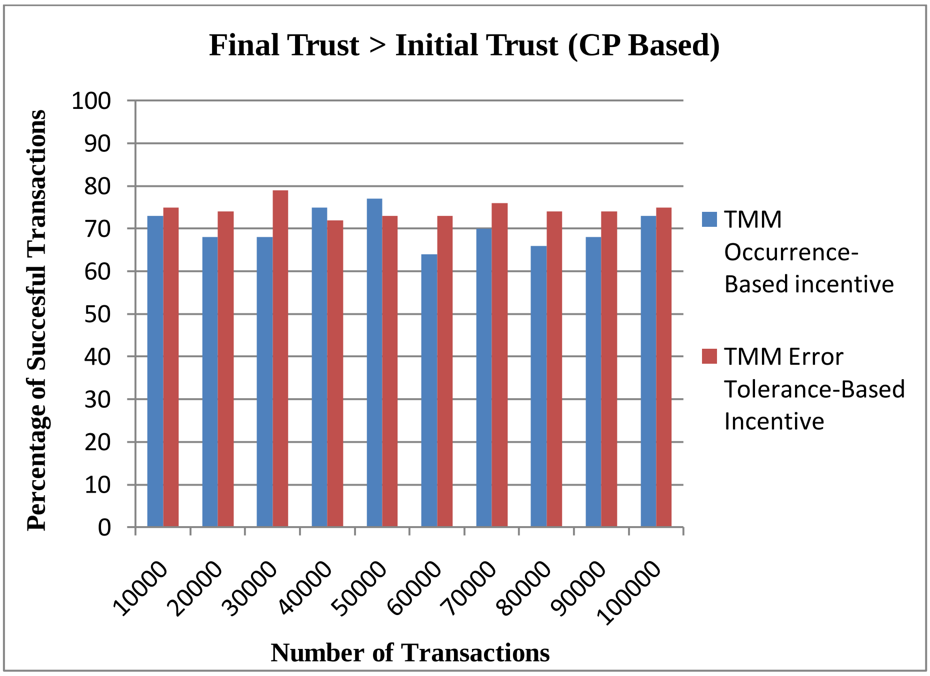

Figure 9.62: Result of simulation to compare TMM occurrence-based with TMM error-tolerance-based (Checkpoint-based G-Benchmark)

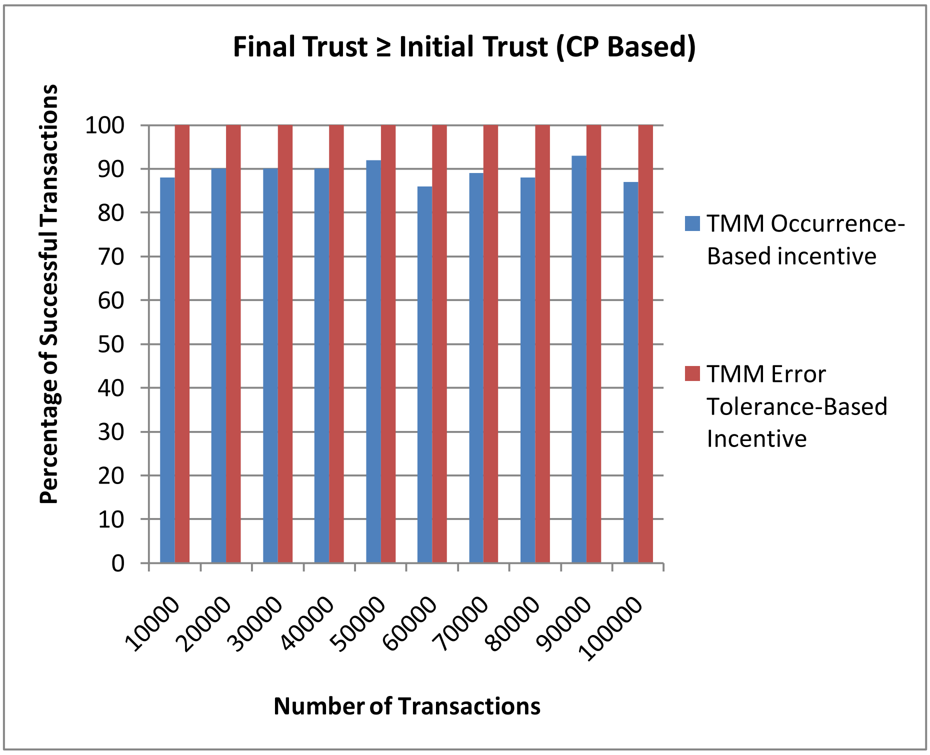

Figure 9.63: Result of simulation to compare TMM occurrence-based and TMM error-tolerance-based (Checkpoint-based GE-Benchmark)

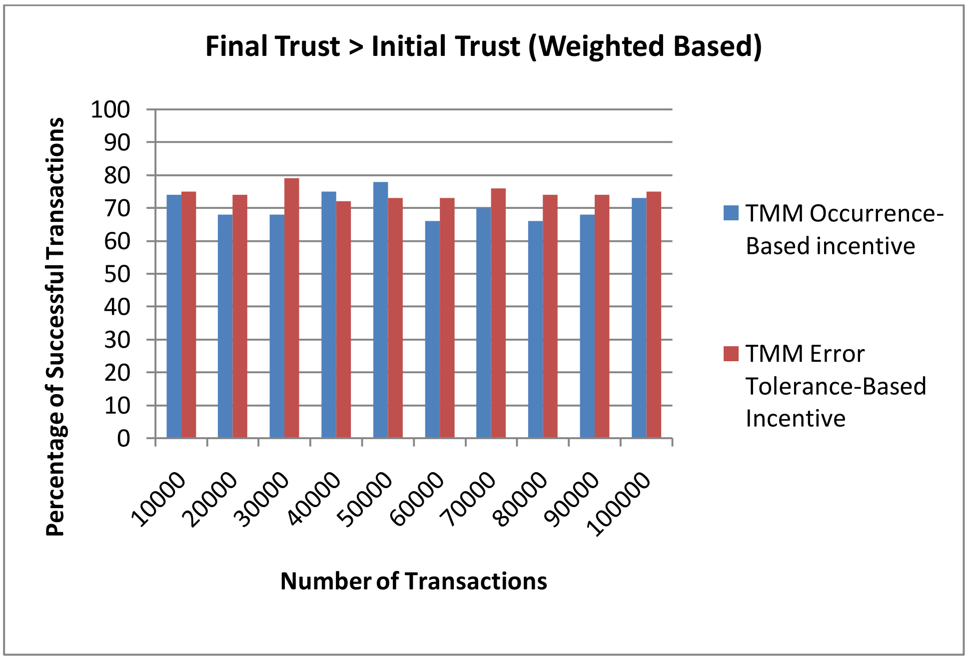

Figure 9.64: Results of simulation to compare TMM occurrence-based and TMM error-tolerance-based (Weighted-based G-Benchmark)

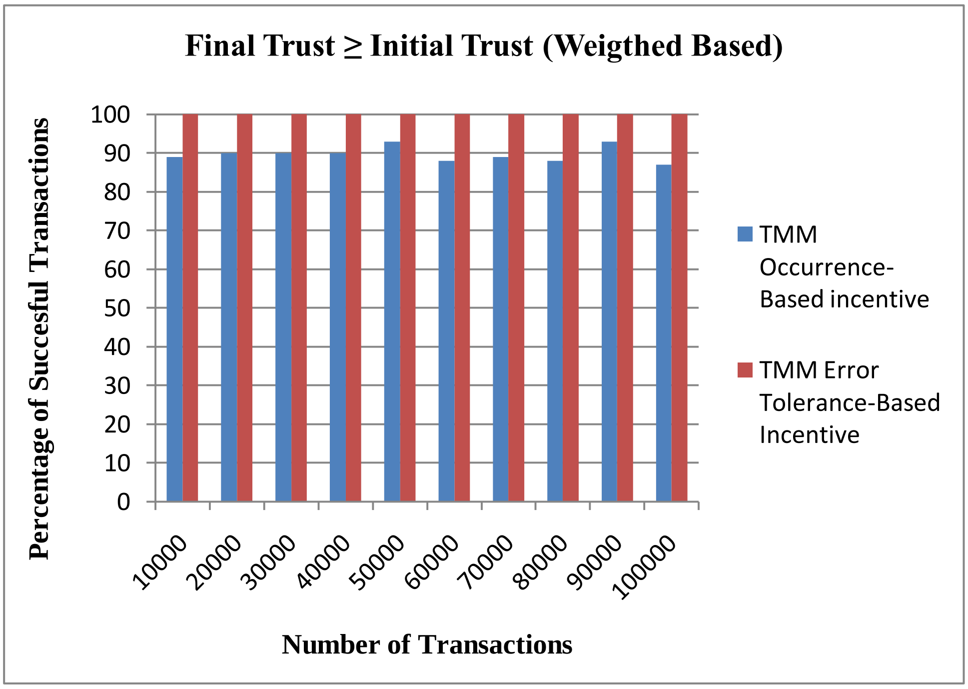

Figure 9.65: Results of simulation to compare TMM occurrence-based with TMM error-tolerance-based (Weighted-based GE-Benchmark)

Figures 9.60 – 9.65 present the results of simulation used to compare the TMM occurrence-based approach with the TMM error-tolerance-based approach. Figures 9.60 and 9.61 show the results of simulation if we calculate the final trust value using the outcome-based approach. As we can observe, by using G-Benchmark, the TMM error-tolerance-based have a higher percentage of successful transactions than those with the TMM occurrence-based incentive. From ten blocks of transactions, the TMM error-tolerance-based incentive has higher performance in eight blocks. Moreover, by using GE-Benchmark, from ten blocks transactions, the TMM error-tolerance-based incentive has higher successful rate than TMM occurrence-based incentive. Moreover, the percentage of successful transaction which using TMM error-tolerance-based incentive is 100%. It means the TMM error-tolerance based incentive help the trusted agent to maintain the trust level with trusting agent. The similar condition also can be investigate if we use the trust final calculation using checkpoint based and weighted based approach. In both G and GE-Benchmarks, the TMM error-tolerance-based incentive always delivers a higher percentage of successful transactions compare to the TMM occurrence-based incentive. Hence, we can conclude that in comparison between TMM occurrence-based incentive and TMM error-tolerance based, the TMM occurrence-based incentive is a better mechanism to help trusted agent maintain the trust level toward trusting agent.

9.7.5 **Discussion of Results Obtained for Objective 3**

Table 9.39 below presents a summary of results of simulations carried out for the purpose of comparing the successful ratio of interactions which use our TMM without incentive and those using TMM with incentive. The TMM with incentive is divided into three different approaches: performance-driven-based, occurrence-based and error-tolerance-based. The table shows the summary of the average simulation results from various parameters as described in the previous section. As we can observe, by using G–Benchmark, the performance of TMM without incentive is lower than TMM with incentive in performance-driven-based, incentive-based and error-tolerance-based approach. However, in occurrence-based, the performance of TMM without incentive is higher. A similar conclusion also can be drawn for the GE-Benchmark. We can conclude that the performance of TMM with incentive is higher than that of TMM without incentive for performance-driven incentive-based and error-tolerance-based methods. With the occurrence-based approach, the performance of TMM without incentive is slightly higher. That is, the performance of TMM in terms of successful transactions shows that by comparison, final trust is greater than trust initial. Hence, if the performance of TMM with performance-driven-based incentive in the weighted-based approach using GE-Benchmark is 98%, this means that in any number of transactions, for 98% of them the condition of final trust is greater than initial trust. For example, if there are 100 transactions in the community, 98 of them are successfully maintaining their trust by using our TMM and employing one of our TMM incentive mechanisms.

Based on the discussion above, it can be concluded that the incentive mechanisms support our methodology for maintaining trust. Additionally, because of an incentive on offer, the agent will be motivated to deliver service as closely as possible to the mutual agreement. It facilitates the continuity of service delivery during trust maintenance phase.

a. **FL Triangular Dynamic Behaviour**

G -Benchmark	TMM without incentive	TMM with incentive		
		Performance –driven-based	Occurrence -based	Error-tolerance -based
Outcome-based	72%	74%	68%	72%
Checkpoint-based	25%	55%	65%	68%
Weighted-based	70%	65%	70%	75%
GE- Benchmark	**TMM without incentive**	**TMM with incentive**		
		Performance –driven-based	**Occurrence - based**	**Error-tolerance -based**
Outcome-based	98%	100%	90.25%	100%
Checkpoint-based	50%	80%	85%	100%
Weighted-based	98%	85%	87%	100%

b. **FL Trapezoidal Dynamic Behaviour**

G -Benchmark	TMM without incentive	TMM with incentive		
		Performance –driven-based	Occurrence -based	Error-tolerance - based
Outcome-based	85.1%	85.9	78.9	85.7%
Checkpoint-based	31.8%	84.5%	31.8%	75.6%
Weighted-based	85%	85.7%	74.87%	79.36%
GE-Benchmark	**TMM without incentive**	**TMM with incentive**		
		Performance –driven-based	**Occurrence -based**	**Error Tolerance -based**
Outcome-based	100%	100%	85.2%	100%

Checkpoint-based	48.3%	99.2%	82.3%	99.8%
Weighted-based	99.9%	79.7%	85.2%	100%

c. FL Hybrid Dynamic Behaviour

G -Benchmark	TMM without incentive	TMM with incentive		
		Performance –driven-based	Occurrence -based	Error-tolerance - based
Outcome-based	81.8%	81.8%	78%	82.4%
Checkpoint-based	50.4%	50.4%	78%	70.8%
Weighted-based	80.6%	80.6%	73%	83%
GE- Benchmark	**TMM without incentive**	**TMM with incentive**		
		Performance –driven-based	**Occurrence -based**	**Error-tolerance - based**
Outcome-based	93.6%	93.6%	100%	100%
Checkpoint-based	61.7%	61.7%	100%	100%
Weighted-based	92.5%	92.5%	95%	100%

Table 9.39: Summary of results of comparison between TMM with incentive and TMM without incentive

Moreover, from Table 9.39 above, we can ascertain which incentive mechanism approach best facilitates successful service delivery and trust maintenance. As we can see, for the outcome-based G-Benchmark, the performance-driven-based approach yields the highest percentage of successful service delivery followed by error-tolerance-based and occurrence-based. However, if we consider this from the checkpoint-based perspective for trust final value calculation, the best performance is shown by error-tolerance-based, follow by occurrence-based and performance-driven-based. Another pattern can be inferred from the weighted-based approach. In this case, the error-tolerance has the highest performance, followed by occurrence-based and performance-driven-based.

In addition, if we consider this from the perspective of the dynamic behaviour of agents throughout the transactions, with the FL triangular approach, the performance of TMM non-incentive-based method is lower than for the TMM incentive-based. Of these three incentive mechanisms, the error-tolerance-based approach has the highest performance in terms of percentage of successful transactions. In the case of representing dynamic behaviour using the FL trapezoidal, the performance of TMM non-incentive-based is slightly lower than that of the TMM incentive-based. Of the three incentive mechanisms, the error-tolerance-based approach shows better performance compared with the other two. However, if we determine the dynamic behaviour of agent using FL Hybrid approach, the performance of TMM non-incentive-based is lower than for the TMM incentive-based. Of the three approaches to the incentive mechanism, the occurrence-based incentive approach and error-tolerance-based approach shows the same better performance than performance-driven-based incentive approach. Hence, we can conclude from comparing the TMM incentive-based and TMM non-incentive based approaches to dealing with the dynamic behaviour of agents, that the TMM incentive-based has a better performance than TMM non-incentive based. It means, by having an incentive mechanism in our TMM, the trust final has been maintained more successful than in transactions with TMM but do not have incentive mechanism. This is because the availability of incentives encourages or motivates the trusted agent to perform as closely as possible to the terms of the mutual agreement. For example, in the performance-driven-based approach, an agent will increase his performance level in response to receiving an incentive.

The second scenario is the comparison of final trust value against initial trust value using the GE-Benchmark. In the outcome-based approach, the error-tolerance incentive-based approach and the performance-driven-incentive approach present the same percentage of successful service delivery which is 100%. This means that the incentive has been successful in encouraging the trusting agent to maintain its trust level in terms of successful service delivery. Moreover, by using the checkpoint-based approach, the error-tolerance-based method produces a best result, followed by occurrence-based and performance-driven-based. And by using the weighted-based approach, the error-tolerance-based incentive approach has the highest performance, followed by occurrence-based and performance-driven-based methods.

Based on the discussion above, we can conclude that if we use the outcome-based approach to calculate the final trust value, the performance-driven-based approach is the best incentive mechanism to facilitate the trust maintenance by means of successful service delivery. However, if we refer to the weighted-based approach in final trust calculation, the error-tolerance-based approach is the best for providing incentive in our TMM. This is because, in the performance-driven-based approach, the condition of intermediate performance which leads to the calculation of intermediate trust level is influenced by the availability of an incentive checkpoint. Hence, if by the end of the transaction we calculate the final trust using the outcome-based final trust value approach, the intermediate trust value is not taken into account. Moreover, with the performance-driven incentive-based approach, the performance of the trusted agent increased after an incentive has been given. The incentive is designed to motivate the trusted agent to comply as closely as possible with the terms of the mutual agreement. Hence, by the end of the transaction, the trusted agent will fully comply according to its initial behaviour or trust level. As outcome-based final trust value is calculated after the actual delivery of service by the end of the interaction without considering how the trusted agent has actually behaved at each checkpoint, the final trust value is the same as or may be greater than the original trust value.

On the contrary, in the case of the weighted-based approach, error-tolerance-based has a greater ratio in terms of percentage of successful transactions. This is because in the weighted-based final trust value, the final trust is calculated by giving weight to intermediate performance and outcome-based performance. The error-tolerance-based incentive mechanism is an incentive which is given if the trusted agent performs above the error-tolerance as agreed. Hence, the trusted agent does not need to show increased performance in response to receiving an incentive as is the case with the performance-driven-based incentive.

9.8 Conclusion

In this chapter, we presented the multi-agent system that we engineered to validate the proposed methodology for maintaining trust. In Section 9.2, we discussed the aims and objectives of engineering these systems. In Section 9.3, we gave an overview of each of the phases involved in running the multi-agent system. Subsequently, in Section 9.4 we discussed the parameters used in the multi-agent system. Additionally, in Section 9.5 we demonstrated the effectiveness of our TMM when the behaviour of agents is dynamic. We evaluated the results by comparing the transactions which used our TMM with the non-TMM transactions. The results show that the percentage of successful transactions was higher for those employing our TMM than those not using TMM. Moreover, in Section 9.6, we demonstrated the effectiveness of our TMM when the behaviour of the agents in the transaction is dynamic. The results show that, although the behaviour of agents is dynamic, for transactions where our TMM is used, we achieve a better ratio of successful transactions than do those transactions which do not use our TMM.

In Section 9.7, we presented the effectiveness of having an incentive mechanism in our TMM. By proposing three different approaches for an incentive mechanism to facilitate the successful delivery of service, it can be concluded that this mechanism successfully facilitates the TMM since it encourages the agent to comply as closely as possible with the mutual agreement. Of the three different approaches for incentive mechanisms (performance-driven-based incentive approach, occurrence-based incentive approach and error-tolerance-based incentive approach), we concluded that the performance-driven-based incentive approach is the best incentive mechanism, followed by error-tolerance and occurrence-based. However, this situation depends on the way that final trust is calculated using our approaches. Nonetheless, by having an incentive mechanism, our TMM successfully helps the trusted agent to maintain its level of trust in the trusting agent.

In the next chapter, we will propose some additional performance benchmarks to measure the effectiveness of our methodology.

9.9 **References**

Fachrunnisa, O. and F. K. Hussain. "A Methodology for Modelling Temporal Nature of Trust in Trust Maintenance for Digital Enterprise". International Journal of Computer Systems Science & Engineering, To Appear on May 2012.

Chapter 10 - **Additional Performance Validation of TMM**

10.1 **Introduction**

As discussed in the previous chapter, we measure the validation of our TMM in terms of 7 (seven) broad objectives. In Chapter 9, we presented the validity of methodology from the 3 (three) broad objectives which are: (a) the comparison between transactions with TMM and transactions without TMM, (b) the successful ratio in terms of comparison between initial trust and final trust in a transaction, and (c) the effectiveness of the incentive mechanism attached to the TMM. Additionally, we evaluated the performance of our TMM in both situations where the behaviour of the agent is either static or dynamic.

In this chapter, we present the remaining 4 (four) broad objectives as additional performance validity to further rigorously validate our proposed TMM. In order to do so, we introduce and define additional performance testing benchmarks. These particular benchmarks are primarily to evaluate whether our methodology can be used to facilitate sustainability by maintaining the compliant behaviour of community members. Section 10.2 presents the aims and objectives of the engineering systems. Section 10.3 presents the parameters used in the simulations. In Sections 10.4 – 10.7, we present the workflow, simulation results and discussion. Section 10.8 concludes the chapter. The research outcome presented in this chapter regarding this validation has been documented in two publications (Fachrunnisa and Hussain, 2010; Fachrunnisa and Hussain, 2011).

10.2 **Objectives of Engineering the Prototype System**

Unlike the objective of the engineering system in the previous chapter, the objective of the engineering system in this chapter is to determine the extent to which our proposed TMM contributes to sustaining a virtual community by either increasing or maintaining the level of trust amongst the members. The term 'sustainability' has been broadly used in the literature to describe and refer to a number of concomitant issues related to continuity or continuance. In this thesis, we refer to and examine the sustainability of a virtual community from the perspective of the compliant / non-compliant behaviour of its constituent members and the ability of an intelligent framework (such as our proposed methodology) to quickly identify non-complying members, so that the virtual community is able to continue over a longer duration of time. The central question that we intend to answer is: given the effectiveness of our TMM (as demonstrated in Chapter 9), does complying behaviour amongst members of a community lead to a sustainable virtual community? Additionally, this benchmark is also used to validate the third party agent selection mechanism as explained in Chapter 5. We evaluate the effectiveness of the availability of third party agent in the community or in the interaction between trusting agent and trusted agent in the trust maintenance phase.

In order to measure this, we continue carrying out the validity test of our proposed TMM with the following four objectives:

1. **Objective 4**: The accuracy of third party agent's information

   In this fourth objective, we make use of the engineered prototype to evaluate the effectiveness of the methodology in terms of the role of the third party agent in the community. This benchmark measures whether the third party agent is able to provide accurate information regarding the performance of any members in a community. This performance information is related to the compliance behaviour of an agent when carrying out a transaction in the trust maintenance phase. As was discussed in Chapters 4 and 5, the role of the third party agent is to supervise and monitor the interaction between trusting agent and trusted agent. Additionally, the third party agent will provide assistance to both parties if there is a performance discrepancy during the interaction. Therefore, the third party agent has information about the performance of each community member in carrying out the transaction. Any member in the community may have a query about the performance of the other member in such transactions during the maintaining phase. This member will refer to the third party who has supervised a transaction involving the queried agent. The aim of the simulation is to evaluate the level of accuracy of information provided by the third party agent.

2. **Objective 5**: The ability to identify all non-compliant agents in a community

   We further investigate the role of the third party agent in the community. The fifth objective is to measure whether the third party agent can help the community to identify all its non-compliant agents. The aim of this benchmark is to capture the number of interactions needed to identify all of the non-compliant agents in the community. This is directly related to the number of non-complying agents that have been identified accurately by the third party agents. We evaluate this benchmark by computing a correlation between number of transactions and the percentage of the correctly identified non-compliant agents in the community. The sustainability of a community can be achieved if the community comprises only compliant agents.

3. **Objective 6**: Maximizing social welfare of the community

   The purpose of these experiments was to determine whether our proposed TMM can help the community to increase the social welfare of its members. We define social welfare as the amount of gain that community members obtain from interacting with other community members. The sustainability of a virtual community can be achieved if all community members derive maximum gain and suffer minimum loss from their interaction with any members in community.

4. **Objective 7**: Measuring Sustainability Index

   In this chapter, we propose a metric to measure the community sustainability index. Such an index can be used by the administrator of the virtual community to measure the sustainability of their community. This is to assist communities to measure the extent to which their community is sustainable. This index is derived from two benchmarks as discussed in points (2) and (3) above: the ability to identify all non-compliant agents in the community, and the social welfare of members in the virtual community.

In order to achieve these four objectives, we engineered a multi-agent system using the JADE Multi Agent-Based Framework similar to that in the previous chapter. The functionality of the JADE Multi Agent-Based Framework was extended using Java. The engineered multi-agent system has an interface, whereby the user can specify the necessary input parameters. The engineered multi-agent system is meant to reflect the interaction between entities in virtual communities. Hence, we created virtual communities in which agents have roles as community members, third party agent, and administrator. We then established several evaluation benchmarks to assess the performance of the proposed methodology and its ability to support sustainability in virtual communities. The simulation framework is available at http://blade1.debii.curtin.edu.au:8080/trustMaintain/.

The phases of the multi-agent system for this simulation are exactly the same as those discussed in Chapter 9, Section 9.3; the objectives however, are different. In the next section, we explain the parameters used for simulations to achieve the above objectives.

10.3 **Parameters used in the Simulation**

In this section, we present the parameters that have to be specified by the user prior to the simulation. We present the parameters included for each objective as explained in Section 10.2. The fourth objective of our engineered system in this thesis is to analyse the level of accuracy of third party agent information regarding the performance of community members in carrying out a transaction during the trust maintenance phase. Table 10.1 presents the parameters used in simulation 4 (the accuracy of third party's agent information).

Parameter	Description	Valid Domain Values
Agent No.	The user can specify the total number of agents in the community.	$0 < x$ Where 'x' is the maximum number of agents that can be specified by the user.
Apply all non-compliant ratio	The user can specify the number (percentage) of non-compliant agents in the community. The available ratio is from 0.1 to 0.9. If the user selects this option, the system will present the results (the number transactions needed to identify non-complying members corresponding to the specified percentage) with the percentage of non-compliant agent in the community as 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 0.9 respectively.	Select this option if the user wants to apply all non-compliant ratio.
Apply one-by-one non-compliant ratio	The user can specify the preferred percentage number of non-compliant agents in the community.	$0 \leq x \leq 1$ Where 'x' denotes the percentage of non-compliant agents in the community that can be specified by the user.

Table 10.1: Parameters used in simulation for analysing the accuracy of third party's information

The fifth objective of the system is to analyse the ability of our proposed TMM to identify all non-compliant agents in the community. Table 10.2 presents the parameters used in the simulation for objective 5.

Parameter	Description	Valid Domain Values
Agent No.	The user can specify the total number of agents in the community.	0 < x Where 'x' denotes the maximum number of agents that can be specified by the user.
N (to confirm non-compliant)	The user can specify the number of non-compliant performances shown by an agent to confirm that this particular agent is categorized as a non-compliant agent. Put simply, after how many non-compliant performances will an agent be categorized as a non-compliant agent?	0 < x Where 'x' denotes the maximum number of transactions to confirm non-compliant performance that can be specified by the user.
Iteration number	The user can specify the number of iterations or the number of repeated transactions in this same parameter	0 < x ≤ 20 Where 'x' denotes the number of repeated transactions that can be specified by the user
Apply all non-compliant ratio.	The user can specify all the percentage numbers of non-compliant agents in the community. The available ratio is from 0.1 to 0.9. If the user selects this option, the system will present the results with the percentage of non-compliant agents in the community as 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 0.9 respectively.	Select this option if the user wants to apply all non-compliant ratio in the community.
Apply one-by-one non-compliant ratio.	The user can specify the preferred percentage of non-compliant agents in the community.	0 ≤ x ≤ 1 Where 'x' denotes the percentage of non-compliant agents in the community that can be specified by the user.

Table 10.2: Parameters used in simulation for analysing the ability of third party agent in identifying all non-compliant agents in the community

The sixth objective of our system is to analyse the correlation between successful interactions with the gain utility of all community members. This is to evaluate whether our proposed TMM can be used to help maximize the social welfare of community members. Table 10.3 shows the parameters used for this simulation objective.

Parameter	Description	Valid Domain Values
Agent No.	The user can specify the total number of agents in the community.	0 < x Where ‘x’ denotes the maximum number of agents in the community that can be specified by the user.
Transaction No.	The user can specify the total number transactions that will be carried out by agents.	0 < x Where ‘x’ denotes the maximum number of transactions carried out by agents in the community that can be specified by the user.
Apply all non-compliant ratio.	The user can specify all the numbers (percentages) of non-compliant agents in the community. The available ratio is from 0.1 to 0.9. If the user selects this option, the system will present the results with the percentage of non-compliant agents in the community as 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, and 0.9 respectively.	Select this option if the user wants to apply all non-compliant ratio in the community.
Apply one-by-one non-compliant ratios.	The user can specify the prefer percentage number of non-compliant agent in the community.	$0 \leq x \leq 1$ Where ‘x’ denotes the percentage of non-compliant agents in the community that can be specified by the user.

Table 10.3: Parameters used in simulation for maximizing the social welfare of the community

The seventh objective of the engineered system is to measure the sustainability index of a community. Table 10.4 presents the parameters used in the simulation for objective 7 (seven).

Parameter	Description	Valid Domain Values
Agent No.	The user can specify the total number of agents in the community.	$0 < x$ Where 'x' denotes the maximum number of agents in the community that can be specified by the user.
Transaction No.	The user can specify the total number transactions that will be carried out by agents.	$0 < x$ Where 'x' denotes the maximum number of transactions carried out by agents in the community that can be specified by the user.
Alpha (α)	The user can specify the value of weighted for weighting the first criteria to measure the sustainability index.	$0 \leq \alpha \leq 1$ *)
Beta (β)	The user can specify the value of weighted for weighting the second criteria to measure the sustainability index.	$0 \leq \beta \leq 1$ *) *) the total value of $\alpha + \beta = 1$
Apply all non-compliant ratio.	The user can specify all the percentages of non-compliant agents in the community. The available ratio is from 0.1 to 0.9. If the user selects this option, the system will present the results with the percentage of non-compliant agents in the community as 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 respectively.	Select this option if the user wants to apply all non-compliant ratios in the community.
Apply one-by-one non-compliant ratio	The user can specify the preferred percentage of non-compliant agents in the community.	$0 \leq x \leq 1$ Where 'x' denotes the percentage of non-compliant agents in the community that can be specified by the user

Table 10.4: Parameters used in simulation for measuring the sustainability index of the community

10.4 **Simulation for Objective 4: The Accuracy of Third Party Agent's Information**

In this section, we present the details of the simulation to analyze the accuracy of third party agents in providing information regarding the performance of community members in carrying out interactions during the trust maintenance phase. We also present the workflow of this simulation including the screenshot of the benchmark tool used to input the parameters prior to simulation. Subsequently, we present the discussion of the results.

10.4.1 **Workflow of Simulation for Objective 4: The Accuracy of Third Party's Agent Information**

The steps involved in this simulation are as follows:

a. Step 1. The user specifies all the parameter values used in this simulation as presented in Table 10.1.

b. Step 2. During the bootstrapping phase, the agents are created and each of them is assigned a given behaviour level. In this simulation, each agent is assigned only one compliance level - either 0% (non-compliant) or 100% (compliant). A non-compliant agent is an agent who is not at all cooperative in any interaction. If this non-compliant agent carries out a transaction, s/he will never comply with the interaction agreement. On the other hand, a compliant agent with a 100% degree of compliance is an agent who always complies with the interaction agreement. From the trust perspective, a non-compliant agent is an untrustworthy agent and a compliant agent is a trustworthy agent.

c. Step 3. During each transaction, a trusting agent and a trusted agent are randomly chosen. The trusting agent is chosen such that it is always a compliant agent which means this trusting agent has a 100% level of compliance. However, the compliance level of the randomly chosen trusted agent could be either total compliance or total non-compliance. The agents carry out an interaction guided by our TMM. In order to achieve the objective of this scenario, we created a situation whereby for each block of interactions (the whole interactions are divided into ten equal blocks), a certain number of agents query the trust values of other agents in the community. The third party agents reply to the querying agents (with the trust value of queried agents) who then pass on the trust values to the administrator. The administrator agent collates all the replies and computes their accuracy by comparing the replied trust value with the actual trust value.

d. Step 4. The statistical outcome of this simulation is gathered and presented to the user. It provides the number of transactions needed to identify all the non-compliant agents, number of queries and amount of accurate information provided. We then analyze the results corresponding to the objective.

10.4.2 **Simulation Results for Objective 4: The Accuracy of Third Party Agent's Information**

Figure 10.1 below shows the simulation framework prompting the user to input the parameters as shown in Table 10.1.

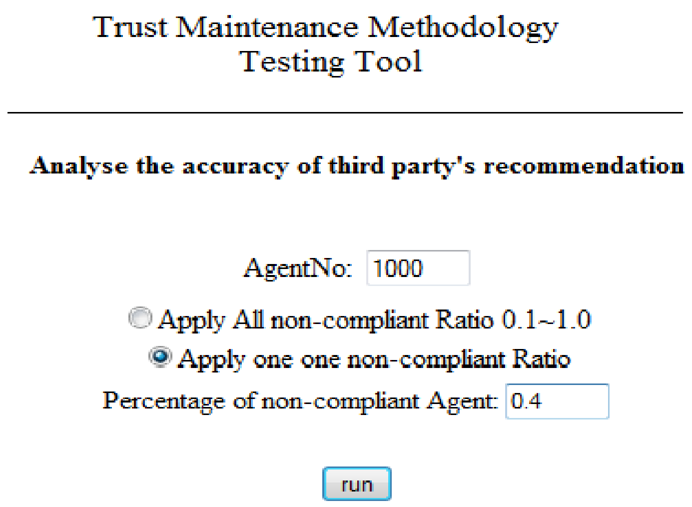

Figure 10.1: Screenshot of testing tool for analysing the accuracy of third party's information

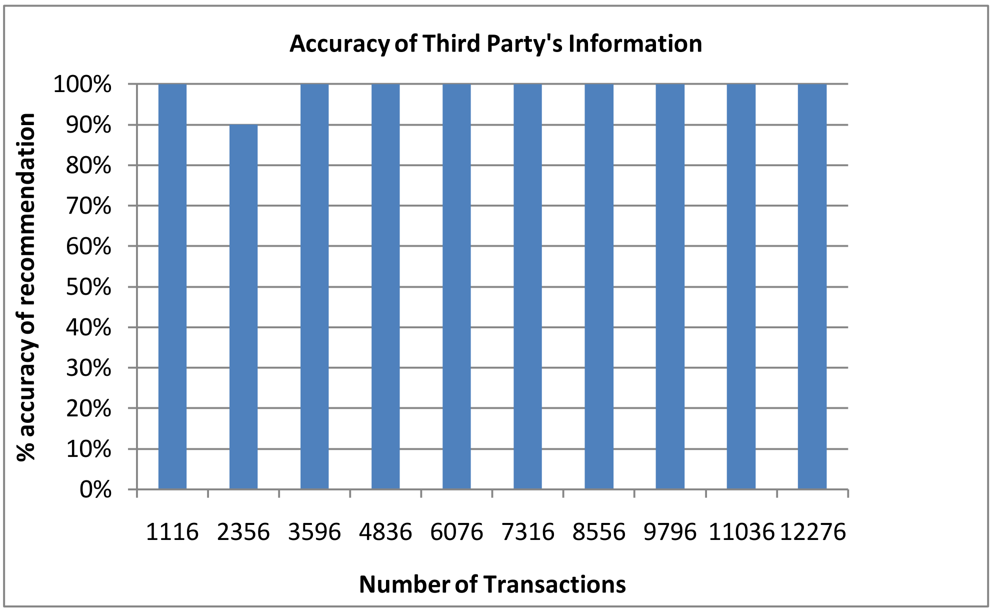

Figure 10.2: Simulation using 1500 agents in the community with 10% of them being non-compliant agents.

	Transaction Spot	% of determined non-compliant agents	Number of Information Queries	Amount of Accurate Information	Accuracy Level

		$(\frac{Identified\ non-complying\ agents}{Total\ non-complying\ agents})$			
1	0-1116	13	10	10	100%
2	1117 - 2356	31	10	9	90%
3	2357 - 3596	47	10	10	100%
4	3597 - 4836	62	10	10	100%
5	4837 - 6076	75	10	10	100%
6	6077 - 7316	86	10	10	100%
7	7317 - 8556	94	10	10	100%
8	8557 - 9796	98	10	10	100%
9	9797 - 11036	99	10	10	100%
10	11036 - 12276	99	10	10	100%

Table 10.5: Descriptive result for simulation with 1500 agents in the community with 10% of them being non-compliant agents.

Figure 10.2 and Table 10.5 provide the results of a simulation using a community with a total of 1500 agents, with the total number of non-compliant agents in the community being 150 (10% of 1500). The results presented in Table 10.5 indicate that it takes 12276 transactions to determine all the non-compliant agents in the community. In other words, after 12276 transactions, the third party agent is able to identify all the non-compliant agents in the community. Additionally, as we can observe from the table, with the increasing number of transactions, the percentage of confirmed non-compliant agents in the community increases.

In this scenario, for simplicity, we divided the number of transactions into ten equal blocks. At every block, there are ten queries and the number of accurate recommendations is shown in Table 10.5. As indicated by Table 10.5 and Figure 10.2, the accuracy level of recommendations provided by a third party agent is almost 100%. It means that of 10 queries, 10 are provided with accurate information about the trust value (performance/behaviour) of the other agents in the community.

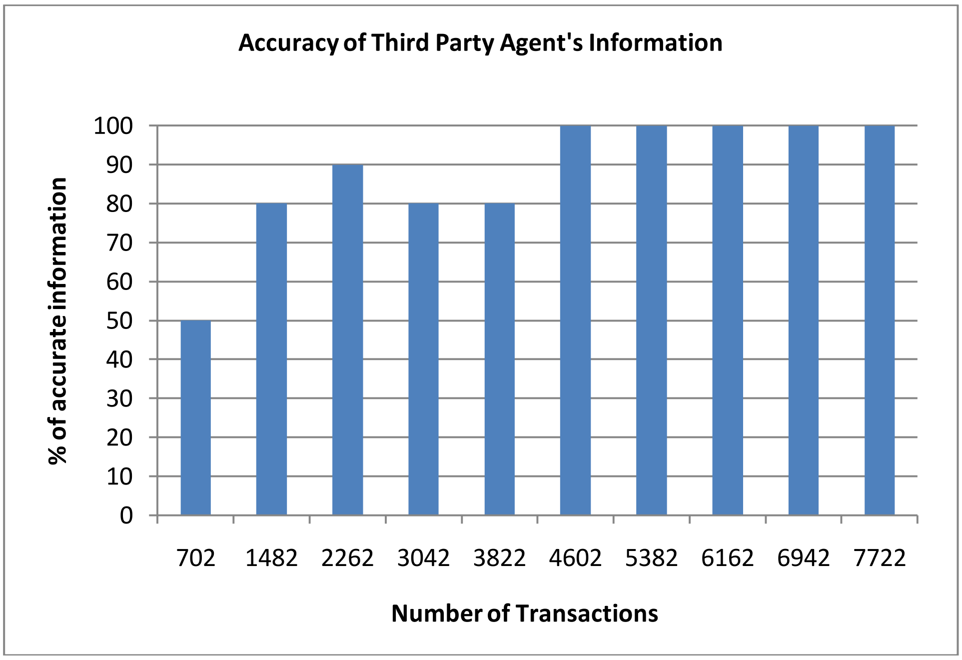

Figure 10.3: Simulation using 1500 agents in the community with 20% of them being non-compliant agents

Figure 10.3 presents results of simulation from number of agents in the community is 1500 and the percentage of non-compliant agents is 20%. As we can observe from Figure 10.3, the accuracy of the third party agent's information is more than 90%. In the first two ten blocks of interactions (shown above), the accuracy is slightly low; however, as the number of transactions increases, so too does the level of accuracy.

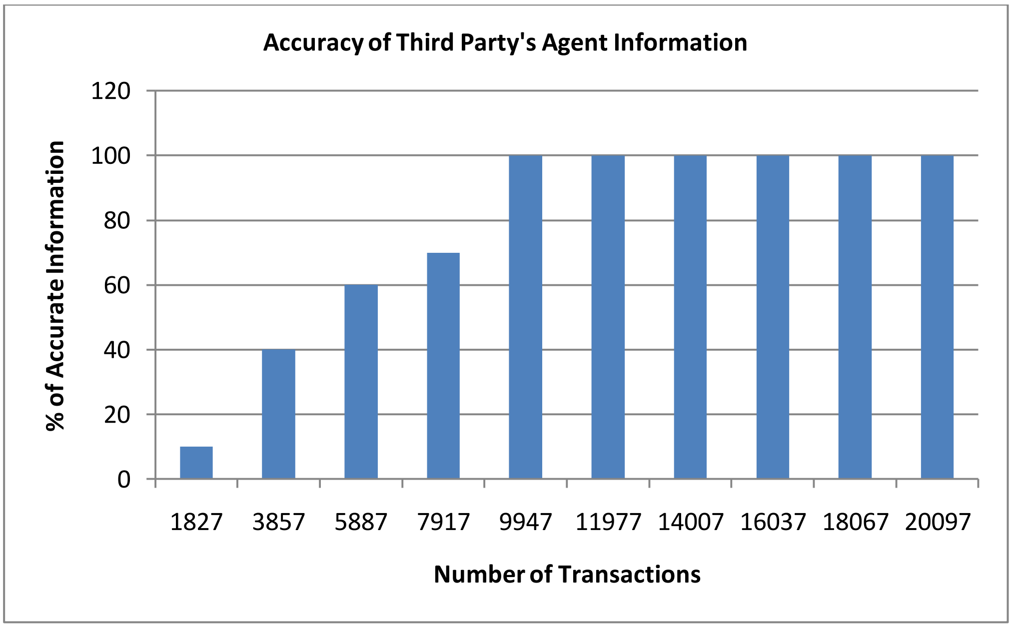

Figure 10.4: Simulation using 5000 agents in the community with 70% of them being non-compliant agents

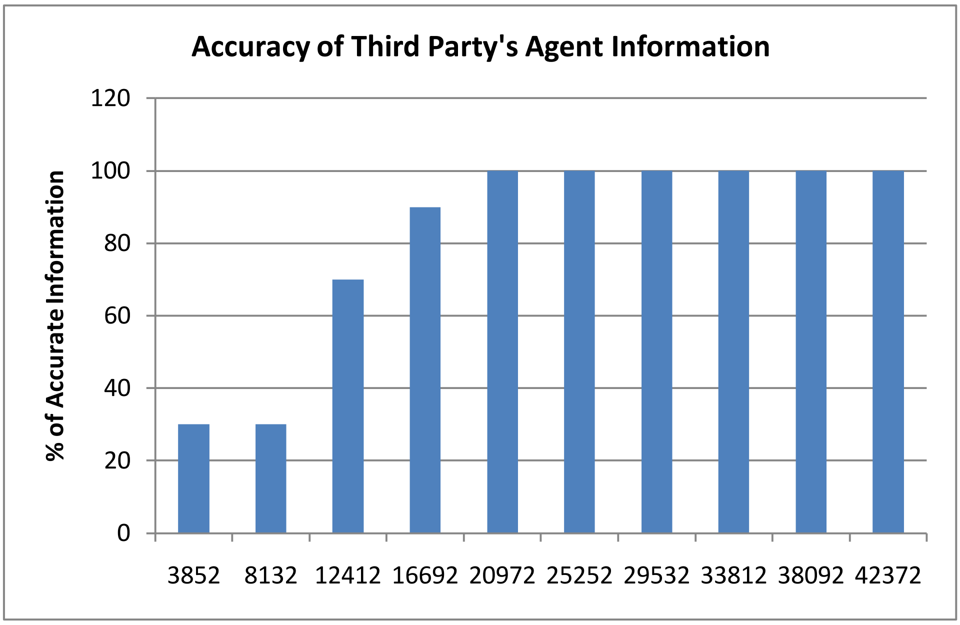

Figure 10.5: Simulation using 10000 agents in the community with 75% of them being non-compliant agents

Figures 10.4 and 10.5 present the results of the simulation with particular input parameters. As we can observe from the figures, it takes 20097 transactions to identify all the non-compliant agents. Similar to the previous experiments, we divided the transactions into ten blocks to evaluate the accuracy of the third party agent in providing information. It is observed that for the first four blocks, the accuracy of the third party's information is less than 100%. Once it reaches 9947 transactions, all information provided by the third party agent regarding community members' performance is accurate. We can also conclude that as the number of transactions increases, the accuracy of the third party's agent information also increases.

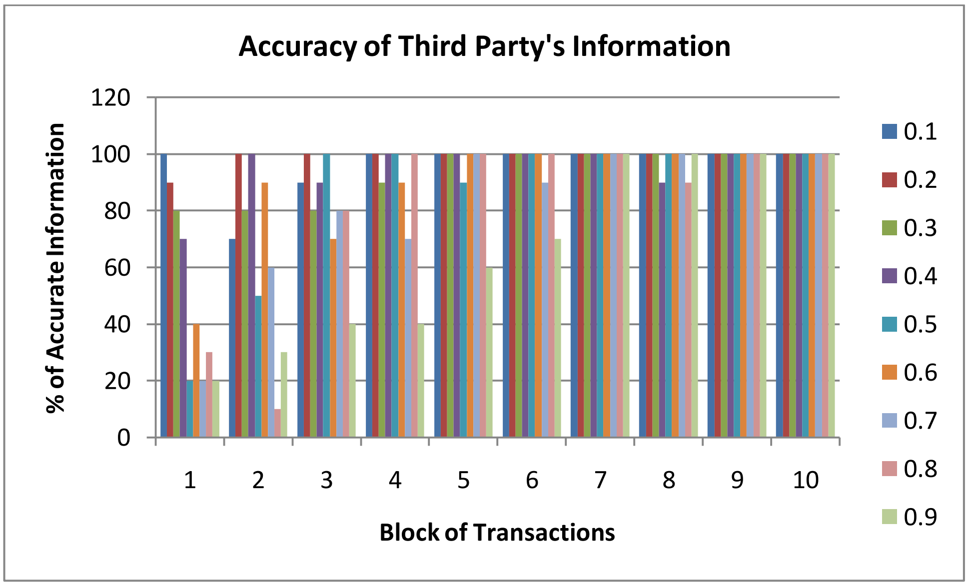

Figure 10.6: Simulation using 5000 agents in the community with the percentage of non-compliant agents varying from 0.1 – 0.9

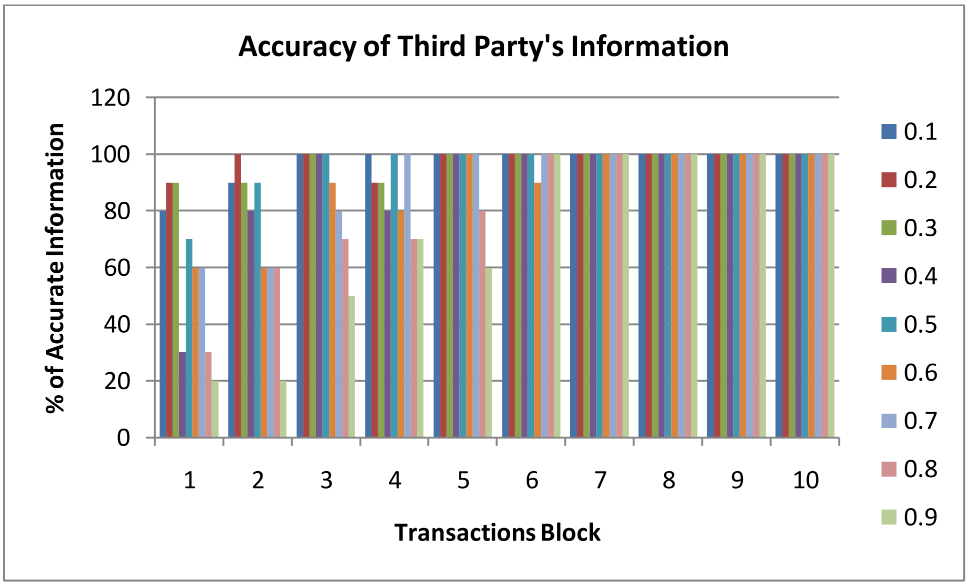

Figure 10.7: Simulation using 20000 agents in the community with the percentage of non-compliant agents varying from 0.1 – 0.9

In addition, Figures 10.6 and 10.7 present the result of simulation using 5000 agents and 20000 agents in the community and where the percentage of non-compliance agents in the community varied in a range from 0.1 to 0.9. We divided the total number of transactions into 10 equal blocks. As can be observed from the figure, as the number of transactions increases, the accuracy of third party agent's information increases as well. In the first five blocks of transactions, with the different percentage of non-compliant agents in the community, the percentage of accurate information varies. However, once it reaches in sixth block, the accuracy level is 100%. Hence, we can conclude that the third party agent has correctly identified the non-compliant agents and retrieved accurate information for community members who query other community members' trust value.

10.4.3 Discussion of Results Obtained for Objective 4: The Accuracy of Third Party Agent's Information

This simulation is designed to measure the effectiveness of the communicated recommended / information by the third party agent in facilitating the sustainability of the community. As was explained in Chapter 6, the role of the third party agent is to supervise and monitor the transaction carried out by both trusting agent and trusted agent. Hence, third party agents will have databases regarding the performance history of agents under their supervision. An agent in the community can query regarding the performance of existing members (or potential interacting partners) before making a decision to carry out a particular transaction. Third party agent will provide information in response to the query. In this context, the accuracy of the communicated information by third party agents is extremely significant. If the third party agent provides accurate information about the performance of an agent, then the agent who queries the information will make a correct decision about whether or not to carry out a transaction with the purpose of maintaining trust. With this benchmark, we evaluate the level of accuracy of information provided by the third party agent. This is to support an agent who intends to maintain trust with another agent in the community.

Based on the results presented in the previous section, we concluded that the third party agents are able to provide accurate information regarding the performance of community members. We carried out simulation according to various parameters. The results show that on average, the accuracy level of information provided by a third party agent is more than 90%. Hence, we can conclude that our TMM supports the sustainability of a community by providing assistance to the neutral agent that supervised the transaction between trusting agent and trusted agent in the community.

10.5 Simulation for Objective 5: The Ability to Identify All Non-compliant Agents in the Community

The fifth objective is to evaluate the ability of the third party agent to identify all non-compliant agents in a community. The aim of this benchmark is to capture the number of interactions needed to identify all of the non-compliant agents in the community. This is directly related to the number of non-complying agents that have been identified accurately by the third party agents. In this section, we present the workflow of the simulation, the simulation results and the discussion of the results.

10.5.1 **Workflow of Simulation for Objective 5: The Ability to Identify All Non-compliant Agents in the Community**

The steps involved in this simulation are as follows:

a. Step 1. The user specifies all the parameter values used in this simulation as presented in Table 10.2.

b. Step 2. During the bootstrapping phase, the agents are created and each of them is assigned a given behaviour. In this simulation, each agent will be assigned only one compliance level - either 0% (non-compliant) or 100% (compliant). A non-compliant agent is an agent who is not at all cooperative in any interaction. If this non-compliant agent carries out a transaction, s/he will never comply with the interaction agreement. On the other hand, a compliant agent with a 100% degree of compliance is an agent who always complies with the interaction agreement. From the trust perspective, a non-compliant agent is an untrustworthy agent and a compliant agent is a trustworthy agent.

c. Step 3. During each transaction, a trusting agent and a trusted agent are randomly chosen. The trusting agent is chosen such that it is always a compliant agent which means this trusting agent has a 100% level of compliance. However, the compliance level of the randomly chosen trusted agent could be either total compliance or total non-compliance. The agents carry out an interaction as described in our TMM. In order to achieve the objective of this simulation, we added a scenario by which the third party agent has a record of both agents' performance during the transaction. Following the last step of our methodology, the trusting agent will inform the third party agent of the 'non-compliant' behaviour of the trusted agent. Subsequently, the third party agent will investigate this non-compliant behaviour and by using the performance track record, if a trusted agent is repeatedly non-compliant, this agent will be placed on the 'black list' which is a list of community members who have been found to be non-complying at certain times. In each community, the administrator will establish a policy regarding how or when an agent will be placed on either the black or white list. A possible policy could be based on a certain number of repeated untrustworthy or trustworthy behaviours during a specified time period. The threshold of the number of times that an agent could behave in an untrustworthy manner so as to be characterized as an untrustworthy agent and placed in the blacklist, could be specified by the user as shown in Table 10.2 (N (to confirm non-compliant)).

d. Step 4. The statistical outcome of this simulation is gathered and presented to the user. It presents the number of interactions and the percentage of non-compliant agents in the community. We then analyze the results in terms of the objective.

10.5.2 Simulation Results: the Ability to Identify all Non-compliant Agents in the Community

This simulation is designed to find the number of interactions needed to identify correctly all the non-compliant agents in the community. This simulation is intended to determine the number of interactions required in order for the system to be able to accurately identify all of the non-compliant agents in the community. Figure 10.8 shows the benchmark tool used to input the parameters prior to the simulation.

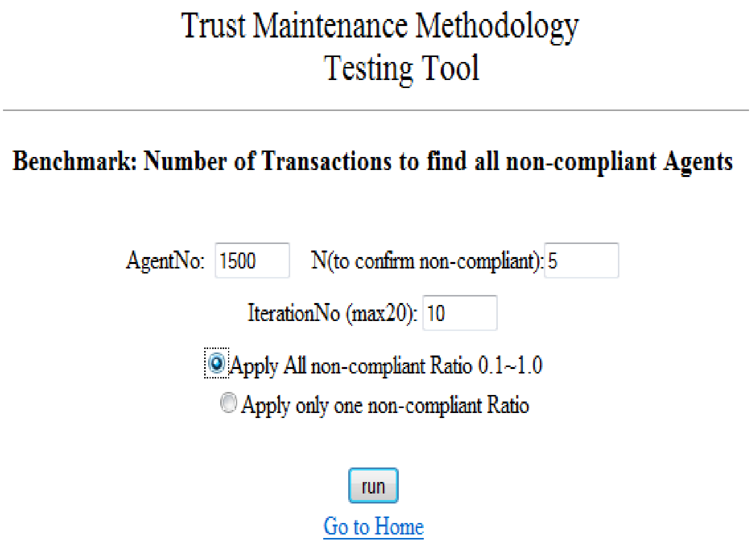

Figure 10.8: Screenshot of testing tool to identify all non-compliant agents in the community

Figures 10.9 to 10.13 below present simulation results from various numbers of agents in the population with the percentage of non-compliant agents in the community ranging from 0.1 to 0.9

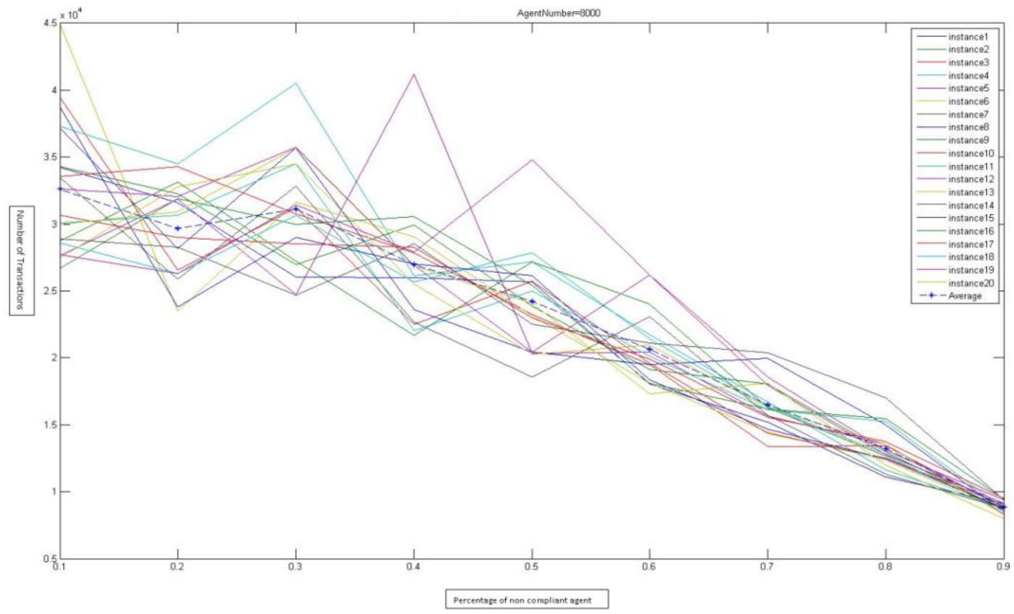

Figure 10.9: Simulation using 8000 agents in the community with the percentage of non-compliant agents varying from 0.1 – 0.9

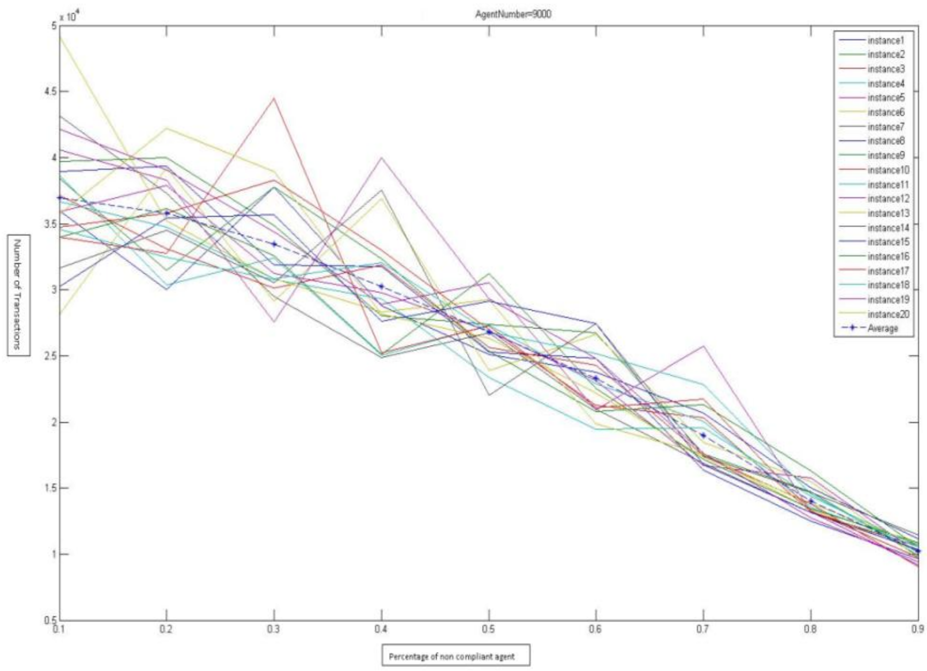

Figure 10.10: Simulation using 9000 agents in the community with the percentage of non-compliant agents varying from 0.1 – 0.9

Due to the random nature of agent selection (trusted agents) during simulation, we conducted 20 series of experiments for every community size, as depicted in Figures 10.9 to 10.13. In order to remove any selection bias, finally, we computed an average for those 20 experiments as shown in these figures. Results of experiments show that as the percentage of non-compliant agents in the community increases, the average amount of time required to identify all of them as a function of the number of transactions, decreases. If the community has a large number of non-compliant agents, then it will be quicker to identify all of them. Consider, for example, Figure 10.9 which plots the experimental results for a community size of 8000 agents. With 10% of them being non-compliant agents, on average, it takes 320000 transactions to identify all the non-compliant agents in the community. However, if the percentage of non-compliant agents in the community is 90%, on an average, it takes only 90000 transactions to identify all of them. We repeated the experiments with several different total numbers of agents in the community. Let us consider another experiment result from Figure 10.12 which illustrates a community size of 80000 agents. With 10% of them being non-compliant agents, on average, it takes 4500000 transactions to identify all of them. However, if the percentage of non-compliant agents is 90%, on average, it takes only 100000 transactions to identify all of them. A similar pattern of results was also found for a community size of 9000 (Figure 10.10), 70000 (Figure 10.11), 80000 (Figure 10.12) and 90000 (Figure. 10.13).

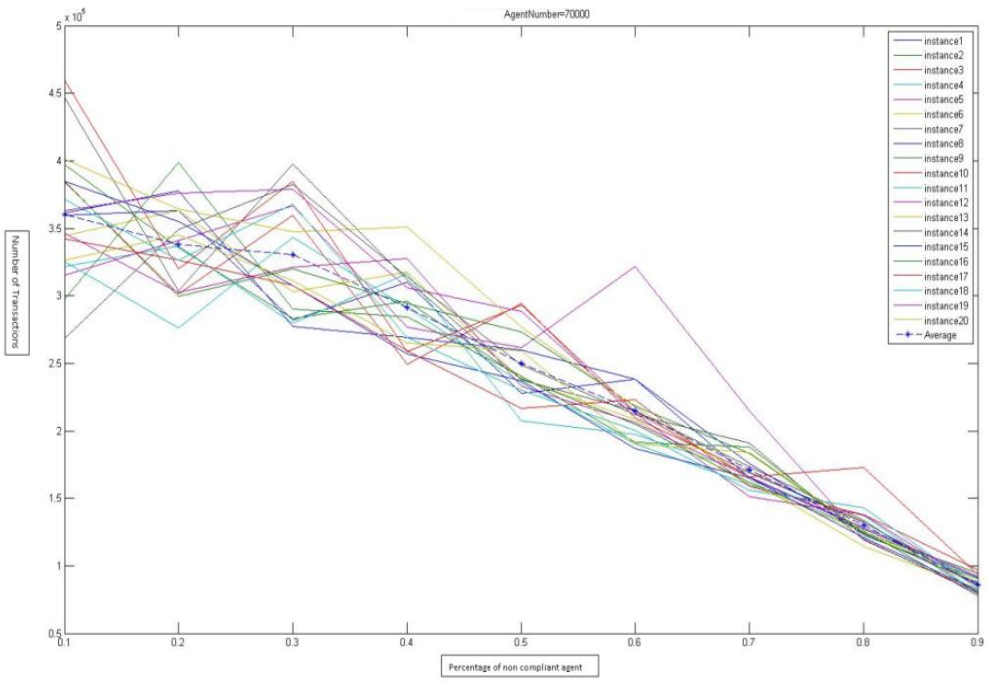

Figure 10.11: Simulation using 70000 agents in the community with the percentage of non-compliant agents varying from 0.1 – 0.9

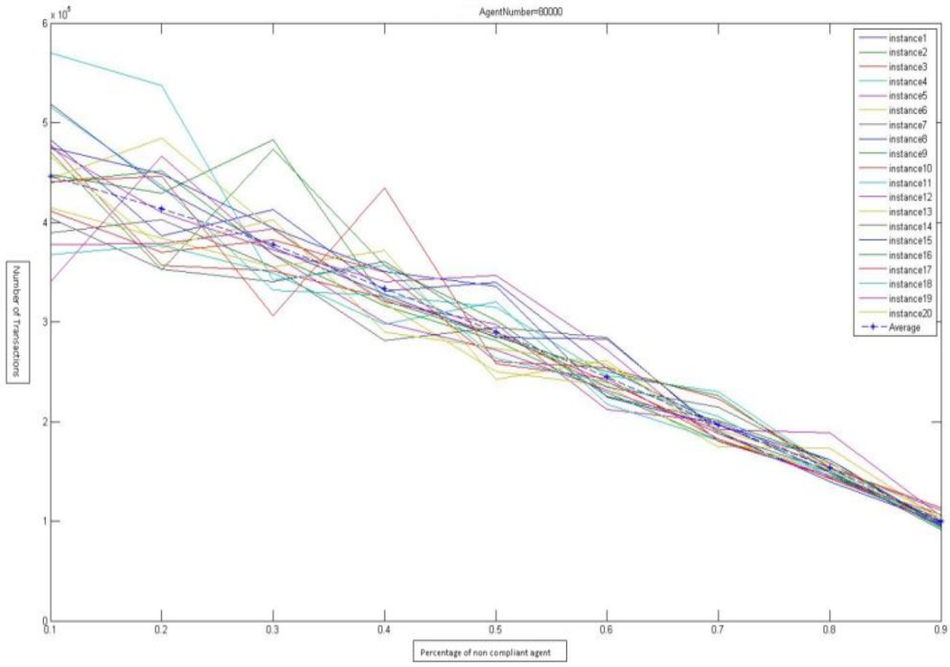

Figure 10.12: Simulation using 80000 agents in the community with the percentage of non-compliant agents varying from 0.1 – 0.9

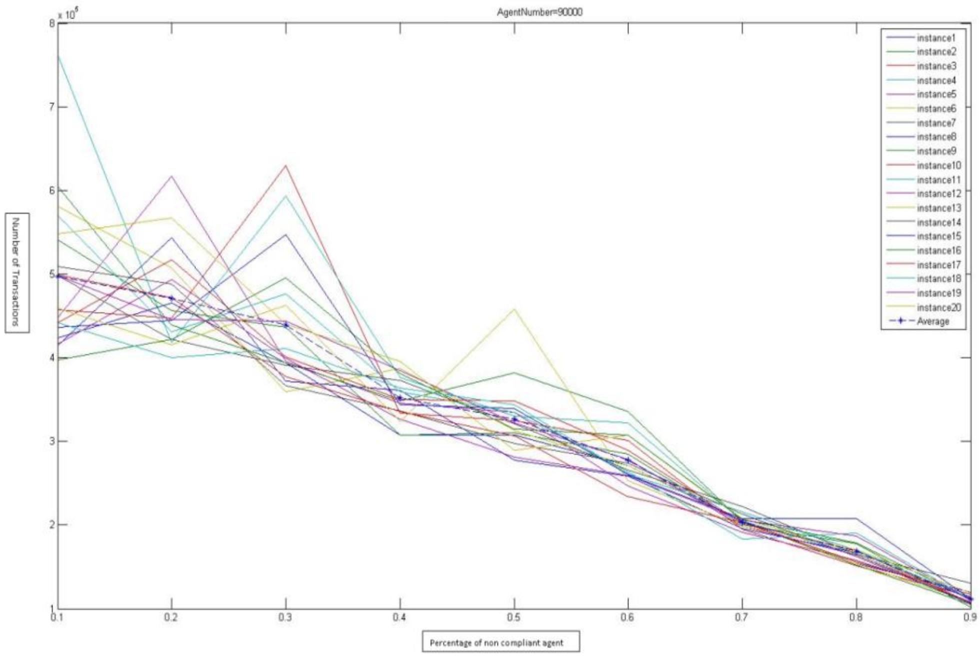

Figure 10.13: Simulation using 90000 agents in the community with the percentage of non-compliant agents varying from 0.1 – 0.9

Moreover, in this experiment, we also investigate the effectiveness of our proposed TMM in identifying all the non-compliant members in the community. The aim of this benchmark is to analyse the correlation between the number of transactions and the percentage of non-compliant agents correctly identified in the community. This is directly related to, and dependent on, the number of non-complying agents that have been identified accurately by the expert agents.

We created a virtual community with varying numbers of agent populations: 10000, 55000, 100000 and 200000 agents. They carry out an interaction guided by our proposed TMM. The agent population size can be specified prior to running the simulation. For each different agent population size, we introduced a certain percentage of non-compliant agents into the community environment. The system randomly assigns a compliance level to each member agent of either 0% (non-compliant) or 100% (compliant). A non-compliant agent is an agent who will not fully deliver according to criteria factors as agreed. This non-compliant agent will never comply with the mutual agreement. Conversely, a compliant agent is an agent who fully delivers the criteria factors as agreed or an agent who always complies with the mutual agreement. The percentage of non-complying agents in the community varies from 0.1 to 0.9.

In this simulation, the user specifies the number of times that a non-compliant agent will behave as a 'non-compliant' agent before it is placed on the black list. The simulation process described above is repeated for the number of interactions specified by the user at the start of the simulation. In the initial stages of simulation, the compliance of agents is not modelled completely or accurately, or both. By 'complete modelling' of compliance levels, we mean that the third party agent should know the compliance levels of all the agents in the community. On the other hand, by 'accurate modelling' of the compliance level, we mean that the actual level of compliance of the agents in the community should be as close as possible to the modelled or determined compliance levels established by the expert agents. Once the third party agent's information reflects accurately and completely the compliance of the agents in the community, non-complying interactions will not occur. In other words, this would create a community in which non-complying agents are blacklisted and only complying agents would be available to carry out transactions with other complying agents.

As depicted in Figures 10.14, 10.15, 10.16 and 10.17, for each community size we have different experimental results. These results show that as the number of transactions increases, the percentage of non-compliant agents that are correctly identified by the third party agent increases as well. For example, Figure 10.14 shows the result of simulation using 55000 agents, 65% of which are non-compliant and carried out 100000 transactions. In the first 1000 transactions, only 14.86% of non-compliant agents are correctly identified. However, as the number of transactions increases, the percentage of non-compliant agents that have been identified correctly by expert agents also increases. By the end of 100000 transactions, 92.77% of non-compliant agents have been correctly identified. A similar situation is depicted in Figure 10.15 with 150000 agents, 30% of them being non-compliant and carrying out 200000 transactions.

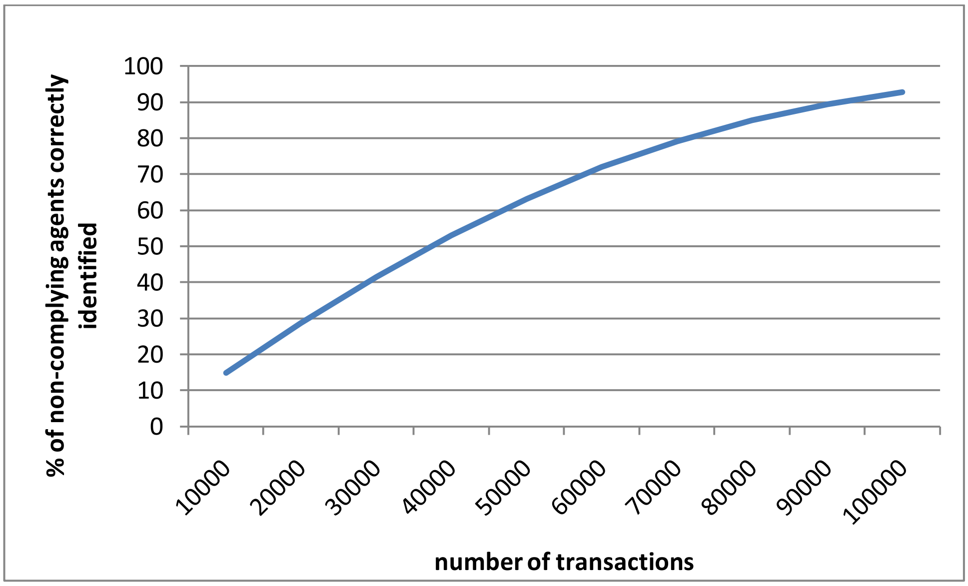

Figure 10.14: Simulation using 55000 agents with 65% of them being non-compliant and carrying out 100000 transactions

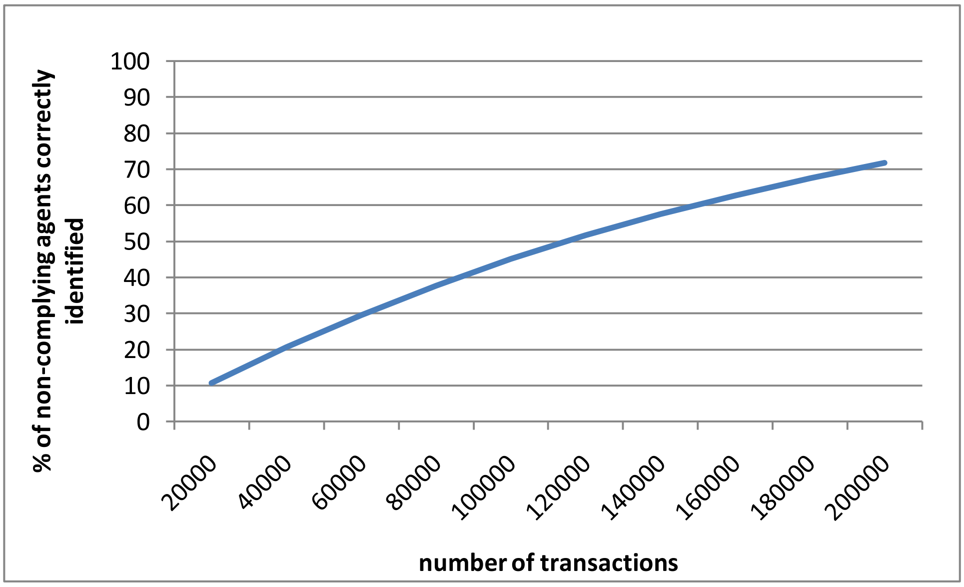

Figure 10.15: Simulation using 150000 agents with 30% of them being non-compliant and carrying out 200000 transactions

Moreover, Figures 10.16 and 10.17 below present the result of simulation with a community population size of 100000 agents. In Figure 10.16, the agents carried out 120000 transactions while in Figure 10.17, the agents carried out 200000 agents. The percentage of non-compliant agents in this community varies from 10% to 90%. As we can observe, as the percentage of non-compliant agents in the community increases, the percentage of them being correctly identified also increases as a function of time or as a function of the number of transactions. Figure 10.16 plots the simulation results for a community with 100000 agents after 120000 transactions have been carried out. We continuously analyze the percentage of non-complying agents identified at every 1000 transactions. For example, in the first 1000 transactions, the percentage of non-compliant agents who were correctly identified by the third party agent is less than 10% for every percentage of non-compliant agents in the community. However, after several thousand transactions, the percentage of those correctly identified is over 70%. A similar pattern of results is also shown when the number of transactions carried out by agent increases by 200000 as presented in Figure 10.17. As the number of transactions increases, the percentage of correctly identified non-complying agent also increases.

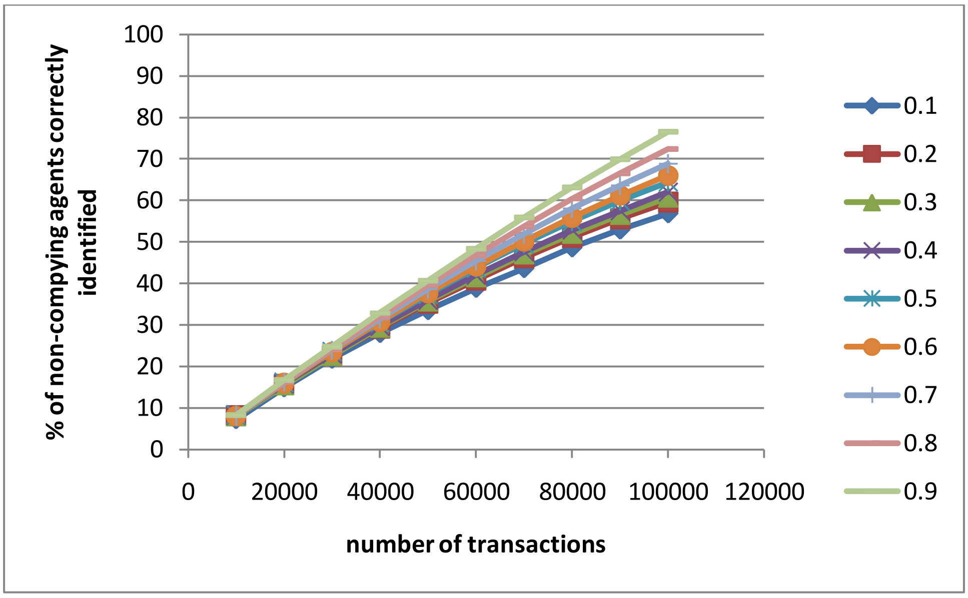

Figure 10.16: Simulation using 100000 agents that carried out 120000 transactions, percentage of non-compliant agents varying from 0.1 – 0.9.

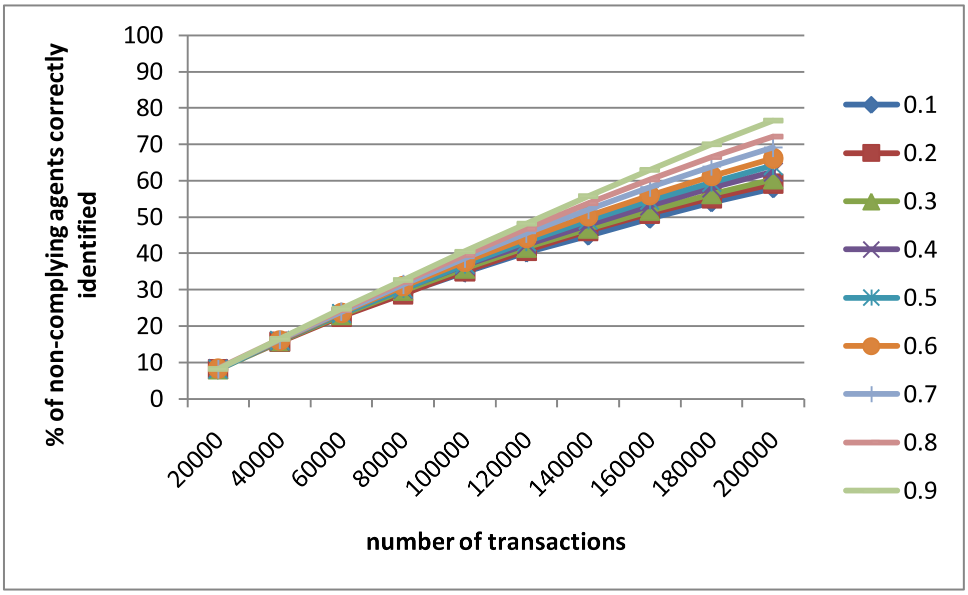

Figure 10.17: Simulation using 100000 agents that carried out 200000 transactions, percentage of non-compliant agents varying from 0.1 – 0.9.

10.5.3 Discussion Results Obtained for Objective 5: The Ability to Identify all Non-compliant Agents in the Community

Based on several results presented in the previous section, we conclude from these experiments that our TMM is effective in identifying all the non-compliant agents in the community. The role of the third party agent in monitoring the interaction based on the mutual agreement is a key in identifying those who are not trustworthy. If all non-compliant agents are identified, then the community will consist of only those members who are trustworthy or fully comply when carrying out a transaction. When the community is comprised of only compliant agents, then community sustainability can be achieved. We also conclude from these experiments that our proposed TMM is effective in accurately and reliably identifying the non-complying members in the community.

10.6 Simulation for Objective 6: Maximizing Social Welfare of the Community

The purpose of this objective is to determine whether our proposed TMM can help the community to increase the social welfare of its members. We define social welfare as the amount of gain that community members obtain from interacting with other community members. The sustainability of a virtual community can be achieved if all community members derive the maximum gain and incur minimum loss from their interaction with other members in community. In this section, we present the workflow of the simulation, the simulation results and discussion of associated results.

10.6.1 Workflow of Simulation for Objective 6: Maximizing Social Welfare of the Community

The steps involved in this simulation are as follows:

a. Step 1. The user specifies all the parameter values used in this simulation as presented in Table 10.3.

b. Step 2. During the bootstrapping phase, the agents are created and each of them is assigned a given behaviour. In this simulation, each agent will be assigned only one compliance level - either 0% (non-compliant) or 100% (compliant). A non-compliant agent is an agent who is not at all cooperative in any interaction. If this non-compliant agent carries out a transaction, s/he will never comply with the interaction agreement. On the other hand, a compliant agent with a 100% degree of compliance is an agent who always complies with the interaction agreement. From the trust and QoS delivery perspective, a non-compliant agent is an untrustworthy agent and a compliant agent is a trustworthy agent in delivering on the service requirements.

c. Step 3. During each transaction, a trusting agent and a trusted agent are randomly chosen. The trusting agent is chosen such that it is always a compliant agent which means this trusting agent has a 100% level of compliance. However, the compliance level of the randomly chosen trusted agent could be either total compliance or total non-compliance. The agents carry out an interaction as described in our TMM. Additionally, in order to measure and quantify the objective of the simulation, we added a scenario by which the third party agent has a record of both agents' performances during the transaction. The third party agent then passes this information to the administrator. The administrator uses this information as an input for a database of the agents' behaviour when carrying out transactions in a virtual community.

   The administrator then gives the third party agent access to this database in order to determine whether an agent should carry out or otherwise terminate a transaction with another agent. Hence, our proposed methodology provides a mechanism by which a third party agent will help an agent to determine whether or not to carry out an interaction with another agent. The determinants of gain or loss from an interaction are as follows:

   - If a given agent (say A) intends to interact with another trustworthy agent (say B), and the third party agent suggests that the interaction go ahead, then agent A will gain. Conversely,
   - If a given agent (say A) intends to interact with another trustworthy agent (say B) and the third party agent suggests that the interaction not go ahead (due to incorrect trust modelling of that agent by the third party agent), then agent A will lose (or incur loss).
   - If a given agent (say A) intends to interact with another untrustworthy agent (say B) and the third party agent suggests that the interaction go ahead, then the agent A will lose. Conversely,
   - If a given agent (say A) intends to interact with another untrustworthy agent (say B) and the third party agent suggests that the interaction not go ahead, then agent A will gain.

d. Step 4. The statistical outcome of this simulation is gathered and presented to the user. It presents the total units of gain or loss from various numbers of transactions. We then analyze the results corresponding to the objective.

10.6.2 Simulation Results for Objective 6: Maximizing Social Welfare of the Community

Figure 10.18 below shows the sustainability benchmark tool prompting the user to input the parameters as shown in Table 10.3.

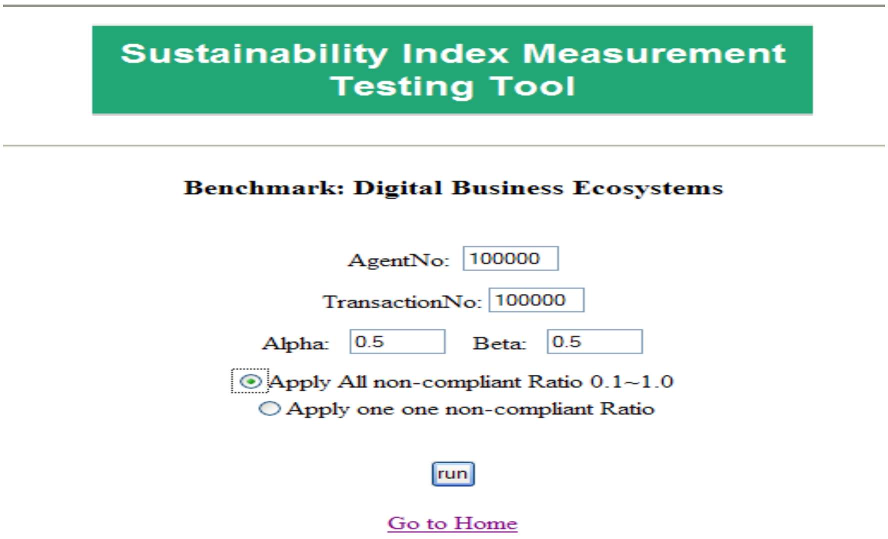

Figure 10.18: Screenshot of testing tool for maximizing social welfare of the community

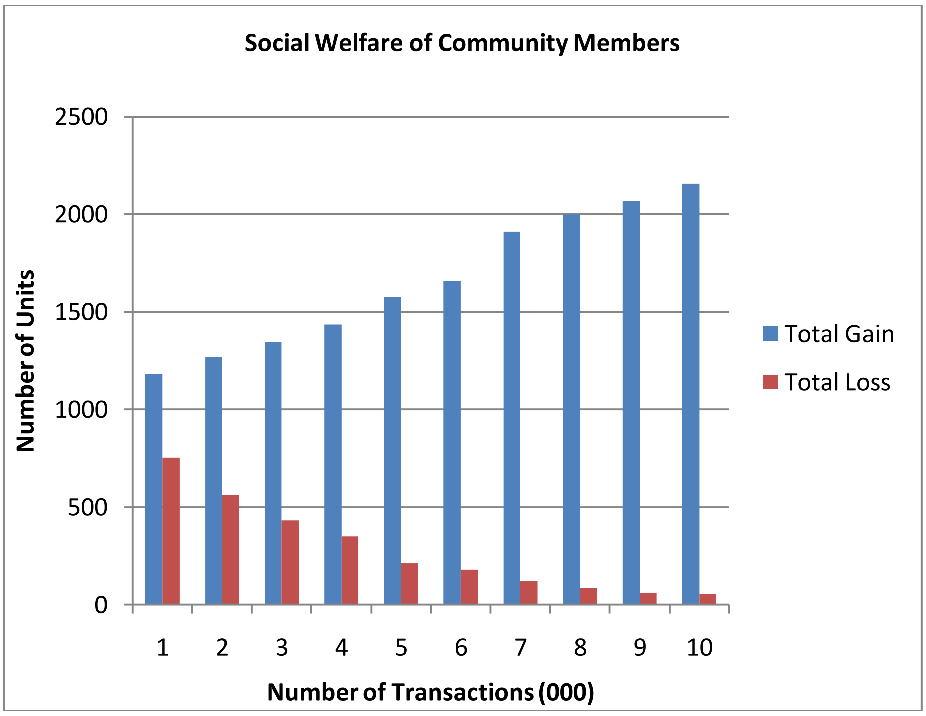

Figure 10.19: Simulation using 10000 agents that carried out 1000 transactions with 50% of them being non-compliant

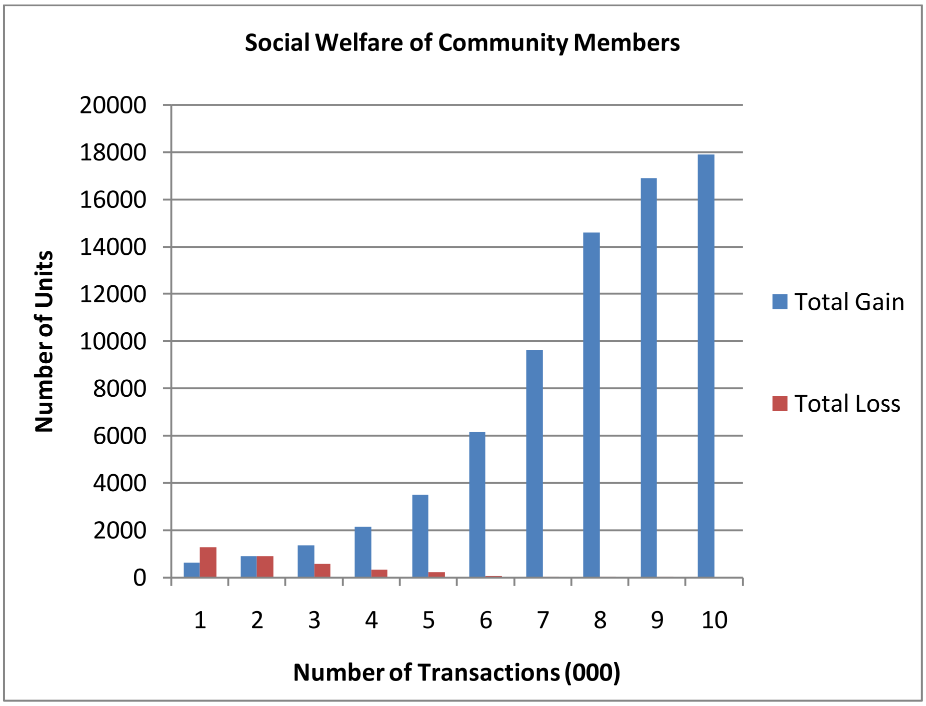

Figure 10.20: Simulation using 10000 agents that carried out 1000 transactions with 90% of them being non-compliant

Figure 10.19 shows the result of an experiment using a population of 10000 agents, 50% of which are non-compliant. They carried out a total of 10000 transactions. As we can observe, as the number of transactions increases, the total gain of community members increases and the total loss of community members decreases. It can be concluded that our mechanism can help community members to interact and transact with trustworthy agents only, so that the total community gain is high while total loss is low.

On the other hand, Figure 10.20 shows the total gain and total loss from 10000 agents in a community where 90% of them are non-compliant. As the percentage of non-compliant agents is very high, we can observe that in the first 1000 transactions, the total loss is higher than the total gain. However, with the passage of time, the third party agent is able to increasingly model the compliance of the agents in the community accurately and completely. As a result of increasing 'accurate' and 'complete' compliance modelling of the agents in the community by third party agents, we can observe that after 5000 transactions, the total gain of the community (between 4000 – 5000 transactions) is greater than the total loss of the community (between 1001 – 2000 transactions, 2001 – 3000 transactions, and 3001 – 4000 transactions). Moreover, the total loss of the community is higher than the total gain in the initial interaction (between 1000 – 2000 transactions) and almost similar in interaction between 2001 – 3000 transactions. This is because, in the initial number of transactions, the third party agent is not yet modelling accurately and completely the compliance behaviour of the agents in the community. However, with the passage of time, after 5000 transactions, the total loss is almost '0'. A similar conclusion can be drawn for the total gain and total loss in the community as the number of transactions (time) increases.

Moreover, Figures 10.21, 10.22, and 10.23 show a comparison of total gain and total loss from 50000, 100000, and 200000 agents in community and the percentage of them being non compliant varies from 10% to 90%. The community members carried out a total of 100000 transactions and we show the total gain and total loss of the community in ten separate continuous transactions.

a. Simulation Results from a community with 50000 agents, the number of transactions is 100000, and the percentage of them being non-compliant varies from 10% to 90%.

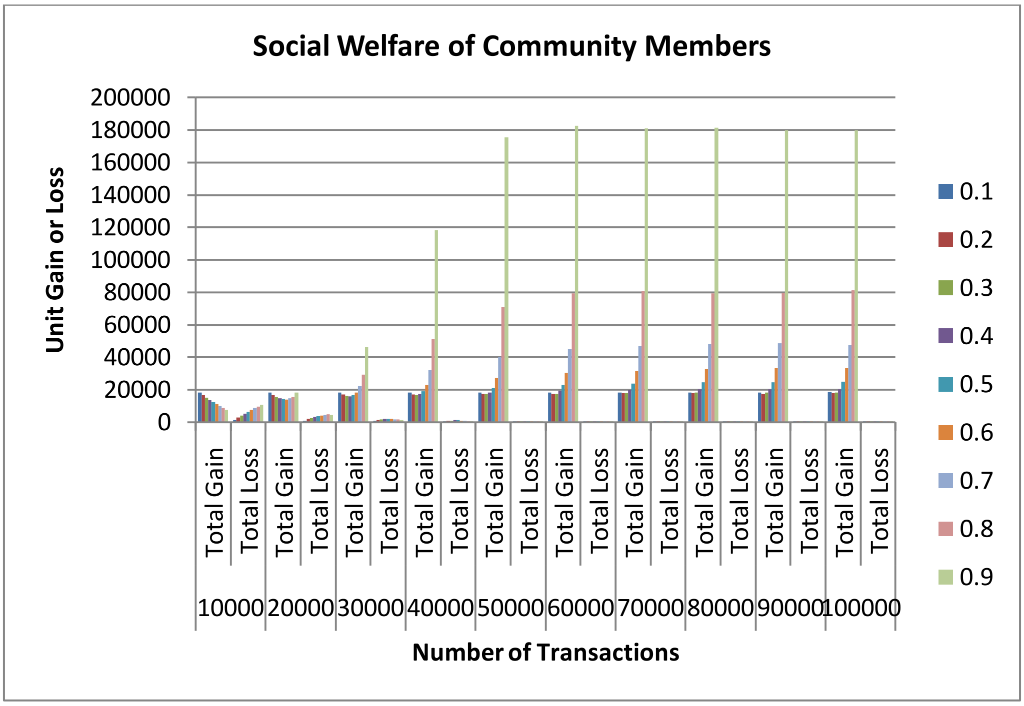

Figure 10.21: Simulation using 50000 agents that carried out 1000000 transactions with the percentage of non-compliant agents varying from 0.1 – 0.9

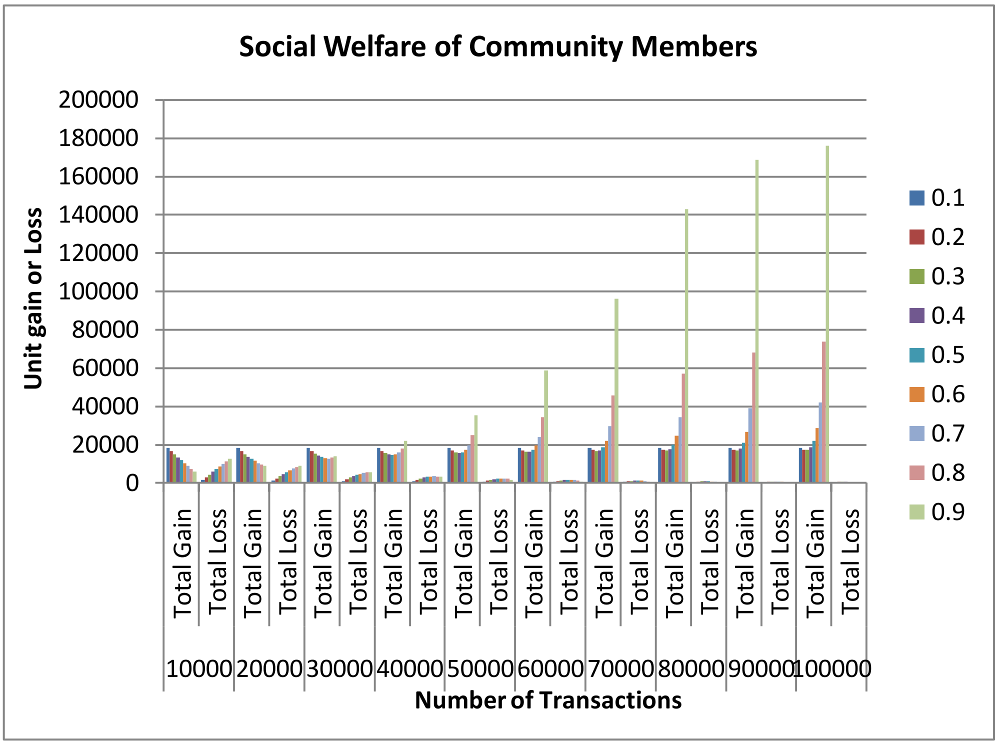

Figure 10.22. Simulation using 100000 agents that carried out 100000 transactions with the percentage of non-compliant agents varying from 0.1 – 0.9

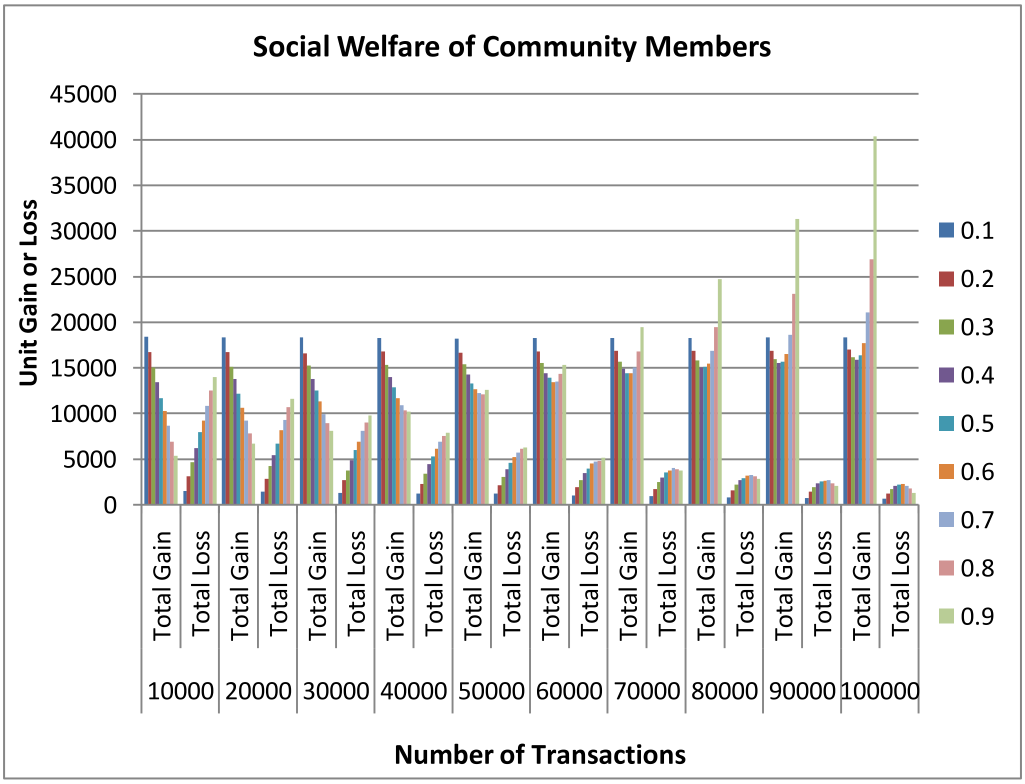

Figure 10.23: Simulation using 200000 agents that carried out 1000000 transactions with the percentage of non-compliant agents varying from 0.1 – 0.9

10.6.3 Discussion of Results Obtained for Objective 6: Maximizing Social Welfare of the Community

The purpose of this benchmark evaluation is to capture the correlation between the percentage of non-compliant agents in the community and the total gain and total loss of community members. The results from several experiments as described in the previous section indicate that as the percentage of non-compliant agents in the community increases, total gain decreases and total loss increases. As a measure of the effectiveness of our methodology in creating a sustainable community by ascertaining the social welfare of community, the figures of the simulation results above show that the total gain is always higher than the total loss for each number of transactions. We also conclude from these experiments, that by using our TMM, the social gain of the community members steadily increases over time and the social loss of community members steadily decreases over time.

Another purpose of this benchmark is to determine whether the members of the community can derive a maximum amount of total gain and minimum amount of total loss from carrying out an interaction with other community members. The role of the third party agent is to identify correctly the non-compliant agents as described in objective 2 of the engineered system in this chapter, and attempt to exclude these non-compliant agents from membership of the virtual community at the next point in time, thereby successfully gaining maximum welfare for the community. If all non-compliant members are correctly identified, then the community will consist of only those members who are trustworthy agents (or complying) who would comply with the mutual agreement when carrying out an interaction. Hence, the community's total gain will be greater than its total loss. When the social welfare of the community has been established, then sustainability can be achieved.

10.7 Simulation for Objective 7: Measuring the Sustainability Index of the Community

In order to calculate the level of community sustainability, in this section, we propose a metric to measure the community sustainability index. This is to assist communities to measure the extent to which their community is sustainable. Two benchmark factors as described in the previous section are taken into consideration: the number of non-compliant agents in the community who have been correctly identified, and the social welfare of the community. The quicker the community is able to identify all its non-complying members, the faster is its progress toward sustainability. The second factor is the net gain value derived from an agent always insisting on interacting only with compliant agents. If the administrator successfully identifies and isolates those who are non-complying members, and retains compliant members in the community, then the community has a large number of compliant members. It may lead to a higher sustainability index. The formula used to calculate this index is as follows:

$$Sustainability\ Index = \alpha\left(\frac{\text{Total number of non-complying members correctly identified at time 't'}}{\text{Total number of non-complying members in the community}}\right) + \beta\left(\frac{\text{Total Gain - Total Loss at time 't'}}{\text{Total Gain + Total Loss}}\right)$$

Equation 10.1

where $\alpha\ and\ \beta$ denote the weighting for the number of non-complying agents in the community and social welfare (total gain and total loss) of community members. The total value of α and β are '1'. The scores of the sustainability index range from '0' to '1'. The higher the sustainability index, the more sustainable is the virtual community. In order to show the progress of the sustainability index as a function of time using our methodology, we created a virtual community similar to the simulation for objective 4 – objective 7. The user can assign varying population sizes and number of transactions which will be carried out by the agent and the percentage of community members who are non-compliant. Figure 10.22 below shows the benchmark software tool for measuring the sustainability index.

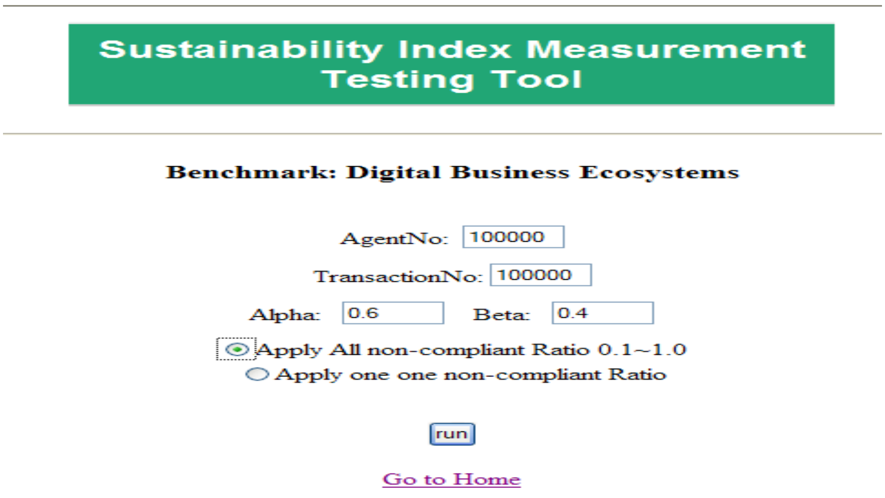

Figure 10.24: Benchmark testing tool for measuring the sustainability index of the community

Figure 10.25 below illustrates the result of simulation using 5000 agents in a community with 25% of them being non-complying agents. These 5000 agents carried out a total of 5000 transactions. We divided the total number of transactions into 5 x 1000 transactions. Hence, the sustainability index in time t' is a representation of the sustainability index after 1000 transactions cumulatively.

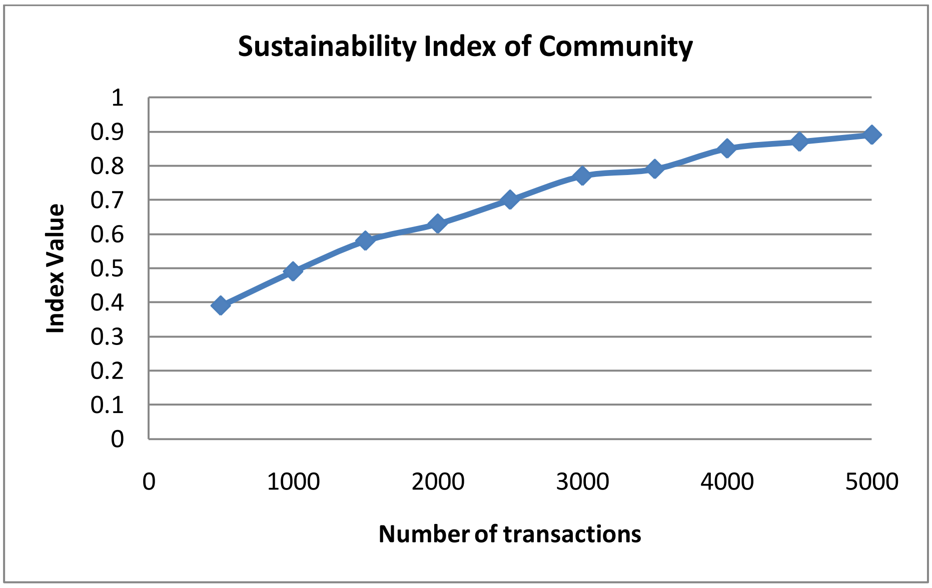

Figure 10.25: Sustainability index of community with 5000 agents, 25% of them being non-compliant agents and carrying out 5000 transactions.

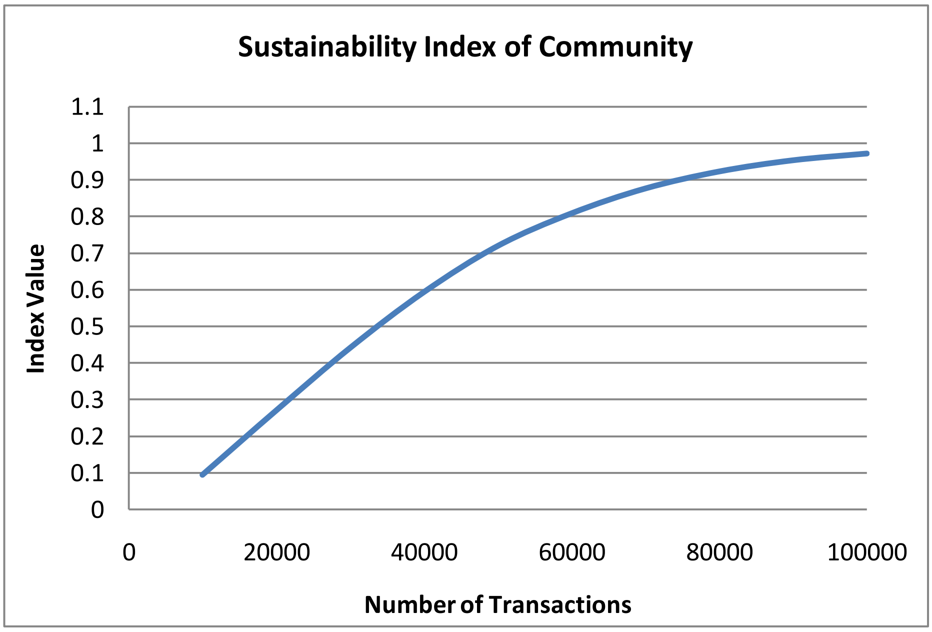

Figure 10.26: Sustainability index of community with 100000 agents, 70% of them being non-compliant agents and carrying out 100000 transactions

As we can observe from Figures 10.25 and 10.26 above, as the number of transactions increases, the sustainability index also increases. It means that our proposed TMM is able to support the increasing sustainability of a virtual community. The role of the third party agent in identifying the non-complying agents in the community is significant for creating the social welfare of community members. Figures 10.27, 10.28, 10.29 show the progress of the sustainability index with a different community size with the predefined percentage of non-compliant agents in the community varying from 0.1 to 0.9.

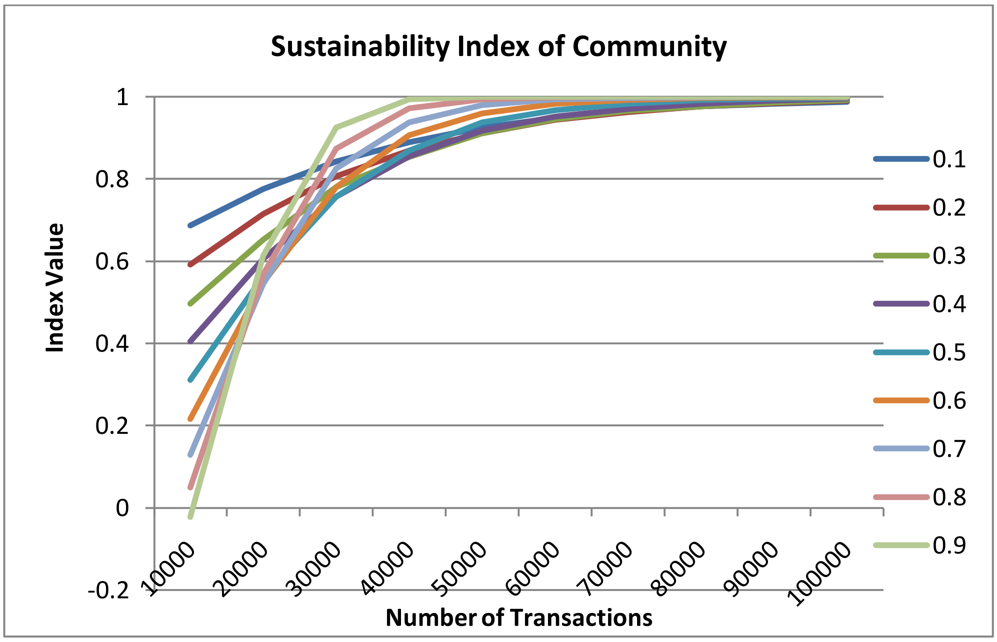

Figure 10.27: Sustainability index of community with 50000 agents that carried out 100000 transactions, percentage of non-compliant agent varying from 0.1 - 0.9

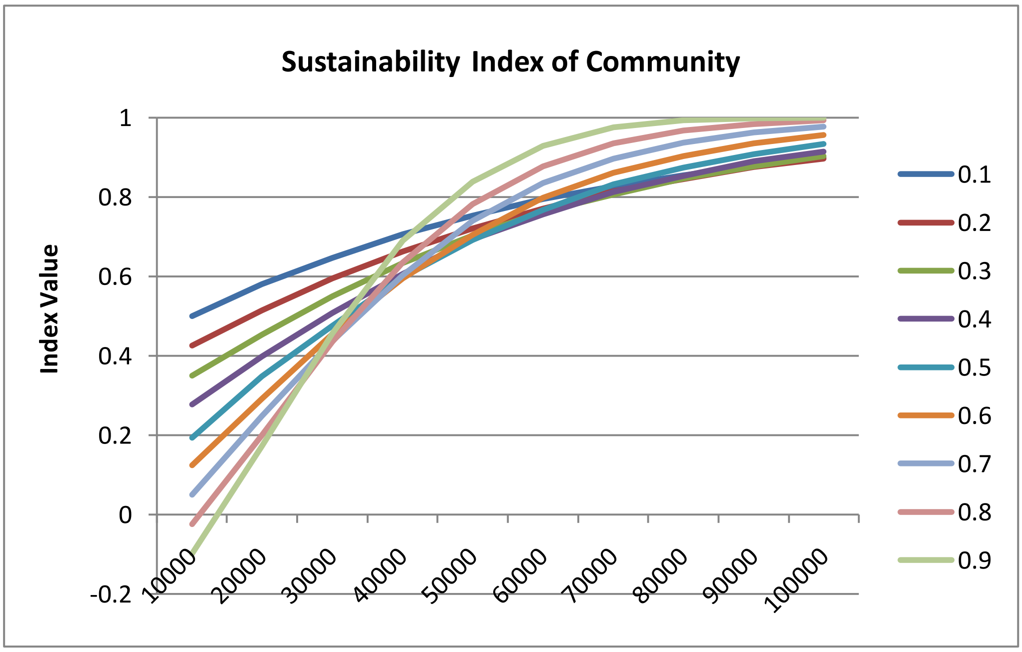

Figure 10.28: Sustainability index of community with 100000 agents that carried out 100000 transactions, percentage of non-compliant agent varying from 0.1 - 0.9

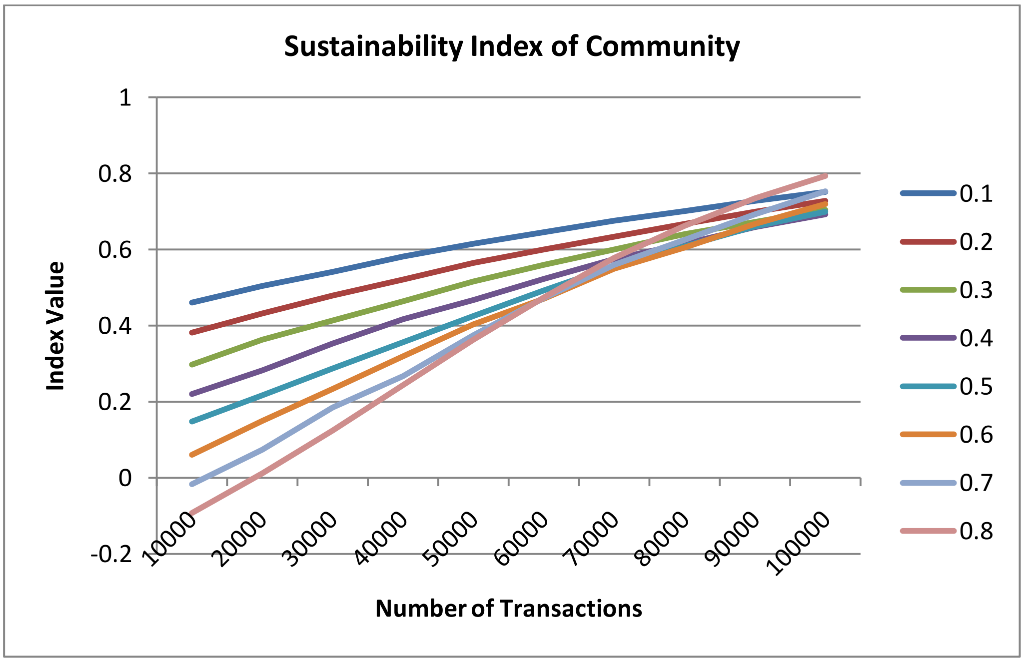

Figure 10.29: Sustainability index of community with 200000 agents that carried out 100000 transactions, percentage of non-compliant agent varying from 0.1 - 0.9

10.7.1 **Discussion of Results Obtained for Objective 7: Measuring the Sustainability Index of the Community**

Based on the results of several experiments, we can conclude that:

a. The larger the percentage of non-complying agents in the community, as a function of time, the quicker (less number of transactions) it will be to identify non-complying agents in the community. Hence, communities with a large percentage of non-complying agents will progress toward a higher level of sustainability faster relative to communities with a lower percentage of non-complying agents.
b. Irrespective of the percentage of non-complying agents, we can observe that for a given population size, the sustainability index gradually increases from 0 to the maximum value (which in some cases the value is 1). This demonstrates the effectiveness of our methodology (compared to communities with a lower number of non-compliant agents in the community).
c. As the population size continues to increase, so too does the amount of time it takes to achieve sustainability.

10.8 **Conclusion**

In this chapter, we present an additional performance validation for our proposed TMM. We further evaluate the effectiveness of our proposed TMM in facilitating the sustainability of a virtual community in terms of maintaining the trust level between members and identifying the non-compliant agents in the community. In this chapter, the effectiveness of our proposed TMM is measured from these 4 (four) perspectives: (a) the accuracy of information provided by third party agent, (b) the ability to identify all non-compliant agents in the community, (c) maximizing the social welfare of the community, and (d) measuring the sustainability index of virtual community.

Based on several benchmarks to evaluate the proposed methodology, we conclude that our methodology can help the community to identify the non-compliant members so that the administrator can make a decision to eliminate them from the community. Therefore, after a certain number of interactions, the community will be primarily comprised of those members who perform in a compliant manner when carrying out a transaction with any other community members. The sustainability of a virtual community can be determined by decreasing the number of non-complying agents in the community who will not (or most likely not) deliver service as agreed by their interacting party. Using our proposed TMM, community members (either as service provider or service requester) will interact according to their mutual agreement and supervised by a third party agent. The role of the third party agent who is independent and unbiased is to proactively monitor this interaction.

Furthermore, with the help of our methodology, communities are able to measure the gain (social gain) and loss (social loss) of the community. This social gain and loss indicates the social welfare of a virtual community. By having only those community members who always comply with the mutual agreement in carrying out interactions with their interacting parties, the social welfare of the community will increase. The experimental results show that the higher the percentage of non-compliant members in the community, the quicker the community can identify them, thereby increasing the sustainability index much faster. Hence, by using our methodology, the sustainability index of a virtual community will progress significantly as a function of time (number of interactions carried out by members).

Furthermore, we presented a metric to measure the sustainability index for a virtual community. We used the two criteria for virtual community sustainability (identifying non-compliance agent and social welfare) as inputs to measure the sustainability index. The result shows that with the help of our methodology, as the number of interactions increases, a virtual community will be able to identify all the non-compliant agents in the community, thereby promoting and increasing social welfare. Hence, the sustainability index will progress significantly as a function of time (number of interactions).

In the next chapter, we recapitulate this work and provide suggestions for future research.

10.9 **References**

Fachrunnisa, O., F.K. Hussain (2010), *"A Framework for Creating Sustainable Community in Virtual Environment"*, Proceeding of the 12th International Conference on Information Integration and Web-based Application & Services (iiWAS 2010), 8 - 11 November 2010, Paris, France, ACM: 735 - 742

Fachrunnisa, O. and F.K. Hussain. "A Methodology for Creating Sustainable Virtual Multimedia Communities". Multimedia Tools and Applications: an International Journal, Accepted with minor revision on 26th August 2011

Chapter 11 - **Recapitulation and Future Work**

11.1 **Introduction**

The field of trust management and modelling has been given much attention by researchers. One of the key strategies in trust management is trust modelling. Studies on modelling trust and reputation values in online environments have been extensive due to the growing importance of this area. Generally speaking, this research area (trust modelling) can be broadly classified into two parts, namely, 'trust determination' and 'trust prediction'. Trust determination refers to the process of computing the trust value of an entity, at the current point in time, by making use of the current or previous trust values of the corresponding entity. In contrast, trust prediction refers to the process of making use of the current trust value or previous trust values of an entity to reliably predict its trust value at a future time slot. Both the trust determination and trust prediction can be seen as attempts to assign a trust value to a trusted agent (Raza, Hussain et al. 2010).

However, after a trusting agent assigns or holds a trust value to another agent in a specific context, it is important that this trust value be maintained. Maintaining trust means retaining this value or, preferably, increasing it over a pre-defined duration of time. Moreover, trust is dynamic by nature in any kind of interaction, particularly in virtual environments where the interaction is not face-to-face. The trust value that a trusting agent has in a trusted agent may change dynamically due to the changing behaviour and performance of the trusted agent. As is evident from the literature review in Chapter 2, the fostering of a trust-based relationship has an evolutionary pattern. The pattern of this evolution can be classified into two broad classes:

continuous increasing and non-linear increment. The continuous increasing assumes that a trust value will increase over time as a function of the length of the relationship. The non-linear increment assumes that the trust value in an interaction follows a life cycle pattern just like a biological pattern in life. The life cycle pattern starts with building, then moves on to maintaining and then goes to declining. However, most of the current literature on trust modelling focuses only on trust determination. From the perspective of trust evolution, the literature is mainly concerned with how to build trust between two entities in an interaction. Very few studies are concerned with ways to maintain this trust value after it has been determined and established.

Additionally, as is evident from Chapter 2, several researchers have suggested or noted the importance of trust maintenance. Additionally, several proposals have been made by various researchers to address the need for trust maintenance. At the same time however, the major shortcoming of these proposals is that none can be regarded as a complete methodology for maintaining trust. The reason for this is that firstly, most of the proposals present factors, variables and certain mechanisms based on a single factor or single component or single activity in order to maintain trust. Secondly, they use the terms *building trust* and *maintaining trust* synonymously. According to our analysis and evaluation of the trust and relationship evolution as presented in Chapter 2, there are different characteristics and features of the trust and relationship condition in each phase of the trust evolution cycle. This leads to the distinction between building trust and maintaining trust. As is also evident in Chapter 2, after closer examination it is apparent that several works which use the term *'maintaining trust'*, do not define maintaining as part of maintaining the trust value after trust determination or as part of the phase following trust building. Hence, the term '*maintaining trust'* that they use is actually referring to *'building trust'*. Thirdly, the factors or variables proposed to maintain trust lack empirical validation.

In order to propose a complete methodology for trust maintenance in virtual environments, in this thesis we identified and addressed seven related research issues. In the next section, we discuss the problems related to trust maintenance in virtual environments that were addressed in this thesis. In Section 11.3, we outline and discuss the contributions of this thesis to the existing literature. Section 11.4 concludes the thesis and sets the stage for future work.

11.2 **Problems Addressed in This Thesis**

In this thesis, we addressed seven major issues associated with trust maintenance in virtual environments. In this thesis, we have attempted to:

1. Defined the concepts of trust evolution, trust building, trust maintenance and trust decline including the features and characteristics of trust condition and relationship in each phase of the trust evolution cycle.
2. Propose a framework for third party agent selection. In a TMM, we introduced the notion a third party agent into the relationship between two parties. This third party agent is a neutral party that will help both the

interacting parties to establish a successful relationship and ensure that trust has been maintained. Our proposed methodology contains frameworks to select a third party agent to supervise relationships in virtual environments.
3. Proposed a framework for formalization and negotiation of service requirements. This framework enables two interacting parties to arrive at an agreement or create an SLA for their interaction in the trust maintenance phase. It involves activities such as both parties articulating the service requirements, negotiating on the service requirements, re-negotiating on certain service requirements, etc. The framework also presents guidance on how to construct an SLA based on the outcome of the negotiation process.
4. Proposed a framework for real-time, proactive continuous monitoring of service deliverability. This framework is used to proactively monitor the performance of both parties during the time space of interaction and to maintain the level of trust between the two parties.
5. Proposed a framework for providing an incentive mechanism to ensure the service delivery. This framework is used to motivate interacting parties to perform as closely as possible according to the terms of the mutual agreement.
6. Proposed a framework for trust re-calibration. This framework is used to re-calibrate the condition of the trust level of both interacting parties at the end of the interaction time space.
7. Validate the proposed methodology for proof of concept by simulation and experiments.

11.3 Contributions of This Thesis to the Existing Body of Literature

The major contribution of this thesis to the existing literature is that it proposes a complete methodology for maintaining trust in virtual environments. The complete solution for TMM encompasses five frameworks which form the major contribution of this thesis to the existing literature. The frameworks are as follows:

1. A framework for third party agent selection and a service business model proposal for an ASTM (Arbitration Service for Trust Maintenance) company.
2. A framework for formalization and negotiation of service requirements. This is a framework for formalizing service requirements, negotiation of any conflicting requirements, and SLA construction.
3. A framework for real-time, proactive continuous monitoring of service deliverability. It is a framework to proactively monitor the performance of both parties during the time space of interaction and to maintain the level of trust between the two parties.
4. A framework for providing an incentive to ensure the service delivery. This framework encourages better performance by an agent in order to deliver service as close as possible to the terms of the mutual agreement.

5. A framework for trust re-calibration. This is a framework that enables the trusting agent to calibrate its trust level in the trusted agent by the end of the interaction which occurs in the trust maintenance phase.

In addition to the abovementioned frameworks, this thesis proposes conceptual definitions of the notions of trust evolution, trust building, trust maintenance and trust decline in virtual environments. This thesis provides a comprehensive state-of-the-art survey of the various proposals in the existing literature for trust evolution and trust maintenance, which is an additional contribution of this thesis to the existing literature. Finally, a comprehensive validation of the proposed methodology was performed by conducting several simulations and experiments, the results of which are presented in this thesis. Additionally, in order to incorporate the dynamic nature of trust in a relationship, in simulation and experiments, we model the behaviour of agents as being both static and dynamic. Finally, we discussed how the sustainability of virtual communities can be achieved using our proposed methodology.

In this section, we provide a very brief overview of all the seven contributions made by this thesis to the existing literature.

11.3.1 Contribution 1: State of the Art Survey of Present Literature

In Chapter 2, we carried out an extensive survey of the existing research in trust evolution and strategies for maintaining trust. To the best of our knowledge, existing researchers who have presented studies on trust evolution (Jones and George 1998; Marcy and Skvoretz 1998; Currall and Epstein 2003; Vlaar, Bosch et al. 2007; Ybarra and Turk 2009) did not present details of the features and characteristics of trust and relationship at each stage or phase of the trust evolution process. Moreover, the literature survey carried out and presented in Chapter 2 of this thesis is the first of its type to focus comprehensively and in detail on the relationship characteristics and the trust level condition at each phase of trust evolution.

Moreover, we present the definition of each phase of the trust relationship which comprises: building, maintaining and declining. In addition, we carried out an extensive survey of the proposals in the existing literature regarding trust maintenance. As we discussed in Chapter 2, none of them proposes a complete methodology for maintaining trust in virtual environments.

For the purpose of discussion and evaluation, we divided the existing literature into three classes based on the research approach employed by a given proposal to maintain trust. The three categories under which we classified the existing literature are as follows:

1. Factors / Variables-based Approach
   The existing approaches are classified under this class if they present factors or variables that need to be considered in trust maintenance. Put simply, we placed proposals into this class if they suggested what could be done to maintain trust between entities.

2. Process-based Approach
   The existing approaches are grouped under this class if they present mechanisms or events or activities to maintain trust. For simplicity, we placed the existing proposals into this class if they addressed the issue of how to maintain trust between entities.
3. Hybrid-based Approach
   The existing literature is placed in this class if it provides a combination of factors-based and process-based approaches.

We grouped the proposals by various researchers according to one of the above three classes and reviewed them. On reviewing them, we found shortcomings with the current approach which set the scene for solving the research problems addressed in this thesis.

11.3.2 **Contribution 2: Definition of Related Concept in Trust Evolution Pattern**

As was mentioned previously, the existing literature does not provide a definition of trust evolution or a definition of each phase of trust evolution. Additionally, the existing literature fails to provide details about the characteristics and features of trust level and relationship condition between both trusting agent and trusted agent in each phase of the trust evolution process.

The second major contribution of this thesis is that it proposes a definition of trust evolution during a long-term interaction. The concept of trust evolution and its phases (building trust, maintaining trust and declining trust) were defined in Chapter 4. The various characteristics and features of the trust and relationship in each phase were explained clearly in Chapter 4. To the best of our knowledge, this thesis is the first attempt to provide a clear distinction between and definition of 'building trust' and 'maintaining trust'.

11.3.3 **Contribution 3: Framework for Third Party Agent Selection**

The third contribution of this thesis is that it proposes a framework for third party agent selection in virtual environments. The framework was discussed in Chapter 5. To the best of our knowledge, the existing literature does not discuss the role of a third party agent in such a relationship between trusting agent and trusted agent from the perspective of '*soft trust'*. Most of the discussions in the existing literature regarding the provision of a third party agent are from the perspective of hard trust. In this thesis, we consider the role of the third party agent from the perspective of soft trust. The difference between hard trust and soft trust was explained in detail in Chapter 1, Chapter 2 and Chapter 4.

Moreover, the third party agent that we proposed has a different role from that of the third party agent that has been widely discussed in the literature. Our proposed third party agent is a 'proactive-corrective' agent, whereas in the existing literature, the role of the third party agent is 'corrective' only. Hence, ours is a novel framework for choosing a third party agent in virtual environments. Additionally, we also propose a new service business model in the case of an agent intending to build a new service company which offers the services of a professional third party agent in virtual environments. Finally, we validate this framework by analyzing the effectiveness of the role of third party agent in relationship between two parties in maintaining the trust level.

11.3.4 Contribution 4: Framework for Formalization and Negotiation of Service Requirements

The fourth major contribution of this thesis is that it proposes a framework for the formalization and negotiation of service requirements to construct an SLA. This SLA would be used as the basis for trust monitoring and trust re-calibration at the end of the interaction. The framework was discussed in Chapter 6. To the best of our knowledge, the existing literature does not propose any framework for formalizing and negotiating service requirements in the trust maintenance phase. The salient features of this framework are as follows:

1. It presents a service formalization template by which both parties can articulate their service requirements in a structured way. This structured information will facilitate the negotiation process in order to reach a Service Level Agreement.
2. It presents a service description map (SDM) to enable both interacting parties to identify any conflicting requirements that they will address in the negotiation phase.
3. It proposes a method by which the interacting parties can negotiate and agree upon the service criteria which could be based on several previous interactions (interactions during the trust building phase).
4. It proposes a method by which the interacting parties can determine and articulate the service requirements to formalize the delivery of service criteria being agreed to during the interaction.
5. It provides a negotiation framework by which the interacting parties can negotiate any conflicting requirements.
6. It provides a method by which the interacting parties translate the service criteria agreement into an SLA.

11.3.5 Contribution 5: Framework for Proactive Continuous Performance Monitoring

The fifth major contribution of this thesis is that it proposes a framework for proactive continuous performance monitoring which was discussed in Chapter 7. To the best of our knowledge, the existing literature does not propose any framework for proactive continuous monitoring which takes into account the dynamic nature of trust, the dynamic nature of an agent's performance and the characteristic features of the trust maintenance phase. The salient features of this framework are as follows:

1. It presents a mechanism for determining the number of time slot(s) and checkpoints in an interaction. This number of time slot(s) and checkpoints are designed to review the performance of the trusted agent continuously and proactively.
2. It proposes a mechanism by which both the interacting parties and third party agent can gather the information regarding the performance of both interacting parties in real time.
3. It proposes a method for addressing the scenario in which there are performance gaps during the interaction.
4. It presents a mechanism for calculating intermediate trust value in an interaction.
5. It models the static and dynamic behaviour of agents in the community in delivering service as mutually agreed.
6. We validate the effectiveness of the framework by comparing transactions which use our framework for proactive continuous monitoring with transactions which do not use this framework

11.3.6 Contribution 6: Framework for Incentive Mechanism for Successful Service Delivery

The sixth major contribution of this thesis is that it proposes a framework for an incentive mechanism during the interaction in the trust maintenance phase. The details of the framework were discussed in Chapter 8. To the best of our knowledge, the existing literature does not propose incentive mechanisms for trust maintenance. We validate the three different incentive mechanisms by running several simulations in our engineered prototypes. We show the effectiveness of transactions which use our incentive mechanism framework compared with transactions which do not use this framework.

11.3.7 Contribution 7: Framework for Trust Re-calibration

The seventh major contribution of this thesis is that it proposes a framework for trust re-calibration at the end of the interaction. It is important to note here that the trust re-calibration is carried out at the end of the interaction. To the best of our knowledge, the existing literature does not propose any framework for trust re-calibration in interaction which occurs during the trust maintenance phase. The detailed framework was discussed in Chapter 9. The salient features of this framework are as follows:

1. The framework takes into account all the criteria involved in the interaction with the trusted agent, when calculating the intermediate trust and final trust value.
2. The framework takes into account whether a given criterion, based on which the trusting agent is going to assign a trustworthiness value to the trusted agent, has been mutually agreed to by the interacting partners.
3. The framework takes into account the importance of each criterion involved in the interaction between the trusting agent and the trusted agent.

4. The framework takes into account the static and dynamic behaviour of agents during the interaction.
5. The framework takes into account the incentive involved in proactive continuous performance monitoring.
6. It proposes three different approaches for trust re-calibration, each of which is unique and can be used for preferences bases.
7. In order to demonstrate the workability of this framework, we validate this framework by running several simulations under various conditions using our engineered prototype.

11.3.8 Contribution 8: Facilitating the Sustainability of Virtual Community

By using our TMM, in this thesis we additionally demonstrated how it can be used to promote the sustainability of a virtual community. Hence, the eighth major contribution of the thesis is that it proposes a framework for facilitating the creation of sustainability of a virtual community. It is important to note here that sustainability has been discussed widely in the existing literature. However, none of the works has considered the sustaining or maintaining of a trust value in interactions between members in the community as a factor that needs to be considered in order to sustain the community. The details of the framework were discussed in Chapter 10 along with the validation process of the framework. The salient features of this framework are as follows:

1. The framework is the first and only one of its type which is concerned with developing a sustainability measurement index as a means of capturing the sustainability of the virtual community. This is also the first work of its type to deal with the creation of sustainable virtual communities.
2. The framework assists administrators or organizers of a virtual community to identify untrustworthy agents. The presence of non-compliant agents in a virtual community can be seen as signal-to-noise that is very detrimental to the sustainability and growth of the virtual community.
3. The proposed framework shows how a virtual community can be sustained by means of using a third party agent to conduct proactive continuous performance monitoring of members' interactions.
4. In order to measure the overall sustainability of the virtual community, we propose a sustainability index or sustainability coefficient that represents the degree of sustainability of a virtual community and we validate the sustainability index by running several simulations under various parameters condition.

In Chapters 9 and 10, we demonstrated the effectiveness of our TMM by carrying out several simulations and experiments. We developed various benchmarks to measure the effectiveness of our methodology and conclude that our methodology is capable enough of maintaining trust between parties in virtual environments. Although in the existing literature, policies and strategies have been proposed for maintaining trust in a relationship, there is a lack of empirical validation. Additionally, our TMM is also valid enough for facilitating the creation of a sustainable community in virtual environments.

11.4 **Conclusion and Future Work**

The work that we have undertaken in this thesis has been published extensively as a part of proceedings in peer reviewed international conferences and international journals. We have attached list of selected publications including 4 (four) journal papers currently under review, 4 (four) international conference papers, and 3 (three) journal papers which are being written.

Although we have undertaken much research on the topic of this study, we feel that there is plenty of scope for further work. It is our intention to continue working on this topic, primarily along, but not limited to, the following lines:

1. Use ontology powered negotiation and formalization of service requirements in the trust maintenance phase. A domain driven negotiation ontology will be developed and would be leveraged during the negotiation and formalization process documented in this thesis. This would enable automated negotiation amongst agents and resolve conflicts (semantic in nature) during the negotiation process.
2. Leverage the developed service formalization and negotiation approach to automatically monitoring the performance progress based on the agreed SLA. We will make use of process mining techniques to achieve this.
3. Employ a Fuzzy-logic-based method for trust calculation and measurement which includes the measurement of intermediate trust value and final trust value. Currently, our trust calculation uses crisp data inputs (level of importance and clarity of criteria). In our future work, we intend to use fuzzy logic to deal with uncertainty and the tolerance of imprecise data inputs such as level of importance and clarity of criteria when measuring the intermediate trust and final trust.
4. Develop a methodology for trust dissolution. The methodology would enable a given trusting agent to produce a well-planned interaction dissolution without losing or decreasing the current trust level with its interacting partner. In our future work, we intend to make use of machine learning methods that would enable both the interacting parties to create a formal structure or plan to dissolve a trust based relationship. Such an approach for trust dissolution would result in a win-win solution for both the interacting parties when the parties no longer intend to continue their strategic interaction.
5. Develop a Sustainable Community index for dynamic behaviour in a virtual community. As a part of our future work, we intend to use the dynamic behaviour of members in a virtual community. Currently, in our simulation for creating a sustainable community, we considered the behaviour of members in the community to be static. Additionally, the behaviour of the trusted agent comprises only two types: a compliant or a non-compliant agent. This is unlike the validation to measure the effectiveness of our methodology by comparing initial trust and final trust, whereby the trusted agent can behave according to six classes of trustworthiness value. We intend to carry out further simulations and experiments in which members in the community behave according to six different classes of trustworthiness value.

6. Implement the methodology and framework proposed in this thesis in a virtual marketplace.

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Appendix – Selected Publications

Current Research Trends and Directions for Future Research in Trust Maintenance for Virtual Environments

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ABSTRACT

Trust is widely acknowledged as being important for the efficient and effective operation of business in virtual environments. This is because trust functions like a glue that holds and links virtual agents together as they relate and collaborate remotely. In virtual environments, trust needs to be established swiftly as there is little time to build it gradually in the absence of face-to-face meetings. However, the manner in which trust develops and is maintained is a critical factor in relationships, both physically and virtually. In virtual environments, trust needs to be managed including network connection as well as social aspects of interaction. Maintaining trust in virtual environments is defined as an effort to maximize the benefits of such virtual relationship and to prevent the level of trust from decreasing. In this paper, we undertake a general survey of the current situation of trust maintenance in virtual environments. We review several researches from the perspective of terminology, strategies presented, and types of strategies. We describe the benefits and shortcomings of each strategy, conduct an integrative review of these strategic approaches, and make suggestions for future research.

Categories and Subject Descriptors

E.m [**Miscellaneous**]: Trust

General Terms

Human Factors, Security.

Key Words

Trust Maintenance, Virtual Environments.

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1. INTRODUCTION

The emergence of virtual business denotes an important new type of business strategy [1]. In virtual business, physical location is not important, since network technology and the Internet are used to link members or companies across the world. It allows them to share information, resources and costs that enable them to compete on a world wide scale. Traditionally, a manager is linked to his subordinates through skill, authority and physical location. In virtual environments, companies are linked together on projects for which they may have no prior history, and that negate a manager's ability to provide his knowledge of the task at hand if he/she has never encountered it before. This type of company has many advantages over traditional ones, including the ability to bridge time and space, and better utilize distributed human resources without physical relocation of employees. The strengths of Information and Communication Technology (ICT) play a significant role in supporting business activities.

Kanawattanachai and Yoo [2] state that trust is one of the fundamental factors that drive the success and failure of virtual business. This is because trust functions like an adhesive that holds and links virtual agents together as they operate remotely from each other. However, virtual relationships lack a shared work history which, coupled with the absence of face-to-face communication, makes it harder for virtual agents to gather information and evaluate one another's behaviors. Trust is said to be one party's expectation of the other party's competence, goodwill and behavior [3]. However, this definition ignores the temporal and context-specific nature of trust. Chang et al. proposed a definition of trust which takes into account its temporal dimension [4]. They define trust as 'the belief the trusting agent has in the trusted agent's willingness and capability to deliver a mutually agreed service in a given context and in a given time slot, as expected by the trusting agent'. In a business context, both competencies in a given context and goodwill to deliver are required in order for trust to develop. Competencies such as technical capabilities, skills and knowledge are also required for building trust in a business exchange.

Moreover, Chang et al. state 'in a virtual environment, a trust relationship is established between two parties who normally have never met or may never meet and where communication takes place through a virtual interaction medium'. [4]. Kasper-Fuehrer et al. argue that trust is essential for the functioning and success of the virtual relationship because it acts as a substitute for two critical factors that exist in most traditional business interactions, but which are usually absent in virtual environments [5]. The first of these factors is an endogenous factor: the hierarchical control associated with traditional business. The second is exogenous: the legal framework needed to regulate the formation, operation and dissolution. Therefore, assessing and maintaining the trustworthiness in virtual environments need a different approach as neither party is familiar with the other. This trust has been termed a 'swift trust model', because of the lack of time to build trust gradually. It is assumed from the beginning and then either confirmed or dispelled throughout the duration of the project and both parties' interactions [6].

Trust has evolutionary phases both in physical and virtual environments [7, 8]. The pattern of this trust life cycle involves building, maintaining and destroying. In the first stage of a relationship, the trust level starts from a baseline of either trust or distrust. However, as the relationship progresses, we may find that the level of trust may either increase or decrease (relative to the initial trust level). The direction of the movement of trust value (increase / decrease) and the amount of increase/decrease is dependent on the capability and willingness of the other interacting party. With the passage of time, one may find that trust between two parties reaches a high level (which may be greater than positive trust). This is the optimum time to maintain the relationship between parties as neither party has taken any action that erodes the trust. If, however, trust-destroying occurs, then the level of trust drops quickly into the lower level or may enter the domain of distrust. A significant effort in this destroying stage needs to be made in order to return to just the initial, baseline trust. According to [9], trust in virtual environments appears to be fragile. Despite the fragility of trust in virtual environments, it is important to both build and maintain it..

In the field of virtual trust evolution research, most of the discussions focus on ways to produce and develop trust in virtual environments. Some models have been proposed for producing, developing and enhancing trust. However, in virtual environments, agents meet only occasionally, or not at all. This type of trust is known to be fragile; however, it is dispersed easily. Hence, it is more important to maintain trust than to build it in virtual environments [7]. Some studies also suggested the need for research into ways to maintain the trust level in virtual environments [4, 10] Therefore, in this paper, we briefly review some of the research work on trust maintenance in virtual environments. Additionally, we discuss some strategies on how to maintain trust in virtual environments and provide an integrative review of these strategies.

2. The Dynamic Nature of Trust

Trust is not static and automatic; it involves calculated risks and requires time to build [11]. The traditional models of trust explain the evolution of trust that is mainly built upon accumulated personal knowledge, while the swift trust in virtual environments explains the high levels of trust observed in situations where personal and history-based knowledge is not available [9]. Initial high trust is more robust when the parties have frequent face-to-face interaction. However, in virtual environments, agents have never previously met or worked together and have a limited time to work on completing a task. They do not have ways to engage in more traditional, enduring forms of confidence-building activities that contribute to the development and maintenance of trust. Lacking the traditional sources of trust – familiarity, shared experience and reciprocal disclosure, people are expected to demonstrate low levels of trusting behaviors; however, studies have found the existence of high levels of trust during such virtual interactions [12].

Studies of global virtual teams (GVTs) also have observed high initial trust among team members. According to the traditional view of trust evolution, limited trusting behaviors are expected in GVTs where members have no common past or future physical relationship, are culturally diverse and geographically dispersed, and communicate via various ICTs [9]. The traditional developmental view of the dynamic nature of trust assumes that trust resides in personal relationship. Past or future membership in common social networks would define the shared norms of obligation and responsibility. Rapid development of virtual trust is helped by role-based interaction (rather than person-based interaction), and by the greater use of category-driven information processing. With insufficient time to build proper expectations from prior interactions, agents in virtual environments tend to use expectations built on categories reflecting roles, cultural cues, or occupation and identity-based stereotypes [13].

Moreover, in co-located teams, agents have the opportunity to easily develop relationships. Face-to-face interactions in the physical location allow members to interact socially and get to know each other. They can discuss each other's work and their reactions can be expressed verbally or non-verbally. Both the social bonds and the professional respect leading to trust can be developed during these interactions. On the other hand, when they are dispersed, it is more difficult to create emotional bonds that can lead to trust based on assessment of benevolence [14]. Hence, in virtual environments, where many of the traditional ways in which humans establish bonds through physical contact and socializing are absent or at best limited, the importance of building and maintaining trust assumes pivotal importance [15]

Based on the review of the dynamic nature of virtual trust above, we argue that in virtual environments, the greatest attention should be given to the maintaining phase. Once positive trust has been established in such a relationship, it should be maintained to maximize the benefits of the relationship. However, there is no definition in the existing literature that differentiates between creating, building, developing and maintaining trust. Some models or practices presented in the literature use the terms building, developing and maintaining trust in virtual environments as synonyms.

3. Strategies for Maintain Trust in Virtual Environments

In the existing literature, there are many discussions on strategies for maintaining trust in virtual environments. However, they are more focused on building and establishing the level of trust than on the maintaining phase. In addition, most of the studies presented some good management practices and legal frameworks that can adopted by virtual business entities for building, establishing or maintaining trust in virtual environments [5, 9, 12, 13]. However, there is no clearly established difference between creating, building, developing and maintaining the level of trust. In the next section, we discuss some of the strategies for trust maintenance in virtual environments and conduct an integrative review based on our analysis of 12 articles (see table 1).

3.1 Effective Communication of Trustworthiness

Trust has traditionally been assumed to be based on a history of interactions, through which people come to 'know and trust' one another. However, in a virtual environment, agents meet only occasionally, or not at all. They interact through computer-mediated communication [9]. Therefore, communication of trustworthiness, which is predicated on appropriate use of ICT, has been emphasized by some scholars as a main strategy for building and maintaining trust in virtual environments. Communication of trustworthiness is defined as 'an interactive process that affects, monitors, and guides members' actions and attitudes in their interactions with one another, and that ultimately determines the level of trust that exists between them' [5]. Some authors make a distinction between effective communication to manage this virtual trust based on physical ICT components, and human ICT components.

3.1.1 Physical ICT Components

One characteristic of virtual environments is the lack of face-to-face meeting and physical relationship. Its communication system is mediated by technology such as instant messaging/IM, email, audio and videoconferencing, etc. Some studies say that this electronic linking in order to complete the production process and building trust depends on the good structure of information and communication technology that they used [16]. Adequate quality of communication technology is a requirement among team members to initiate and respond. Therefore, the physical quality of information technology is an enabler of trust in virtual environments [13]. An adequate infrastructure of technology becomes the most important factor to develop communication of trustworthiness and hence, it will develop trust among virtual agents. Moreover, Mezgar [17] argue that there are two approaches in building trust. One of them is the IT approach. In this approach, communication security has to increase by different architecture, protocols, certification, cryptography, authentication procedures and standard. Generating trust by this security service will increase confidentiality, integrity, authentication and identification. As virtual agents lack a social relationship for building trust, computer technology mediated communication has to be extended with more senses (such as touch, taste, smell). It needs to make use of more than just hearing and vision. These arguments show that strategic impact depends on virtual business entities being able to provide satisfactory ICT equipment.

3.1.2 Human ICT Components

This approach is based on the argument that technology does not do anything to improve effective trustworthiness communication in virtual environments without human intervention [9]. Human factor intervention is regarded as an important means of building effective and efficient communication. Mezgar [17] argues that the structure, the communication systems and the collaborating people/teams/organizations must be harmonized to accomplished complex and demanding tasks in virtual environments. Therefore, human habit communication plays a significant role in effective communication to build and maintain trust. Iacono and Weisband [16] suggest that the forming of good communication habits (e.g., checking and responding to email as demanded by task) is important to build active communication and consistent interaction in virtual environments. It becomes a foundation for cooperative and interdependent work in a virtual team. Moreover, Coppola [12] presents a study of trust development in online courses. It suggests that establishment of early communications is needed to perceive that the instructor is physically present among virtual class members. This situation will develop a positive social atmosphere to build trust in virtual environments. Moreover, the reinforcement of predictable patterns in communication and action will encourage the involvement of team members in task completion. In order to achieve this communication pattern, instructors need to motivate, encourage and require participation of virtual members to communicate often. Furthermore, Xiao and Wei offer some principles for trust construction and maintenance in virtual relationship [7]. One of them is the importance of repeated communication to restore trust among members. They argue that communication not only fosters trust development, but it can also re-establish the trust level in their relationship and avoid the existence of distrust.

Therefore, a virtual business network is characterized by face-to-face contact that is too costly or simply not possible. Trust is floating and sustained throughout the ability of communication between trusting parties. Effective communication by means of adequate ICT and communication behaviors of humans is one way of building and maintaining trust in virtual environments.

3.2 Relational Contract or Agreement on Norms and Procedures

Mezgar [17] and Greenberg et al. [14] state that in virtual environments, formal rules, procedures, clear reporting relationships and norms are absent as agents more extensively use informal computer mediated communication and they are distant from each other. However, some authors argue that virtual a business network should agree on the norms or procedures in their relationship in order to improve trustworthiness. Kashper-Fuehrer et al. offer two important factors for development of trust across virtual relationship. Common business understanding (production, cooperation and agreement) is needed to collaborate and achieve a common goal between virtual network members. This common business understanding can be achieved through negotiating a relational contract [5]. Secondly, a high standard of business ethics is also needed amongst virtual collaborators. These two factors will create a mutually agreed behavior or communication pattern in a virtual trust relationship. Even though agents may never or meet rarely, their behavior should be guided by stable normative form that is agreed upon between them.

In addition, Clases et a.l [13] argue that for the building, development and emergence of trust, virtual business entities need to create a culture of proactive collaboration that requires de-contextualized 'rules of the games'. Although their findings show that the clarity of this 'rules of games' has a weaker influence on the emergence of trust, personal-based and trust-based on de-contextualized rules support each other in building reliable relationships. Nevertheless, it seems that various roles need to be institutionalized to direct the collaboration and communication style of virtual agents.Nevertheless, it seems that various proponents of this view, Hung et al. [6] suggest one of the strategies that they offer for managing trust in computer mediated communication is to create well established rules and patterns of using various communication to increase the level of control. This is in order to address one of the characteristics of virtual environments which is the absence of vertical control, hierarchical authority and formalized procedures and policies [18], Javernpaa et al. explain the role of control actions in virtual environments. Control actions such as proactive and task output based, explicit time and process management, frequent and predicative communication will facilitate the development and maintenance of trust in virtual situations [19]. Hence, formalization of control action is an important factor to assist in trust maintenance in virtual environments. The most effective way of maintaining these trust attitudes in virtual environments is to create obligations amongst trusting parties.

3.3 Attention on Task and Group Life Cycle

Some authors argue that the characteristics of virtual business are similar to those of a temporary group setting [9, 16, 20]. Virtual temporary networks and electronic teams convert individual skills into interdependent work products in a short period of time while using computer-based communication technologies to coordinate their work. Members of a virtual network have no prior history of working together and little prospect of working together again in the future. As a result, a temporary virtual group must move forward quickly to accomplish its goal; members must act swiftly and need to work continuously and consistently to maintain expectations of trust [16]. Hence, some authors explore the communication behaviors to develop and maintain trust through the life cycle of a virtual team. A study by Javernpaa et al. [9] divided the communication behaviors and member actions that facilitate trust into early Group's life and later Group's life. Social communication such as communication of enthusiasm to build trust is needed in early group life. At this stage, coping with technical uncertainty and individual initiative from members will facilitate trust early in the group's life. While later in a group's life, positive leadership, predictable communications, substantial and timely response to crises are communication behaviors that maintain the level of trust.

Moreover, Greenberg et al. [14] propose actions from managers and team leaders for each life cycle virtual team stage on how to help members develop and sustain trust throughout the project to its successful completion. They divide the virtual team stage into five stages: establishing the team, inception, organizing, transition and accomplishing the task. In the first stage, choosing members, training and a clear reward structure are needed to build dispositional trust. In the second stage, the introduction of team members and team building exercises are needed to swiftly build and sustain trust. In the third stage, there is an evaluation of member participation and members are encouraged to participate in communicating in a virtual environment in order to change the form of trust from ability- and integrity-based to benevolence- and integrity-based. Moreover, in the fourth stage, transition, leaders and managers must always be available to support and guide members and move their focus from procedures to the accomplishment of the task. In the last stage, the type of trust is based more on benevolence and integrity. Leaders and managers need to encourage supportive communication among members in order to accomplish the task.

Both of those studies focus strongly on communication behavior among virtual agents in order to complete a common task within a finite life span. As they argue that a virtual team is similar to a temporary group setting, the type of trust in each task life cycle would be different. Consequently, they argue that the strategy used to manage trust between members and communication behavior would be different at each stage of the task and group life cycle.

3.4 Benefit and Shortcomings of Each Strategy

3.4.1 Effective Communication of Trustworthiness

Effective communication of trustworthiness is in fact a tool for building and maintaining trust in virtual environments. All of the studies note that efficient and repeated communication is needed to show the sign of trustworthiness between trusting parties. Because they interact in a virtual medium, the quality of ICT requires significant attention. Some authors pay more attention to the technology infrastructure [5, 17] while others focus on the human component [6, 9, 16]. Both of these components - physical quality and human behavior - are important and must be harmonized in creating, developing and maintaining a virtual trust relationship. However, we note that there is no discussion on how to provide feedback in virtual communication to show the level of trustworthiness. Feedback is known as an evaluative response to an action, process or event. We argue that performance feedback is a significant part of the communication process. They do not provide a clear explanation of how to give feedback or evaluations in virtual communication.

3.4.2 Relational Contract or Agreement on Norms and Procedures

Although a virtual business relationship is characterized by a lack of control and authority, some authors argue that a formal, legal framework is still needed to guide the interaction between trusting parties in virtual environments. This argument is reasonable, because the risk of opportunistic behaviour by trusting parties is a challenge to the success of virtual business relationship. However, there is no control design mechanism provided. Most of authors only provide a theoretical foundation on the need of control or legal framework in virtual relationship. The discussion on relational contract also ignores the importance of negotiation to discuss the contract or agreement between parties. As relationship in virtual environments is lack of central authority, hence, control form or legal framework must be negotiated by the trusting parties. Moreover, control approach that offered by [9] only with respect to problems within hierarchical relationship. In inter-organization virtual relationship such as joint venture, outsourcing relationship or value adding partnership (VAP), it is lack of hierarchical structure. Therefore, it needs to develop a negotiation mechanism about control forms that they will use.

3.4.3 Attention on Task and Group Life Cycle

Two authors are concerned with one of the characteristics of relationships in virtual environments that are similar to temporary work groups [9, 14]. Therefore, they provide a different mechanism for building and maintaining trust in each team's life cycle. If, however, the task is repeated many times, it should be not necessary to pay attention to each team life cycle. Hence, attention should be paid more to the dynamic nature of trust or trust life cycle in virtual environments.

4. Integrative Review and Suggestion for Future Research

In this section, we briefly discuss twelve articles for maintaining trust in virtual environments from the perspective of use of terms, strategic approaches offered and type of strategy. It is observed that most studies use the terms *building*, *developing*, and *maintaining* as synonyms of each other, which indicates that in the existing literature, there is much confusion between the terms 'trust formation', 'trust building', 'trust developing' and 'trust maintaining'. They do not distinguish between these activities. However, based on trust evolution theory, there are different phases and activities in the trust life cycle. Therefore, every stage or phase in trust evolution would have a different model or method of organizational practices.

In addition, most of works that have been undertaken by scholars as discussed above offered only some practices, policies and procedures to create, build, engender and maintain a trusting agent relationship in a virtual environment. Moreover, these practices and policies stand alone or run in isolation in virtual environments. Therefore, no complete methodology exists for maintaining trust in an organization. We define methodology as a sequence of steps that can be used by trusting parties to maintain their trust levels in such a relationship. Further research is needed to provide a complete and comprehensive methodology for maintaining trust in virtual environments.

We also note that there is a need to provide an independent third party in a virtual trust relationship. Two of the twelve articles provide the role of managers to develop and maintain this trusting relationship [9, 14]. We argued that a manager plays a role as a third party in virtual relationships between peers. However, there is still need to give attention to the important role of an independent third party in a trusting relationship between a trusting agent and a trusted agent. Firstly, effective communication in virtual environments is more task-performance-based than affective or emotion-based. Although there are many ways to develop emotion-based trust in computer mediated communication, it probably will not suffice to maintain task-competence-based trust in virtual environments. Because competence-based trust is derived from a calculative and rational process, the role of this third party is important. The third party needs to provide task-relevant background information or recommendations on trusting parties in virtual environments. It will make it easier for trusting parties to develop task-performance-based trust as well as emotion-based trust.

Secondly, members' interaction and communication in a virtual environment is computer mediated. The risk of conflict in this situation is higher than in a face-to-face relationship. This is because non-verbal cues are absent in virtual communication. Third party agents should focus on the maintenance as well as the building of trust in this situation. Consistent with the study of Kanawattanachai and Yoo [2], high performing virtual teams were able to maintain high levels of trust in their relationship until the end of the task. The role of the third party agent here is not only to develop trust between parties, but also to monitor the relationship between agents. In order to maintain the level of trust between agents in a virtual network, the third party must have various conflict management capabilities. This capacity is to alleviate conflict before it leads to the degradation of trust between trusted agent and trusting agent.

Thirdly, in virtual environments, agents are free to establish relationships with other agents. In a virtual network, there is no formal and hierarchical authority between trusting agents and trusted agent [20]. Hence, a network broker or integrator is needed to coordinate agents as the complexity of the task relationship increases [20]. We argue that this network broker has a role as an intelligence agent that has mutual trust with trusting parties, is independent and unbiased and therefore able to monitor the performance of a trust relationship. The role of this agent is to advocate or mediate or judge when conflicts or contract disagreements occur that could destroy existing trust levels. Furthermore, a mechanism is needed to determine who this third party will be, how this third party will be chosen, and how the trusting parties report their trust performance to the third party. Additionally, a mechanism is needed to enable a third party to gather information about the performance of the trusted agent and the trusting agent in order to maintain their levels of trust.

5. Conclusion

In this paper, we undertake a brief review of twelve articles on how to produce, build, develop, enhance and maintain trust in business environments, particularly in virtual environments. We conclude and summarized that three strategic approaches have been widely used by scholars to manage the levels of trust in virtual environments. We review these researches based on the use of terms, strategic approach offered, and type of strategy. We describe some of the benefits and shortcomings of each approach, conduct an integrative review of those approaches, and suggest directions for future research. As we can see, a substantial amount of work has been done on trust maintenance but the concept of trust maintenance itself is not properly defined. Additionally, there are some existing strategies for maintaining trust in virtual environments. However, there is no comprehensive and coherent methodology for maintaining trust in virtual environments.

Table 1. Strategies for Maintaining Trust in Virtual Environments

No	Author (s)	Use of term (s)	Strategic Approach	Dimensions of Strategy		
				Practices	Policies	Methodology
1.	[16]	Produce and maintain trust	Active communication and consistent interaction among team members	v	x	x
2.	[19]	Reinforce trust	Proactive behavior, empathetic task communication, positive tone, rotating team leadership, task goal clarity, role division, time management, frequent interaction with acknowledged and detailed responses to prior messages	v	v	x
3.	[9]	Develop and maintain trust	Different communication style in each group life cycle	v	x	x
4.	[5]	Building, developing, establishing and maintaining trust	- Effective Communication - Appropriate use of ICT both on physical component and human component	v	x	x
5.	[13]	Building, developing, and emergence trust	- Agreement of contract by decontextualized rules of the games	v	v	x
6.	[12]	Building and developing trust	- Effective Communication of trustworthiness	v	x	x
7.	[6]	Managing trust	- Effective Communication - Establish rules and patterns of communication	v	v	x
8.	[17]	Building and maintaining trust	- Effective Communication with attention on IT approach and human approach	v	v	x
9.	[22]	Bettering and maintaining trust	Clear definition of objectives, the emphasis in internal communication, the manager as a role model, the worthiness of the people	v	v	x
10.	[18]	Build, develop and maintain trust	- Effective Communication - Sharing values and goals	v	x	x
11.	[14]	Develop and sustain trust	- Different communication style in each team life cycle	v	x	x
12.	[7]	Construction and management of trust	- Effective Communication - Share mutually-valuable information	v	v	x

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State of the art Review for Trust Maintenance in Organizations

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Abstract— **The nature of trust in business relationships is dynamic rather than static. Trust has evolutionary phases or a life cycle. This pattern of evolution can be described as building, maintaining and destroying. Building trust comes at high cost and hard effort. Therefore, once trust has been established in a business relationship, every effort must be made to maintain it. Maintaining trust can be defined as an effort to maximize the benefits of a relationship and to prevent the level of trust from decreasing to the destroying phase. Grounded in state-of-the-art literature, this paper presents current insights for the research into trust maintenance and suggests directions for future research in this field.**

Keywords: Trust maintenance

I. Introduction

Trust research has increasingly attracted growing interest from academics and practitioners, due to its importance and due to the increasing number of business relationship such as strategic alliances, joint ventures, outsourcing relationships and other forms of inter-organizational and intra-organizational exchange [1-3]. However, trust has evolutionary phases. This pattern of a trust life cycle can be described as building, maintaining and destroying [4]. Initially in a relationship, both parties (trusted agent and trusting agent) enter that relationship with activities that establish a level of trust. At this stage, the trust level is zero because the interacting parties lack information about each other. As this relationship proceeds over time, if trust building actions are acceptable, the overall level of trust will remain constant with some minor variations. Both parties then should agree to maintain their level of trust. If, however, they do not agree to maintain the level of trust, the trust will be destroyed. Therefore, the level of trust rapidly decreases to a lower level or may even enter the domain of distrust. In this paper, we offer a brief review of existing researches regarding trust maintenance.

Trust is said to be one party's expectation of the other party's competence, goodwill and behavior [5]. However, this definition ignores the temporal and context-specific nature of trust. Chang et al. proposed a definition of trust, which takes into account its temporal dimension [6]. They define trust as 'the belief the trusting agent has in the trusted agent's willingness and capability to deliver a mutually agreed service in a given context and in a given time slot, as expected by the trusting agent'. This definition considers the nature of trust as being dynamic rather than static. In a business context, competencies in a given context, as well as goodwill to deliver, are required in order for trust to develop. Competencies such as technical capabilities, skills and knowledge are also required for building trust in the professional setting of business exchange. Following an evolutionary process, the more we observe of these three characteristics in other parties, the more likely is our level of trust to increase or decrease. Hence, the level of trust will evolve as the parties interact and are driven by the factors mentioned above.

In the field of trust evolution research, most of the discussion focuses on ways to build and develop trust in such relationships. Some good management practices and policies have been proposed for building and developing trust. However, trust building is a gradual and incremental process. It can be easily and quickly destroyed by a single negative behavior or trustworthiness inconsistencies [4, 7]. Despite the fragility of trust, companies must carefully consider how they can better build and maintain trust to improve long-term business performance. Therefore, another objective in this paper is to discuss some theoretical approaches on how to maintain trust. In addition, we briefly review several approaches to maintaining trust.

II. The Life Cycle of Trust

The ways in which trust develops and is maintained have been recognized as critical factors in human relationships [8]. Trust will evolve and change over time in relationships as knowledge and information about other parties' trustworthiness also evolve in those relationships. Some studies have described this evolutionary pattern. For instance, Curral and Epstein divide the trust evolution pattern into three phases: developing, maintaining and

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destroying [4]. This evolutionary process is shown in fig. 1.

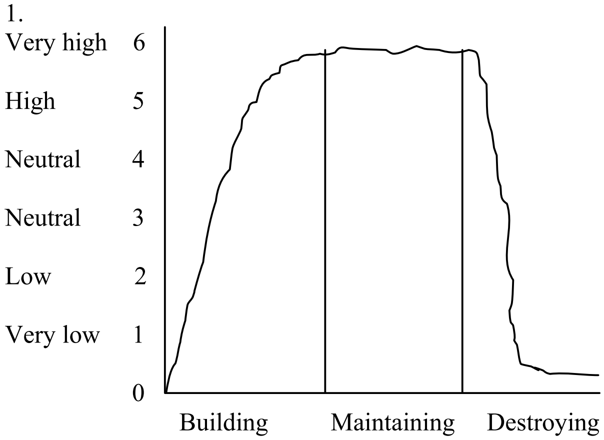

Figure 1. The pattern of trust life cycle

In the first stage of a relationship, the trust level starts from a baseline, as either trust or distrust. As the relationship proceeds over time, the trust level may increase and remain at a certain level depending upon the information and knowledge of other trustworthiness. The trust cycle then enters the maintenance stage. This stage is a very beneficial period during which the relationship between the parties is maintained, as long as neither party takes any action that will destroy the relationship. If, however, the trust level is not well maintained, the level of trust may drop quickly into the lower level or may enter the domain of distrust.

In addition, Rousseau et al. propose that in such relationships, trust changes over time [9]. Research into organizations as well as broader society indicates that a distinct pathway exists in relationships going from developing, building, declining and even resurfacing in long-standing relationships Therefore, trust is a dynamic rather than a static process, as a business relationship can also be considered as a dynamic social system.

Based on trust evolution and trust level changes over time in business relationships, Curral and Epstein argue that the most attention should be given to the maintenance phase [4]. Although the constituents may vary, trust determines the performance of most industries. Members of organizations may come and go, leaders may change, but the determinants of trust, the decision to trust and the level of trustworthiness are applicable across companies. They contend that once trust has been built, parties may actively reject evidence that the other party whom they trust is actually untrustworthy. However, this situation may make trust decrease rapidly to a lower level or even to distrust. Furthermore, they suggest that despite the fragility of organizational trust, managers must think in a systematic manner about what they can do to cultivate and maintain trust with and among the various elements in their industry and company [4].

III. CURRENT RESEARCH ON TRUST MAINTENANCE

Trust maintenance can be defined as an effort to keep the level of trust in a relationship stable, or even to increase it to a higher level. The existing research in trust management focuses more on building and developing the level of trust than on maintenance. Most studies offer some management practices and policies that can adopted by organizations to build and develop trust relationship either between organizations or within an organization [10-12]. However, they sometimes treat the terms 'trust formation', 'trust building', 'trust developing' and 'trust maintaining' as if these were synonymous [10, 13-15]. Therefore, much confusion exists in the current literature regarding the definitions of these terms.

In addition, there are many organizational theories that are used by scholars when suggesting good management practices for developing and maintaining trust. This theoretical approach is often the basis for methods or models of ways to build and maintain trust. In the next section, we discuss some aspects of this approach based on our review of thirteen articles (Table 1).

A. Relational Signalling Theory Approach

Relational signals play a crucial role in trust building. This theory states that in such a relationship between trustor and trustee, both parties learn about each others' trustworthiness based on behavior signals that they deliver. A trustor looks for two things in the behavior and intention of the trustee in order to discover whether the trustee is interested in maintaining the relationship. Firstly, the trustor perceives whether the behavior indicates competence to perform according to expectation (dimension of ability in trustworthiness). Secondly, a trustor looks for signs of whether the behavior of the trustee indicates an interest in maintaining the relationship in the future (intentions dimension). We call these signs as relational signals. Relational signals are 'behavioral cues that allow us to make inferences about other people's interest in maintaining a mutually rewarding social or work relationship with us' [11].

There are two forms of relational signals: positive signal and negative signal. A positive relational signal is any behavior that reassures another party (e.g. trustor) and is perceived by the second individual (e.g. trustee) as a clue that the other party wants to maintain a mutually trusting relationship. On the other hand, a negative relational signal is any behavior which makes another individual feel uncomfortable, judging others' behavior as a clue that the other party does not want to maintain a mutually benefit relationship.

This theory is based on two basic assumptions about a reciprocal process in which both parties are involved interactively in building trust [11]. Firstly, human behavior is goal-directed and any effort which explains social phenomena must consider the goals of the individual. This rationale is strongly bounded by the fact that the various potential goals are not all given equal consideration. Secondly, human behavior is context-dependent and guided by the normative context in which the individual is embedded. This theoretical approach has been used by Dirks [13], Six [11] and Six and George [10] to offer a model for building and maintaining organizational trust.

Dirks [13] proposed a two qualitatively-relational signal in a different theoretical perspective for building trust in a leader. This model comprises two practices and policies from a relationship-based perspective and a character-based perspective. A relational-based perspective focuses on the nature of a leader-follower relationship and more precisely, on how the follower understands the nature of the relationship. This model deals with employee willingness to reciprocate care and consideration which a leader expresses in a relationship. On the other hand, the character-based perspective focuses on the perception of a leader's character and how it impacts on a follower's vulnerability in a hierarchical relationship. This perspective is concerned with the importance of the leader's character. The leader may have the authority to make decisions that have a significant impact on a follower's ability to achieve his or her goals.

From both of these two perspectives, trust in the leader – subordinate relationship is a psychological state experienced by both parties (leader and follower) and involves confident positive expectations about the behavior and intentions of both parties. Dirks' model [13] emphasizes that organizations must encourage leaders to show behaviors that are perceived as being trustworthy by their subordinates in some way through actions such as encouraging participative decision making and open communication, and attempting to understand individuals' explanations of the cause of events and individual perception and judgment about others.

Six [11] proposed some organizational policies for building trust based from the relational signaling perspective. Six argues that in building trust, the actions of involved parties should be guided by a stable normative frame that meets four conditions. These conditions are: suspension of all opportunistic behaviors, exchange of positive relational signals, avoidance of negative relational signals, and stimulation of frame resonance. This normative frame is suitable for building trust in a leader – subordinate relationship. The reciprocal action of exchanging positive relational signals and avoiding negative relational signals is important in order to maintain the trust level in a relationship.

Moreover, Six and Sorge [10] also used the relational signaling perspective to build a model that contains practices and policies to build, maintain and enhance trust in a leader – subordinate, and co-worker relationship. This model is a combination of four inductive activities. If an organization wants to build and maintain the level of trust among organization members, the creation of a relationship culture, facilitation of relational signaling, explicit socialization for new members and a mechanism for managing professional competencies are types of organizational policies that can be adopted by various organizations.

B. Social Exchange Approach

The social exchange approach is widely used by some scholars to develop a model for building and maintaining trust in relationships. In this approach, both parties engage in 'exchange' relationships because they expect that they will derive some benefit(s) from doing so. This involves accepting some degree of vulnerability in the hope of gaining some benefit at the discretion of another person. In a leader and co-worker relationship, perceiving other organization members to be trustworthy increases the likelihood that the trustor will engage in an exchange relationship. Presumably, individuals should be able to complete their job responsibilities more effectively when they receive valued information, knowledge, resources and so on from their leader or co-worker. Moreover, individuals who are perceived as being more trustworthy have the potential to receive more task-performance related resources from others than do individuals who are perceived to be less trustworthy. Therefore, the former will gain a performance advantage.

In addition, exchange theory explains how past behaviors in the relationship are used to diagnose trustworthiness in future exchanges. This social process-based theory also proposes that trust will develop through interaction between two parties. Hence, as trust maintenance is an activity that involves an agreement between two parties in order to maintain their trust level in a future relationship, this approach is one way of maintaining trust.

Whitener proposed an exchange framework of initiating managerial trustworthy behavior [17]. This framework consists of organizational factors, relational factors and individual factors that influence any effort to initiate trust in leaders. Some organizational strategies used to build trust in management include the establishment of an organizational structure, organizational culture and Human Resource policies and practices. The relational factors which develop from social exchange theory and relational signaling theory include such things as initial interactions, expectations, and cost of exchange; whereas individual factors that influence initiating trust in leaders are propensity to trust, self efficacy and personal values. The focus of this framework is the identification of factors that affect trustworthy behavior. Some Human Resource practices and policies in organizations such as training, reward, control and performance appraisal, may facilitate building trust in leaders or trust in higher level management.

C. Organizational Justice Theory

The concept of organizational justice for maintaining organizational trust is based on the perception of fairness. Fairness and honesty are perceived by other parties as being components of trustworthiness. Three of the most commonly studied facets of organizational justice include distributive, procedural and interactional justice. Distributive justice is defined as the perceived fairness of outcomes received; procedural justice is the fairness of a company's policies and procedures used to determine one's outcomes; and interactional justice is the manner in which the reasons behind the outcome are explained. Interactional justice refers to the quality of interpersonal processes and treatment of individuals as well as the extent to which the reasons behind the outcome are explained [18].

Ferres, Connel et al [2] provide three theories as a basis of organizational practices and policies to determine trust in leaders. These theories relate to organizational support, procedural justice and transformational leadership. The authors conclude that leaders can influence trust in their relationships with subordinates in a number of ways. These include the adoption of a transformational leadership orientation, by ensuring procedural justice and supporting employees at every organizational level. Moreover, they also indicate that the formation of trust in leaders goes beyond an employee's general preference when trusting others. Managers can significantly engender trust in their relationships with subordinates in a number of ways. These include practicing transformational leadership and ensuring the adoption of practices that are both supportive and fair.

Furthermore, the empirical research conducted by Forret and Love strongly supports the notion that perceptions about distributive, procedural and interactional justice correlate to perception of co-workers [18]. The distribution of rewards, organizational policies and procedures, and interpersonal treatment by supervisors are important and relate to co-worker trust. Therefore, the authors suggest that leaders in an organization need to enhance the perception of distributive, procedural and interactional justice in the workplace if they want to build and establish trust within a leader – follower relationship.

D. Institutional Theory Approach

Institutional theory states that organizational structure, policies and control mechanisms should be legalized and legitimized in order to foster trust through the perception of individual and institutional legitimacy. Managers use organizational clues to establish or maintain the legitimacy of their actions and consequently to be seen as trustworthy individuals. Institutional theorists have shown numerous ways in which adherence to widely shared beliefs, widely accepted norms, formal rules and procedures can enhance trust. The driving force behind these methods can be explained most succinctly as 'the logic of appropriateness'. When managers wish to preserve or enhance trust in themselves or their institution, they often attempt to influence perceived choice appropriateness, which is judged not merely on contextual criteria of technical effectiveness, but also on what is expected and viewed as legitimate in a particular context.

In [19], the focus is on structural isomorphism or the use of standardized structure, procedures and actions as indicators of trust building, legitimacy-driven behavior. In a leader-subordinate relationship, the leader as a decision maker can institutionalize their decision in order to build trustworthiness. They argue that control as a legitimate power from a leader must be legitimized and institutionalized in order to enhance trust.

In addition, Dwyer and Beauvais [15] propose some principles based on institutional theory that can be used by organizations to build, enhance and maintain trust in a leader – follower relationship. They argue that, although trust is complex both in its composition and in terms of the number of bases on which is rests, the following principles when institutionalized within an organization would enable the organization to enhance levels of both trust and organizational success. The authors then conclude that building and maintaining trust within an organization is not a simple or rapid process. It requires a commitment to creating and sustaining a culture that is focused and respectful of employees. Unlike organizations that only talk about values, organizations that institutionalize the value or principles of trust will build trust in process and promote trust as an important element in the building of a successful organization.

Pucetaite and Lamsa [12] also argue that the development of trust within an organization can be stimulated by raising the level of work ethic through organizational practice. They explain that work ethics are moral principles, norms and rules that guide a person's behavior at work. Moreover, work ethics play a role as principles, particularly regarding compliance with quality standards, self-discipline and commitment to professional norms and the job itself. Accordingly, the idea of enhancing work ethics, as a consequence of management practices that are institutionalized and legitimized by an organization, is a particularly interesting means of developing trust.

E. Control Theory Approach

This approach suggests that managers who build trust often reduce the time and effort needed to measure and monitor the work of their employees, while enhancing the quality of their subordinate's contributions and their capacity to achieve organizational objectives. This control theory is based on the notion that managers integrate their trust-based and control-based actions in ways they think appropriate for specific situations. This theory also argues that managers should actively concern themselves with promoting organizational trust by combining with task control activities that are appropriate for the task and relational context, thereby ensuring that organizational goals are accomplished and positive superior – subordinate relationships are developed and maintained. Moreover, in order to address the dynamic nature of relational and institutional arrangements, managers must balance the mix of trust and control in their organization if they want to achieve organizational goals and cultivate positive social relationships.

TABLE 1. THEORETICAL APPROACHES IN TRUST MAINTENANCE RESEARCH

No.	Author (s)	Use of term (s)	Theoretical Approach	Dimensions of Model for Trust Maintenance			Type of Relationship
				Practices	Policies	Methodology	
1.	[10]	Building, Maintaining Enhancing	Relational Signaling Theory (RST)	v	v	x	Leader – subordinate, and Co-worker
2.	[12]	Developing	Social Exchange Theory	v	x	x	Leader – subordinate, and Co-worker
3.	[14]	Building Maintaining		v	x	x	Co-worker Relationship
4.	[11]	Building	RST	x	v	x	Leader – Subordinate
5.	[18]	Enhancing	Organizational Justice Theory	x	v	x	Leader – Subordinate, and Co-worker Relationship
6.	[15]	Building Enhancing Maintaining	Institutional Theory	x	v	x	Leader – subordinate Relationship
7.	[21]	Developing Trust	Procedural Approach	v	x	x	Co-worker Relationship
8.	[20]	Building Trust	Control Theory	v	x	x	Leader – Subordinate Relationship
9.	[13]	Building Maintaining	RST in Leadership	x	x	x	Leader – Subordinate Relationship
10.	[19]	Building Trust	Institutional and Control Theory	v	v	x	Leader – Subordinate, and Co-worker Relationship
11.	[2]	Engendering	Relational Theory	v	v	x	Manager-Subordinate
12.	[22]	Building and Developing	Social Exchange Theory (SET)	v	x	x	Team work based Relationship
13.	[16]	Developing	SET	v	x	x	Leader – Subordinate

Furthermore, Long and Sitkin [20] examine the ways by which managers balance their interpersonal trust-building and control-based efforts in order to maintain trust in subordinates. Their study focuses on describing task controls which range from formal mechanisms (written contracts, monetary incentives and surveillance), to informal mechanisms (values, norms and beliefs). Managers can use these mechanisms to direct subordinates toward the efficient completion of organizational tasks. There are various control applications for directing subordinate tasks: input controls, process controls and output controls. The purpose of input controls is to acquire a high quality employee through training and socialization to guide the selection and preparation of human and material production process. Process controls are a means of controlling subordinates' performance of tasks to ensure that they follow prescribed task production methods. Output controls measure the employees' outputs (or productivity) against established metrics to ensure that prescribed performance standards are met.

IV. INTEGRATIVE REVIEW AND DIRECTIONS FOR FUTURE RESEARCH

In this section, we briefly discuss research in trust maintenance from the perspective of terminology used, theoretical approach, model offered, and type of relationship (table 1). It is observed that most studies use terms such as 'building', 'developing', and 'maintaining' synonymously. They do not distinguish between these activities. However, based on trust evolution theory, there are different phases and activities in the life cycle of organizational trust. Therefore, every stage or phase in trust evolution should have a different model or method.

In addition, there is no theoretical approach that specifically addresses ways to maintain the level of trust. Those theoretical approaches have argued can be use in the same way on to create, build, engender and maintain leader-subordinate trusting relationship. Further, the most commonly-used theoretical approach is a basic model concerned with maintaining trust based on the completion of organizational tasks. The Social Exchange and Relational Signaling theory approach is concerned with the vulnerability and reciprocity of both parties when sharing valuable resources in order to accomplish a task. Institutional theory focuses on the importance of institutionalized and legalized work ethics and the procedures and norms to be followed when undertaking organizational tasks. Control theory is concerned with measuring and controlling input, process and output of work performance. However, these theoretical approaches work separately as a basis for maintaining organizational trust, specifically in a work relationship. Further research is needed to provide a complete and comprehensive methodology for trust maintenance. We define methodology as a sequence of steps that can be used by trusting parties to maintain their trust levels in a relationship.

We argue that future research into a methodology to maintain trust should incorporate some of these theoretical approaches in an integrative framework. We also note some basic assumptions for trust maintenance activities that may be derived from these theoretical approaches. Firstly, both parties (trusting agent and trusted agent) are vulnerable to reciprocal action. This assumption concurs with the social exchange approach to maintain trust. In social exchange theory, both parties that are involved in a relationship are able to share valuable resources in order to achieve a mutually rewarding goal. The second assumption is that both parties agree to and demonstrate cooperative behavior in order to maintain their level of trust. This assumption correlates with the relational quality approach for maintaining trust in a relationship. The relational quality approach is one whereby parties exchange a positive signal to maintain the relationship and avoid a negative signal that can destroy a trusting relationship. The third assumption is that the level of trust has been reached to a positive high level. Once trust has been established and is at a positive level, it needs to be maintained at that level. When the level of trust is still fairly low or neutral, it needs to be developed or enhanced to a higher level.

V. CONCLUSION

In this paper, we have presented a brief review in the field of trust maintenance research. We considered and summarized, from the existing literature, five theoretical approaches for maintaining trust. We reviewed these researches based on the terminology used, theoretical approach, model offered, and type of work relationship described. Evidently, substantial work has been done on trust maintenance, but the concept of trust maintenance itself has not been properly defined. Additionally, there are some existing good management practices and policies or principles for maintaining trust in an organizational setting. However, there is as yet no comprehensive and coherent methodology for trust maintenance.

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A Framework for Creating a Sustainable Community in Virtual Environments

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ABSTRACT

There is much interest in using the virtual community as a business medium to establish a relationship between customer and stakeholders. While studies on virtual communities have widely discussed ways to sustain this community, there is the need for a complete framework or methodology to regulate members' interactions so as to produce sustainability. In order to achieve this sustainability, it is important to consider the existing trust relationship between community members and ways to identify an untrustworthy agent in a community. In this paper, we propose a framework for creating a sustainable community in Virtual Environments. The role of a third party agent and the effectiveness of continuous performance monitoring are the main keys to creating a sustainable virtual community. We also present the results of an experimental study. The study shows that the framework will help the administrator to identify all non-compliant agents after a transaction or interactions.

Categories and Subject Descriptors

E.m [Miscellaneous]: Trust, H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces – Web-based interaction.

General Terms

Algorithms, Management, Measurement, Performance, Reliability and Security.

Keywords

Sustainable Virtual Community, Trust

1. INTRODUCTION

The rapid growth of virtual communities on the Internet raises the question of what encourages members to join and interact within this community. There is an enormous amount of literature discussing the benefits of virtual communities and social networks. These encourage knowledge sharing [1], provide social space and a social network [2], create co-product innovation based on customer feedback [3], and provide a vast pool of experts able to discuss any ideas virtually [4]. From the business perspective, the new digital economy has resulted in many more virtual communities in business ecosystems. Businesses are encouraged to establish communities in order to foster relationships with their customers and stakeholders [3]. Understanding virtual communities can provide valuable information about the digital economy. Both the knowledge base of the community and the members themselves can be extremely valuable to companies. The knowledge base which is usually publicly available in the form of the community's conversation provides insight into the members' likes, dislikes, demographics, behaviors, and concerns. Members often critique products and services, and thus, organizations can conduct market research by reading the conversation. Although there are many research discussions on the benefits of a virtual community, little research has addressed ways to sustain this community.

The sustainability of a virtual community depends on the behavior of the community members, in this case, their responsiveness and confiding behavior in such interaction. In order that communities be successful and sustainable, there must be trustworthy behavior amongst members. Trust as a socially acceptable behavior is important for the continuity of the community in virtual environments where the workable rules are absent. This is especially noteworthy for virtual communities because research has shown that people in traditional communities work better with those whom they trust, while actively avoiding contact with those they do not trust [5]. Ridings [6] also argued that trust is a significant predictor of virtual community members' desire to exchange information, and especially to obtain information. People access virtual communities to exchange information – either by providing it to others or by soliciting it from others. This exchange is based upon the trust level that members have in each other, and without trust, there would no exchange and the virtual community would cease to exist.

Virtual communities are typically emergent, that is, they arise as a natural consequence of people coming together to discuss a common hobby, mutual interest, personal experience, or even to develop a relationship. These relationships are usually established informally without any involvement of a specific organization. The members of communities are typically strangers to one another. In the virtual community, trust develops between an individual and the group of strangers in his/her community, eventually providing a positive outcome for the community as a whole. Repeated interaction with others and

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the open public reply and discussion of any messages may also enable trust to evolve. However, untrustworthy behavior may be widespread in a virtual community where malicious members might behave dishonestly or inconsistently. For example, some members might flame or ridicule posts or provide members' email addresses to external organizations without permission. Untrustworthy behavior and non-compliant agents are usually considered undesirable in any community. However, there is always a certain probability that an agent is malicious due to opportunistic behavior. The management of this behavior is a difficult task in Virtual Environments where physical social controls are not available. Nevertheless, trust has been acknowledged as a tool which can reduce risk and opportunistic behavior in virtual environments [7].

Therefore, a Virtual Community which wishes to remain viable should have a mechanism for sustaining the community's member interaction and for supporting the formation of a sustainable virtual community. A sustainable virtual community can be created by: (1) providing norms and procedures of interaction for the community's survival; (2) identifying and isolating malicious agents in the community; and (3) accepting a new member based on his/her reputation in conducting interactions. In this research, we propose a framework that can be used to monitor members' interactions within a community. This framework can be utilized to identify any malicious or untrustworthy agents in a community. The other purpose of this mechanism is to protect the community from anyone in the community who demonstrates non-compliant behavior.

Additionally, a Virtual Community should have ways of identifying early signs of malicious agents' behavior and in turn removing or isolating them from the community. The signs of non-compliant behavior can be gathered by outlining the performance reputation of agents in such interaction. The proposed framework in this research provides a mechanism for monitoring community behavior in carrying out an interaction with other agents (i.e. by keeping track of members' performance). By continuously monitoring their performance, the performance monitoring report can show the pattern of the agent's behavior and determines whether an agent is trustworthy or untrustworthy.

The rest of this paper is organized as follows: Section 2 outlines the background and related work on the model of sustainability of a virtual community. Section 3 describes the proposed framework for interaction between community members. Section 4 shows the experimental results. The conclusion and proposed future work are presented in Section 5.

2. BACKGROUND AND RELATED WORK

Abdul-Rahman et al. [8] argued that virtual communities are as real as communities that meet physically or whose members exist in close or convenient proximity. Some researchers argue that Virtual Communities in e-Commerce have a life cycle and it is usually short, even though it hopes to be longer [9-11]. However, only a scant amount of literature focuses on how this longer life can be achieved. The life cycle of Business Ecosystems is explained through a number of stages: birth, expansion, leadership and self-renewal [11]. If the last stage, self-renewal, does not occur, the community disappears.

Moreover, Venkantesh [9] described a pattern of origin, stabilization and change that is embedded in the life cycle of the virtual network. The first stage is origin. In this stage, the network is created based on the members' mutual interest. With the passage of time, members have a greater awareness of assets and resources of their community and start to demonstrate a willingness and capability to exchange. At some point in time after its origin, a community network may become more stable. At this time, the community should become well organized. This can be achieved in several ways. This can be done, firstly, by institutionalizing the relationship between community members. Secondly, it can be achieved through better interaction regarding service delivery. However, after some institutionalization and formalization of interactions' rule amongst members, the community may face a change cycle. This is because the virtual interaction may not be adequate, or members perceive that the community has become formal and strict in its interactions.

It is clear from the discussion above that the existence of virtual communities depends on the amount of effort put in by the administrator or users in this regard. Thus, research is needed to identify the factors that contribute to the sustainability of virtual communities.

Wagner et al. [4] defined sustainability as a demonstration of the growth rate and members' renewal over a certain period. The growth rate is determined not only by the size of readership in online communities such as wiki, but also by the sustained contribution from other users which feeds the community and gives it life. On the other hand, Porra and Porks [12] explained that Virtual Community sustainability has an intrinsic longevity over very long time periods (i.e. over generations). The larger the user membership of a virtual community, the greater is its sustainability. However, Koh et al. [13] argued that the most important factor for the sustainability of a virtual community is the degree of member participation. The most basic activity in social virtual communities is the exchange of information between requester and provider. We argue that this information exchange should occur in a trustworthy manner in both providing information and requesting information. The higher the quality of information that is exchanged between users in a virtual community, the more likely it will be that this community can be sustained. This is because members of this community derive positive benefits from consuming good quality information.

Porra & Parks [12] introduced a systematic model of Virtual Communities Sustainability based on the colonial system model. This model suggested that humanness, ideals and the ability to acquire new members by creating stability within current generation and radical change over generations, determines the sustainability of a virtual community. This model also recommended that effective interaction mechanisms and a high degree of awareness to maintain the community humanness is important to create a sustainable virtual community. Due to the nature of the relationship and interaction in virtual environments where face-to-face meetings do not occur, three necessary components of a sub-community are: persistent people, continuous support by an online space, and flexibility. All of these will promote the growth of the sub-community. Wagner et al. [4] explored the key success factors for a sustainable professional community. By analyzing Slashdot, a highly popular online community, they found five criteria that make Slashdot special and viable. These criteria are: (1) Good content of information exchange that occurs in online discussion. This is measured by news provided and the discussion among participants that encourages users to derive a positive gain from the interaction; (2) Good support of technology quality that enables community members to easily link up with other members; (3) Discussion engine or software that is fair, trustworthy, and quality enhancing; (4) Active participation from members in taking and giving information; and (5) the longevity of members in the community. The longer that members have been part of a community, the more sustainable is this community. However, these findings fail to explore how community members balance the reason to communicate with the effort to communicate, and ultimately place their resources into the community so that community sustainability can be achieved.

Based on the discussion above, it can be concluded that several models have been proposed to support the creation sustainability of virtual community. However, some of them propose only a single practice and policies to sustain the current virtual communities. Other research focuses on the key factors that contribute to the longevity of a virtual community. Yet, none of them proposes a complete framework or methodology to regulate members' interactions so as to produce virtual community sustainability. Moreover, few of them consider the importance of the existing trust relationship between community members to sustain the community and how to identify an untrustworthy agent in a community. Additionally, only some of the related works above have been verified empirically.

In this paper, we propose a framework for creating a sustainable community as mentioned in Section 1. The benefits of this framework for virtual communities are twofold. Firstly, it assists users or administrators to identify untrustworthy entities. The presence of a non-compliant agent in a virtual community can be a signal of noise. A case study of Usenet groups conducted by Ostrom in [14] concluded that a virtual community can be sustained if it has low signal-to-noise ratios. Signal-to-noise ratios refer to the number of non-active users in a community. A low noise ratio signifies a low number of non-active members in the community. If the number of non-active participants is low, then this community will be sustained. Conversely, if the number of non-active participants is high, then the community will not last. The second benefit is that our proposed framework shows how a virtual community can be sustained by means of using a third party agent to conduct continuous performance monitoring of members' interactions. Kollock and Smith [14] also argued that mechanisms which allow members to participate in the negotiation of governing rules such as monitoring others' behavior, designing a system of sanctions and access to low cost conflict resolution etc. contributed to the sustainability of virtual community. By designing a system that is able to monitor others' behavior, signal-to-noise can be easily detected. An overview of the proposed framework is presented in the next section.

3. THE PROPOSED FRAMEWORK

In this section, we provide an overview of the proposed framework for creating sustainable virtual communities. The purpose of this framework is to direct members' interactions in service exchange. From the perspective of service exchange in a virtual community, its members can be categorized as service requester and service provider. A service requester is an agent who requests a service or any information and the service provider is an agent who provides the service. A virtual community can be seen as a collection of agents who can offer services to other agents or obtain services from others. First and foremost, sustainability requires a stable relationship between service requester and service provider in this community. To sustain the community, all members should be able to participate and interact in a trustworthy manner. However, at the same time, the community members or the administrator must be able to identify those who are disrupting the community interaction. In other words, the system should have a mechanism whereby untrustworthy agents can be identified and isolated so that the community is comprised only of trustworthy agents.

3.1 An Overview

The conceptual framework is outlined in Fig. 1 below:

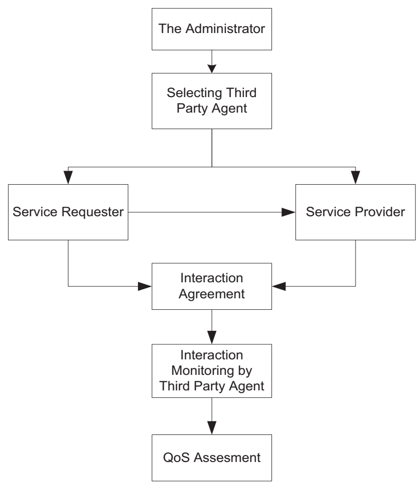

Figure 1. Conceptual Framework

The whole workflow of the system is as follows:

1) First of all, the administrator of a virtual community selects a third party agent or a neutral agent that will be involved in an interaction between service provider and service requester. This is as a pre-interaction activity. The third party agent is a professional agent who is experienced in judging and monitoring an interaction and has particular knowledge about the domain of the community.
2) At the same time, there are the two parties who are involved in any kind of interaction in a virtual community. As a simple example, consider that there is a service requester who requests information or an opinion and there is a service provider who provides information or argument as required. In order to have a guideline for their interaction, and to ensure the satisfaction of both parties during the information or service exchange, the service requester and service provider need to have an interaction agreement that defines the type of service and time frame for service delivery. Let us consider an example from a digital photographer community. An agent requests information on

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how to select a good lens from the new series of a particular digital camera. This agent has certain criteria regarding information that s/he wants from provider. For instance, the provider should have experience or expertise in camera lenses and this particular camera, and information must be provided within one week after the request. There are several other agents (service providers) who are willing and able to provide information based on the requester's requirements. These provider agents also have certain criteria pertaining to the requester. For instance, the requester should be able to provide the information about their camera and lens that they want to use. Moreover, they should reply to any information that provided by provider, etc. Then, both parties make an agreement to interact or exchange information that they need.

3) After both parties have an interaction agreement, the administrator of the virtual community will inform the third party agent about this agreement. The third party agent will use this agreement to monitor the performance of both parties.
4) Subsequently, both parties engage in interaction. They exchange any information that has been agreed upon in the interaction agreement. Both service requester and provider should transact according to this mutual agreement. At the same time, the third party agent monitors the performance of their interaction. Hence, this interaction agreement is primarily used as a guide to monitor both parties' performance progress. Continuing the above example, as a virtual group discussion, other agents (either with a role as requester or provider) may then become involved in the interaction. If the discussion is interesting enough, such activities like requests for further information, replies to requests, discussions of the validity and accuracy of replies, and further questions are prompted by the discussions. Thus, the number of interactions based on this agreement may increase. During performance monitoring, the third party agent will obtain a record of compliant and non-compliant agents in this interaction. A repeated non-compliant agent will be placed on the list of untrustworthy members, while a repeated compliant agent will be listed as a trustworthy agent. Hence, the third party agent would have a data base that contains a black list and white list of agents in a community. This database is updated every time and for every interaction between community members. Moreover, this database will be publicly available so that another agent who wants to joint this community can access information about an agent's reputation in such interactions.
5) At the end of the interaction, both service provider and requester assess the Quality of Service (QoS) that they have exchanged. We use a CCCI metrics that was developed by Hussain et al. [15, 16] to measure the QoS. CCCI metrics is a set of metrics that can be used to measure QoS based on service criteria, clarity of each criterion, and level of importance of each criterion.
6) Finally, both parties will provide the third party agent with the result of QoS assessment. Hence, the third party agent will have information about the performance of both service requester and service provider.
7) With this information, the third party agent will inform the administrator of the untrustworthy agents in this community based on a certain number of interactions. The administrator can then use this information either to isolate these agents from the community or to take the necessary steps to eliminate untrustworthy agents from the community in order to ensure the sustainability of the virtual community.

4. EXPERIMENTAL RESULTS

We conducted a simulation in order to test the performance of the proposed methodology. We repeated a series of experiments with a certain number of total agents in the community: 200, 500, 1000, 2000, 3000, and 4000. In each particular community with its different agent population size, we introduced a certain percentage of non-compliant agents into the community environment. The user assigns a compliance level to each agent either 0% (non-compliant) or 100% (compliant). A non-compliant agent is an agent who is not at all cooperative in any interaction. If this non-compliant agent carries out a transaction, s/he will never comply with the interaction agreement. On the other hand, a compliant agent with a 100% degree of compliance is an agent who always complies with the interaction agreement. From the trust perspective, a non-compliant agent is an untrustworthy agent and a compliant agent is a trustworthy agent. The percentage of non-compliant agents varies from 10% to 90%.

During simulation, a user randomly selects two agents, say 'A' and 'B'. For example, agent 'A' is a non-compliant agent; hence, this agent does not comply with the interaction agreement. By the end of the interaction, 'B' will assign a low QoS value to 'A'. Following the last step of our methodology, agent 'B' will inform the third party agent of this 'non-compliance' by agent B. The aim of the simulation is to determine the number of interactions needed in order to identify all of the non-compliant agents in the community. This is directly related to the number of non-complying agents that have been identified accurately by the third party agents.

Throughout the initial part / rounds of simulation, the compliance of agents is not modeled completely or accurately, or both. By 'complete modeling' of compliance levels we mean that the third party agent should know the compliance levels of all the agents in the community. On the other hand, by 'accurate modeling' of the compliance level, we mean that the actual level of compliance of the agents in the community should be as close as possible to the modeled or determined compliance levels established by the third party agent. Once the third party agent's information reflects accurately and completely the compliance of the agents in the community, it would eliminate non-complying interactions. In other words, this would result in a community in which non-complying agents are blacklisted and only complying agents are available for interaction.

Due to the random nature of agent selection during simulation, we conduct 20 series of experiments for every community size. As depicted in Figures 2, 3, 4, 5, 6 and 7, for every community size we have 20 different experiments and finally we draw an average line of those 20 series. Experiment results show that as the number of non-compliant agents increases in the community, the average amount of time to identify all of them as a function of the number of transactions decreases. If the community has a large number of non-compliant agents, then it will be quicker to identify all of them. Figures 2, 3, 4, 5, 6 and 7 in the Appendix show the experimental results of simulation with the total number of agents in communities 200, 500, 1000, 2000, 3000 and 4000 members respectively. Consider, for example, Figure 2 plots the experimental results for the community size 200. With 10% of them being non-compliant agents, on average, it takes 441 transactions to identify the entire non-compliant agents in the community. However, if the percentage of non-compliant agents in the community is 90%, on average, it takes only 174 transactions to identify all of them. We repeat the experiments with several different total numbers of agents in the community. We conclude from those experiments, that the framework is effective in producing virtual community sustainability. The role of the third party agent to monitor the interaction based on interaction agreement is effective as a means of identifying those who are not trustworthy.

5. CONCLUSION AND FUTURE WORK

In this paper, we propose a framework to create a sustainable community. From the trust perspective, a sustainable community can be achieved if there are no non-compliant or untrustworthy agents in the community. Non-compliant agents are agents who never meet an interaction agreement. Thus, from the perspective of service exchange, such agents never deliver service properly, or they never deliver service fully as agreed. The framework provides a model by which the third party agent and both interacting parties can conduct performance monitoring during such interaction between agents in the community. Both interacting parties will inform the third party agent the result of QoS assessment. Hence, the third party agent will have a data base of non-compliant agents in the community. Further, the third party agent will be forwarding this information to the administrator. The mechanism is experimentally evaluated for robustness by varying the number of parameters in the domain. A good performance can be seen over a range of community size population and certain percentage of non-compliant agents in the population during simulation. Since the number of non-compliant agents keeps increasing in the population, the average number of interactions to identify all of them is decreasing. We plan to extend the simulation by varying the size of communities in our future works.

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Appendix 1.

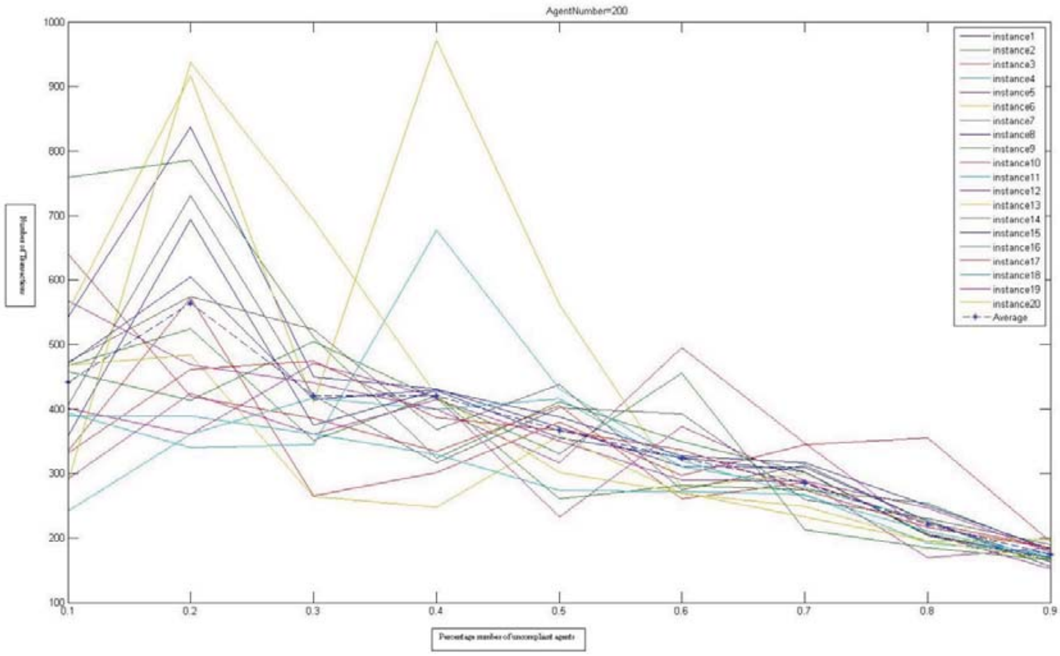

Figure 2. Experimental results in Community size of 200

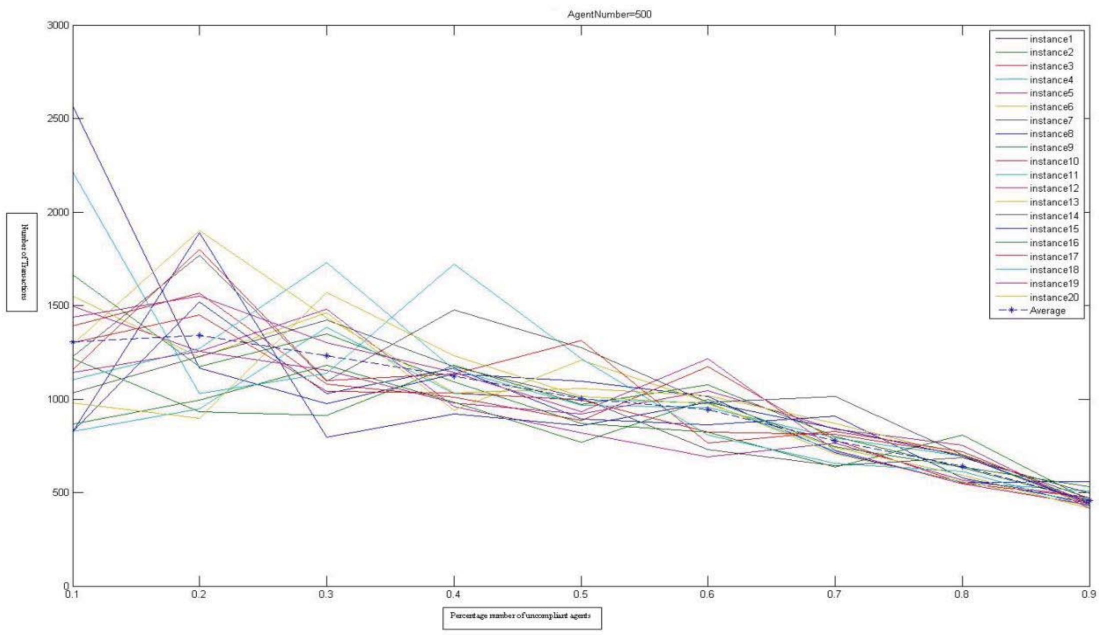

Figure 3. Experimental results in Community size of 500

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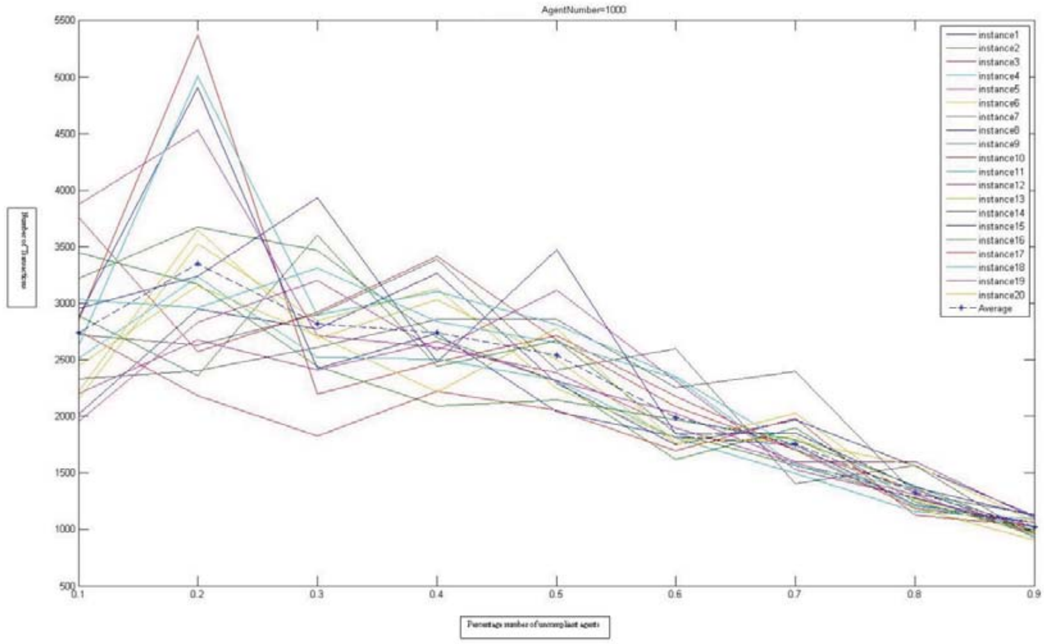

Figure 4. Experimental results in Community size of 1000

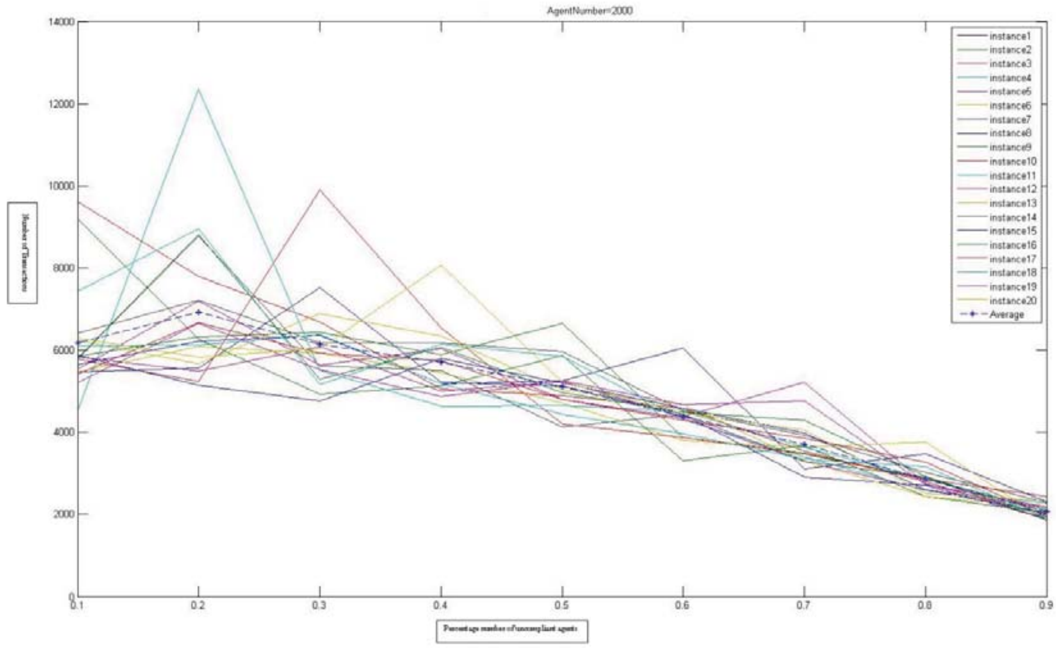

Figure. 5. Experimental results in Community size of 2000

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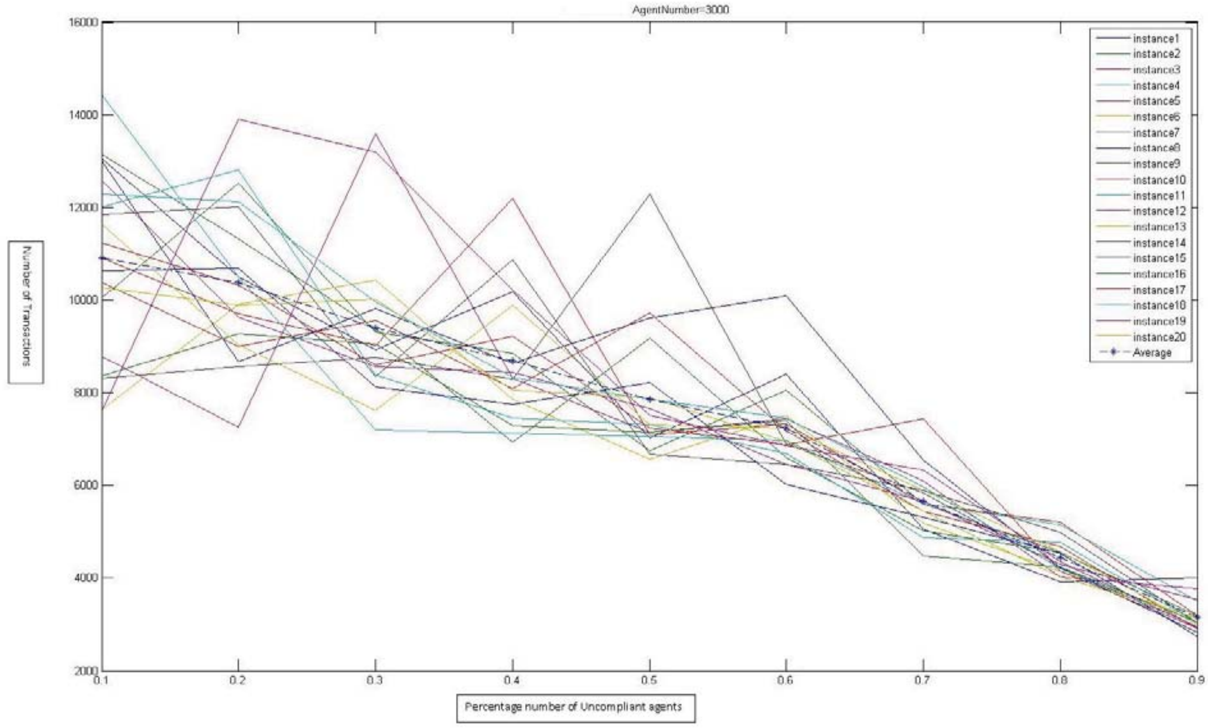

Figure. 6. Experimental results in Community size of 3000

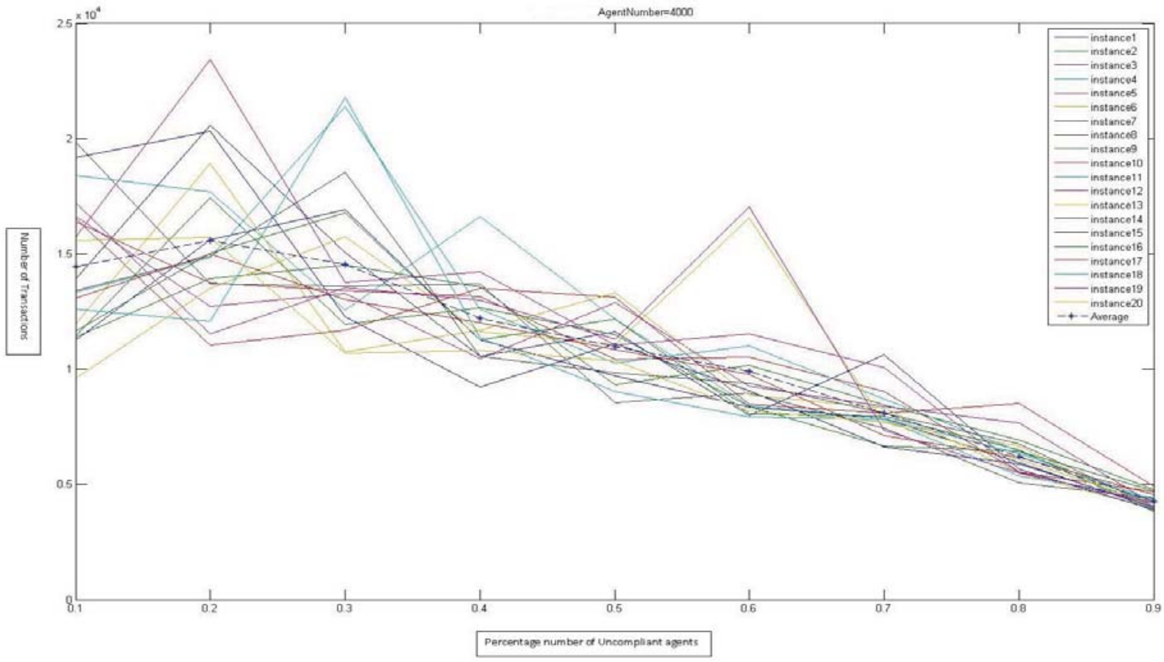

Figure. 7. Experimental results in Community size of 4000

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A Performance-Driven Incentive-Based Approach for Successful Service Delivery

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Abstract— **This paper proposes an appropriate incentive scheme design for service delivery systems to ensure service deliverability. We use proactive continuous performance monitoring to provide qualitative observations and data on how well services are being provided and whether desired service outcomes are being achieved as a result of interaction between two parties (service provider and service requester). The paper provides a general framework for analyzing the effectiveness of incentive and proactive continuous monitoring in ensuring successful service delivery. The objective of the incentive is to motivate the service provider to deliver service as agreed to by both parties. We show the robustness of the framework by running several simulations under various conditions. It is shown that proactive continuous monitoring and incentive are essential for increasing performance which will result in successful service delivery.**

Keywords: incentive, service delivery, digital ecosystems

I. INTRODUCTION

The new paradigm of Digital Ecosystems is built not only on transactions but on establishing, sustaining and improving relationships with existing or potential stakeholders. Hence, trust is always seen as a value which strengthens the business relationship [1, 2]. A key research issue relating to the formation of a successful business relationship is service guarantee and service deliverability. However, the existing literature does not focus on this. By 'service deliverability', we mean a guarantee of continued delivery of service as mutually agreed to by both of the parties involved. A business relationship depends on the strength of the trust and commitment both interacting parties to deliver service according to the terms of a mutual agreement. In this paper, we consider 'trust level' to be a representation of quality of service delivered. Quality of Service (QoS) is defined as 'the fulfillment of the service agreement or mutually agreed service' [3]. Trust is the degree of belief or faith that an interacting party has in another party [3] that forms the basis of QoS and the subsequent establishment of a business relationship [4]. Hence, trust level is the extent to which the trusted agent is capable of delivering service as mutually agreed to by both parties.

In this paper, we present an incentive-based mechanism to improve the performance of a trusted agent in delivering service to the trusting agent. The incentive is an increase in the performance level of the trusted agent in delivering agreed service; hence, we term it 'performance-driven, incentive-based'. Reward and incentive are widely acknowledged as motivators which can encourage agents to improve their performance. Badenfelt [5] stated that trusting agents may use rewards to change the trust levels in organizations. Although several researches have shown that the use of incentives can successfully increase the performance of agents in a non-virtual environment, Ferrin and Dirks [6] suggested that the effects of rewards in trust building in the context of virtual environment should be examined.

In order to support an incentive mechanism, we propose a proactive continuous performance monitoring mechanism for interactions between trusting agents and trusted agents. It is designed to monitor the service delivery at every checkpoint. Checkpoints are intermediate milestones that are created in order to check service delivery during the time space of a transaction. With our mechanism, a service task is decomposed into several intermediate deliveries to ensure the continuity of service delivery until the final desired outcome has been achieved. The main purposes of this checkpoint mechanism are to identify early disagreement (or non-compliance) between actual performance and mutually agreed performance and to resolve any issue(s).

This continuous monitoring enables performance variances to be timely identified. Consequently, both parties will be able to quickly close the performance gap before it inflates into an unmanageable and undelivered service by end of the transaction. The incentive would be used to encourage trusted agents to always comply at each checkpoint. It will guarantee successful delivery of that service. If an agent has not fully delivered service at a particular checkpoint, the remaining undelivered service needs to be delivered at the next checkpoint. If at this checkpoint, the agent increases his compliance performance compared to the previous checkpoint, then this agent will receive an incentive. As a result of receiving an incentive, their performance level at the next checkpoint will increase. We present details of this mechanism in the next section.

The rest of the paper is organized as follows. Section 2 presents a model overview. Section 3 presents the experiment results. In Section 4, we validate the framework by means of a series of experiments. We briefly review the current researches in the field of incentives and rewards for increasing performance in Section 5. Conclusions are drawn and future works are outlined in the final section.

II. BACKGROUND AND RELATED WORK

Several existing works suggest that the level of trust in such service relationships should always be monitored to ensure the success of service delivery. Therefore, although trust has been established between the trusting agent and trusted agent in a transaction relationship, monitoring still plays an important role in ensuring that the partnership relationship continues to operate as intended [7, 8]. Henceforth, even in situations where there is a sufficient level of trust between trusting agents, this trust needs to be underpinned by robust monitoring and, where necessary, reward and sanctioning processes could be utilized [6, 9].

Such continuous performance monitoring activities enable performance discrepancies to be identified early and be resolved. Kumaran et al. [10] proposed a MDBT (Model Driven Business Transformation) for transaction monitoring between service provider, outsourcer and service requester. It provides a service delivery performance management platform which includes notification of any violation of SLAs. The performance is monitored by comparing actual performances against Key Performance Indicators (KPIs). The platform aims to model performance metrics for service delivery and describe how the monitoring and management of KPIs are supported as an integral part of SDM (Service Delivery Management) platform. However, this platform does not provide any mechanism, using reward and incentive, to motivate the service provider to fully comply with SLAs.

Reward and incentive have been acknowledged as factors which contribute to the success of interactions or to increase the involvement of interacting parties [11]. Long and Sitkin [9] examine the various ways to balance interpersonal trust-building and control-based efforts in order to maintain trust-based relationships. Written contracts, surveillance and monetary incentives are examples of formal mechanisms for controlling the delivery of service from trusted agent to trusting agent. They maintain that trusting agents can use incentive mechanisms to direct trusted agents toward the efficient and effective completion of tasks. However, the incentive is given after the completion of tasks at the end of the interaction.

Ferrin and Dirks [6] carried out laboratory experiments to examine whether rewards have a direct effect on trust or whether they represent a catalyst that may set in motion other processes that influence trust. Their research concludes that rewards have a strong impact on the formation of trusting beliefs. However, the incentive is given after the trusted agent had completely delivered the service. They do not propose any mechanism that provides an incentive at intermediate intervals during the delivery of service.

Unlike the existing works in the literature regarding incentives for task completion, in this paper we combine a mechanism of proactive continuous monitoring and performance-driven incentive specifically to support successful service delivery. The service delivery is monitored at intermediate checkpoints and incentives are given at intermediate checkpoints rather than at the end of the interaction. We do not intend to provide an incentive after task completion; instead, it is given during the course of the transaction to minimize the discrepancy between actual performances and mutually agreed to performance.

III. MODEL OVERVIEW

The objective of our system is to motivate trusted agents to maintain their performance in delivering service to the trusting agent. We propose to include the following properties in the design of our incentive mechanism:

1. *Mutually Agreed Performance*. For each transaction, both parties have agreed on mutually agreed performance. This agreement clearly states each service criterion and its associated level of importance.
2. *Time Space*. Before each transaction, the trusting agent and trusted agent determine the entire duration of time over which the complete delivery of agreed service will occur. We term this the 'time space'.
3. *Check point.* In order to ensure the continuity of service delivery, the trusting agent divides the time space into a certain number of checkpoints. At each checkpoint, the agreed performance of service delivery is expressed. This checkpoint system is intended to facilitate continuous performance monitoring during the interaction. With the designed checkpoints, the trusting agent can observe or track changes in the performance of the trusted agent over a time space.
4. *Intermediate Performance.* The performance of the trusted agent in terms of delivering the service is monitored at each checkpoint. It is reflected in the correlation between actual service and mutually agreed upon service at each checkpoint. Hence, at each checkpoint, the trusting agent will allocate a value of intermediate performance. We measure the performance of trusted agent by correlating actual performance with mutually agreed performance. The intermediate performance is calculated using the following formula:

$$P_{\text{int}}\text{CPn} = 6 * \left(\frac{\sum_{C=1}^{N} \mathit{In\ Actual\ Perf}_{criterionc} * \mathit{Clear}_{criterionc} * \text{Imp}_{criterionc}}{\sum_{C=1}^{N} \mathit{In\ MAP}_{criterionc} * \mathit{Clear}_{criterionc} * \text{Imp}_{criterionc}} \right) \quad (1)$$

Where,

$P_{\text{int}}CPn$ denotes intermediate performance at checkpoint n

6 represents the highest level of performance

$\mathit{In\ Actual\ Perf}_{criterionc}$ denotes the actual / delivered criterion representing the fulfillment of each criterion of the trusted agent at an intermediate checkpoint.

$InMAP_{criterionc}$ denotes mutually agreed performance of the trusted agent according to the given criterion at the intermediate checkpoint.

$Clear_{criterionc}$ represents the clarity of each criterion in the service agreement (contract) and whether it is understood in the same way by both parties. For a given criterion, $Clear_{criterionc}$ can have two levels (a) '0' – This criterion or its output or both have not been mutually agreed to by both parties and (b) '1' – This criterion along with its output has been mutually agreed to by both parties.

$\mathrm{Imp}_{criterionc}$ denotes the importance of each criterion that affects the determination of trustworthiness. For a given criterion, $\mathrm{Imp}_{criterionc}$ can have three levels: (a) '0' – not important (b) '1' – important, and (c) '2' – very important.

5. *Incentive CP*. The incentive at each checkpoint will be issued if the performance of a trusted agent at the current checkpoint is higher than for the previous checkpoint. Hence, if $Pint_{CPn} > Pint_{CPn-1}$, the trusting agent will give an incentive to the trusted agent, while $Pint_{CPn}$ is intermediate performance at current checkpoint and $Pint_{CPn-1}$ is the intermediate performance at the previous checkpoint. We term the checkpoint which receives the incentive as the *'incentive CP'*. During one transaction, there would be several checkpoints. It is important to note that the incentive is given only if the agent has shown an increase in performance.

6. *Incentive value*. The trusting agent will give an incentive value as a kind of 'trust value'. In this paper, the highest trust value as an incentive during a transaction is '1'. Hence, the value of incentive for each 'incentive CP' is calculated as follows:

$$Incentive\ CP = \frac{1}{\text{total number of CP}} \quad (2)$$

7. *Increasing performance as a response of incentive.* Once an agent has received an incentive at a certain checkpoint, as a response to this incentive, he increases his performance level for the next checkpoint. The level of increasing performance is calculated as follows:

$$\text{IPL} = \text{CL}_{\text{CPn}} * \text{initial performance level} * \text{brake option} \quad (3)$$

Where IPL denotes as increasing performance level, CL_{CPn} denotes the compliance level at checkpoint n. This CL_{CPn} is chosen randomly by the system at each initial checkpoint. Initial performance is randomly assigned early in the simulation. Brake option is a value of 0 – 0.9, which represents the degree of performance increasing after receiving an incentive.

8. *Final Performance*. At the end of the interaction or time space, the final performance as a representation of successful service delivery is calculated by aggregating the intermediate performance during the transaction. It can be calculated by using the following equation:

$$\mathrm{P}_{\mathrm{final}} = \left(\frac{\sum_{c=1}^{N} P_{\mathrm{int}}}{\mathrm{n}} \right) \quad (4)$$

While P_{int} is performance at intermediate point and *n* denotes the total number of check points in an interaction. P_{int} value can be calculated by using (2) above.

Let us consider the following case study for elucidation purposes. Agent 'A' is a trusting agent who requests that agent 'B' delivers 1000 service units for the duration of one month time space. Agent 'A' then divides the time space into 4 checkpoints. At each checkpoint, it is agreed that agent 'B' will deliver 250 units. As explained previously, the checkpoint is designed to monitor the progress of performance continuously rather than at the end of the interaction.

Let us consider that at the first checkpoint, agent 'B' delivers only 200 units which is below the intermediate mutually agreed performance. At this first checkpoint, by using (1), the intermediate performance for this checkpoint 1 is 4.8. In our model, we propose a mechanism by which the performance gap at the previous checkpoint is handed over to the next checkpoint. Hence, in this case, the agreed performance for the second checkpoint is 300 units instead of 250 units. If at this checkpoint, the ratio of actual performance against the mutually agreed performance is greater than checkpoint 1, this checkpoint is characterized as an incentive checkpoint. For example, if the agent delivers 290 units, using (1) the $P_{\mathrm{int}}\mathrm{CP}_2$ is 5.8. As $P_{\mathrm{int}}\mathrm{CP}_2$ is greater than $P_{\mathrm{int}}\mathrm{CP}_1$, this checkpoint 2 is marked as incentive CP.

As a result of receiving the incentive, this agent will increase his compliance level at checkpoint 3. The increasing performance level is calculated by using (3). This mechanism continues until the end of the transaction time space. Finally, at the end of the transaction, we measure the final performance as the aggregate value of intermediate performances. If the final performance is greater than the initial performance, we may conclude that incentive has facilitated the successful delivery of service by increasing the agent's performance level.

The initial performance and final performance are compared in order to show that the trusted agent has been increasing his performance level in response to receiving an incentive. This will lead to the completion of service delivery from trusted agent to trusting agent.

IV. IMPLEMENTATION AND RESULTS

In order to determine the effectiveness of our mechanism, we engineered a multi-agent system using the JADE Multi Agent-Based Framework which has an interface enabling the user to specify the parameters prior the execution. The user can specify the total number of interactions (or transactions) that need to be simulated. Additionally, the user specifies the total number of agents in the multi-agent system that needs to be classified into six classes, with each class corresponding to one particular trustworthiness value and associated compliance level.

During the bootstrapping phase, the agents are created and each of them is assigned a given behavior, to represent the degree of their performance level. Hence, each agent would have an initial performance level. Each performance level corresponds to one trustworthiness value. For example, the behavior belonging to agents with trustworthiness value '1' (TV_1) would contain a behavior that would specify the action or the way that agents carry out a transaction. Hence, we propose that the performance level of an agent is the degree to which an agent complies with mutually agreed performance.

Since there are six different trustworthiness values, there are six different performance behaviors. In this simulation, we propose a correctness of agent's compliance level using Fuzzy Trapezoidal Performance Level. In this approach, the behavior of each agent corresponding to a trustworthiness value is represented using a membership function as shown in Table 1. The degree of compliance behavior of an agent in each trust value is determined with the help of a statistical graph which corresponds proportionally to the measurement of 100 scale intervals. The number '0%' denotes the lowest level of compliance, meaning that the agent is totally non-compliant, and '100%' denotes perfect performance or full compliance. A fuzzy trust grade set is defined as the fuzzy measurement result, which is denoted by Trust Value (TV) = [1, 2, 3, 4, 5, 6]. These six grades TV_1, TV_2, TV_3, TV_4, TV_5, and TV_6 denote the gradational measurement results ranging from the fully compliant to fully non-compliant as depicted in Fig. 1 below.

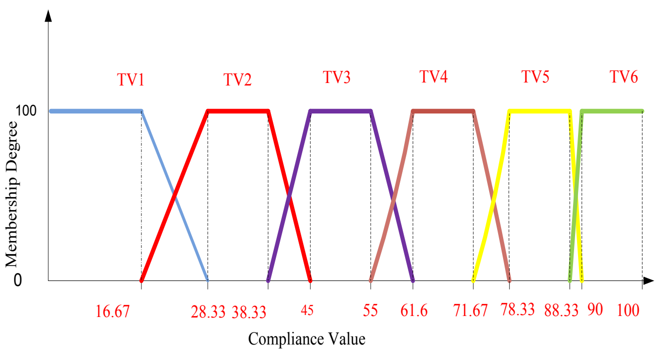

Fig 1. Trapezoidal Membership Degree and Compliance Value.

The graph above shows the degree of membership and value of compliance for every agent in each trust value. It can be seen that the nature of membership functions is primarily trapezoidal; hence, we term this set of compliance 'fuzzy trapezoidal compliance'. An agent with a certain level of compliance will have a certain trust value. Membership degree *(y)* which ranges from 0 to 1 is a mapping called the membership function of the fuzzy set TV, and level of compliance *(x)* indicates the degree of belongingness or membership value of *'x'* in any Trust Value. Therefore, a certain compliance level acquires two trustworthiness (membership) characteristics.

During simulation, the user randomly selects an agent with the probability of having a compliance value ranging from 0% to 100%. There are six grades of TV_1, TV_2, TV_3, TV_4, TV_5, and TV_6. Each compliance value will correspond to a certain degree of trust value membership. For example, if the user chooses an agent with level of compliance 28%, his behavior will express some degree similarity of TV_1 and TV_2 characteristic as this point has a certain degree of membership in TV_1 and TV_2. However, the total degree of membership is always 1.

The equations representing fuzzy trapezoidal compliance corresponding to TV_1, TV_2, TV_3, TV_4, TV_5, and TV_6 are shown below:

TABLE 1
TRAPEZOIDAL COMPLIANCE LEVEL FUZZY RULE

TV	Membership Degree	x value
TV_1	0	$x \geq 28.33$
	$\frac{28.33 - x}{28.33 - 16.67}$	$16.67 < x < 28.33$
	1	$0 \leq x \leq 16.67$
TV_2	0	$x < 16.67$
	$\frac{16.67 - x}{28.33 - 16.67}$	$16.67 < x < 28.33$
	1	$28.33 \leq x \leq 38.33$
	$\frac{45 - x}{45 - 38.33}$	$38.33 < x < 45$
TV_3	0	$0 \leq x \leq 38.33$
	$\frac{x - 38.33}{45 - 38.33}$	$38.33 < x < 45$
	1	$45 \leq x \leq 55$
	$\frac{61.67 - x}{61.67 - 55}$	$55 < x < 61.67$
TV_4	0	$0 \leq x \leq 55$
	$\frac{x - 55}{61.67 - 55}$	$55 < x < 61.67$
	1	$61.6 \leq x \leq 71.67$
	$\frac{78.33 - x}{78.33 - 71.67}$	$71.68 < x < 78.33$
TV_5	0	$0 \leq x \leq 71.67$
	$\frac{x - 71.67}{78.33 - 71.67}$	$71.67 < x < 78.33$
	1	$78.33 \leq x \leq 83.33$
	$\frac{90 - x}{90 - 88.33}$	$88.33 < x < 90$
TV_6	0	$0 \leq x \leq 88.33$
	$\frac{x - 83.33}{90 - 88.33}$	$88.33 < x < 90$
	1	$90 < x \leq 100$

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In this approach, consider for example that we have an agent with a compliance level of 60%. This agent will behave according to some degree of TV_3 and to some extent of TV_4. Therefore, the calculation of compliance behavior is as follows:

$$\text{Compliance Behavior} = (\text{membership degree} * TV_{3\,char}) + (\text{membership degree} * TV_{4\,char}) \quad (5)$$

Membership degree is the level of membership based on calculation using the fuzzy rule above, while $TV_{n\ char}$ is a characteristic of trust value as derived from the crisp compliance level. Based on the above rule, the compliance level of this agent is 62.5% as a result of the following calculation:

TABLE 2
COMPLIANCE BEHAVIOR CALCULATION

TV	x value	Membership Degree	Compliance Behaviour
TV_3	$\frac{61.67 - x}{61.67 - 55}$	$\frac{61.67 - 60}{61.67 - 55}$	0.25*50=12.5
TV_4	$\frac{x - 55}{61.67 - 55}$	$\frac{60 - 55}{61.67 - 55}$	0.75*66.67 = 50.0025
Total		0.75 + 0.25 = 1	12.5 +50.0025 = 62.5025

Moreover, the user can also specify the bonus bias which ranges from 0.1 to 0.9. This bonus bias is a parameter to determine the increasing behavior of an agent after an incentive has been given.

In order to show the effectiveness of the incentive mechanism in supporting successful service delivery, we compared the simulation results from transactions with incentive and without incentive. In transactions without an incentive mechanism, if an agent performs better than at the previous checkpoint, there is no incentive and no increasing performance for the next checkpoint as well.

Figure 2 below shows the comparison result from simulation of interactions with incentive and without incentive from 1000 agents who carried out 1000 transactions; bonus bias in the incentive mechanism benchmark is 0.9.

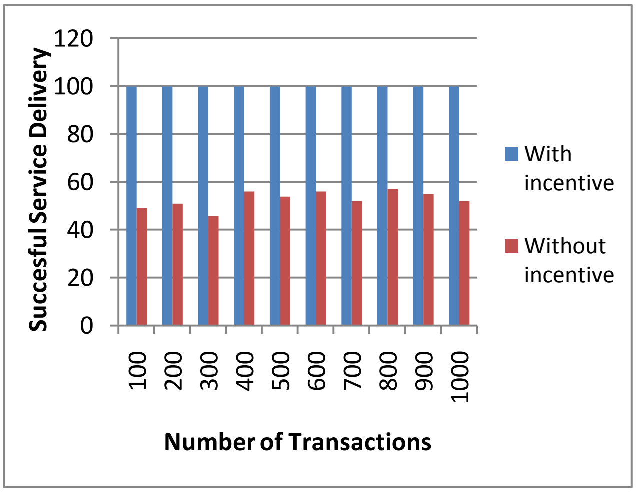

Fig. 2. 1000 agents carried out 1000 transactions (bonus bias 0.9)

As we can see from figure 2 above, the successful service delivery resulting from a transaction with incentive is higher than for a transaction without incentive. We measure the successful delivery as a comparison between initial performance level and final performance level. If the final performance level is greater or equal than the initial performance level, then it indicates that an agent in that particular interaction has increased his compliance level. It does not mean that the service has been delivered at a full compliance level (100%); rather, it depends on the initial compliance level as a representation of the trustworthiness value of agent.

As observed in interactions with incentive, the successful service delivery remains 100% throughout the interaction. It means that all agents have shown an increase in performance as a result of the incentive. In contrast, for interactions without incentive, the successful service delivery is less than 60%. This means that during transactions, only 60% of agents have shown improved behavior.

Figure 3 below illustrates the results of an experiment using transactions with 3000 agents who carried out 2000 transactions and the bonus bias is 0.9.

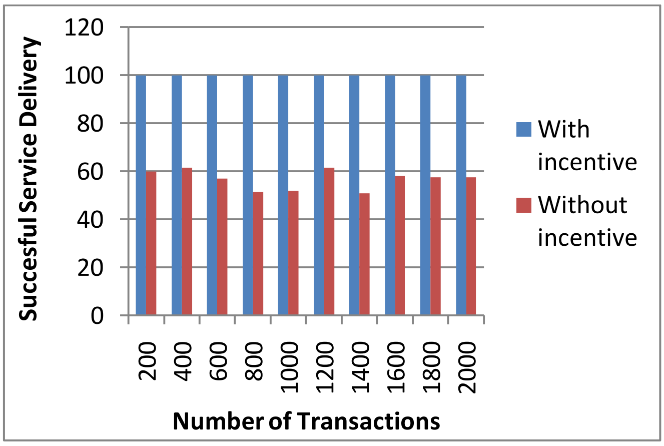

Fig. 3. 3000 agents carried out 2000 transactions (bonus bias 0.9).

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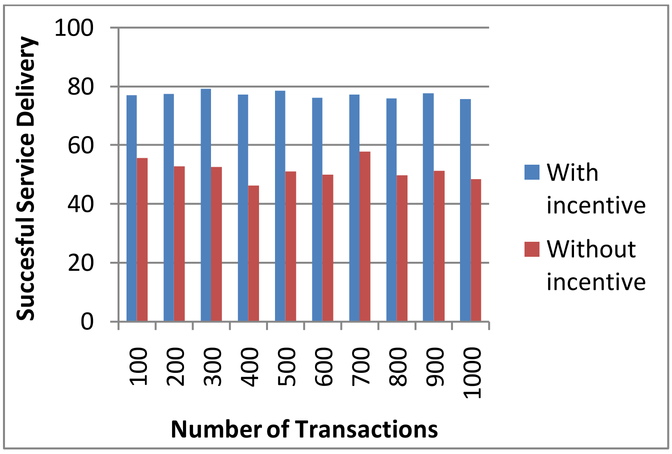

Fig. 4. 2500 agents carried out 5000 transactions (bonus bias 0.5)

It is also observed from Figures 3 and 4 that with the larger number of agents and interactions, there are significant differences between two transaction scenarios. Interactions with an incentive mechanism have a higher rate of success than do those interactions without an incentive mechanism.

It can be inferred from the simulation results, that incentive is effective as a means of increasing the performance of trusted agents to deliver services to the trusting agents at each checkpoint. Moreover, the proactive continuous monitoring with checkpoints is designed to support the continuity of service delivery. With the proactive continuous monitoring, the trusting agent will be updated about the performance of the trusted agent and this will help to close the performance gap in real time. Hence, it guarantees service deliverability at the end of transactions.

V. CONCLUSION AND FUTURE WORK

In this paper, we present a mechanism for proactive continuous monitoring and performance-driven incentive in business interactions between service providers and service requesters. These two mechanisms are intended to support the successful delivery of service. At each transaction, the service task is decomposed into several intermediate deliveries as agreed to by both parties. Hence, the service delivery is monitored at intermediate checkpoints and incentive is given at intermediate checkpoints if the trusted agent has shown an increase in performance.

Unlike existing works, incentive is given at transaction milestones as a part of continuous performance monitoring, rather than at the end of transaction. If an agent performs consistently according to the mutually agreed performance at each checkpoint, then this agent receives an incentive. As a result of this, the agent will increase his performance or compliance level. Therefore, any performance gap is identified and resolved in real time. It will guarantee the successful of delivery of service by the end of the transaction.

In our future works, we intend to introduce another scheme of incentive according to the degree of compliance level. We also plan to design a penalty system for unsuccessful service delivery.

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