Assessing trust of suppliers' solutions offered in an electronic marketplace

by

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ABSTRACT

Observations about 232 members of the Eclipse Marketplace and 16 suppliers' solutions are used to: (i) define a model to measure trust; (ii) implement an automated approach to calculate trust opinion values of suppliers' solutions offered in the marketplace; and (iii) produce insights on ways to increase belief and decrease customer's uncertainty about suppliers' solutions. Results suggest that trust values decrease customer uncertainty about a supplier's solution but do not increase customer belief in the solution.

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1 INTRODUCTION

This research examines trust of suppliers' solutions published in a vendor neutral marketplace.

The problem being addressed is how to measure trust of solutions published in a marketplace operated by a keystone organization. A solution to this problem enables a keystone to increase trust of suppliers' solutions and reduce customers' uncertainty.

For the purpose of this research, a vendor neutral marketplace is a website operated by a keystone organization that is not dominated by a single supplier. The website allows its members to publish solutions and review solutions published by suppliers in the website.

A keystone is the organization that owns, operates, and evolves a platform (product, process, location, service or technology) and corresponding marketplace that deliver value to a community of members. The two main responsibilities of the keystone organization are to increase the: i) volume of transactions among members; and ii) efficiency of new product or service creation.

Marketplace members include suppliers, customers, investors, complementary service providers, and other organizations and individuals that benefit when suppliers sell to customers. A member is an individual or a company representative that has access to the marketplace. Members can publish their solutions in the marketplace and review other members' solutions.

A solution is software created using the platform and distributed to customers using the marketplace.

A customer is a potential buyer of a solution that is visiting the marketplace.

Trust is essential to growing marketplaces. According to Iansiti and Levien (2004):

“Trust is essential to good market operation because ultimately it decreases operating costs and risk exposure. A well-trusted marketplace will need to spend less in attracting customers and in managing their interactions, which means that it will be much easier to scale.”

Traditionally, a supplier sells its solutions directly or through intermediaries. In a new approach a supplier can leverage the benefits of an established platform and a marketplace operated by a keystone.

1.1 Objective

The objective of this research is to examine: (i) how to measure trust of suppliers' solutions offered in a marketplace and (ii) which mechanisms increase customer belief and decrease customer uncertainty about solutions provided by suppliers.

Trust is measured using trust opinion values as defined in trust network analysis with subjective logic (Jøsang et al., 2006).

Figure 1: Trust opinion and trust opinion values

Figure 1 shows that a trust opinion (ω) is a vector of four values: belief, disbelief, uncertainty, and a-priori trust. Three of them (belief, disbelief, and uncertainty) are based on trust observations¹. The fourth one (a-priori trust) is based on the truster's² pre-disposition to trust.

Belief refers to the extent to which a truster believes that a trustee³ will deliver what was promised. Belief is calculated based on the number of positive and negative observations available on the trustee.

Disbelief refers to the extent of distrust from a truster to a trustee. Distrust defined as the incredulity that a trustee is able, reliable, and benevolent.

¹ Observations in trust network analysis with subjective logic are any positive or negative experiences of a truster about a trustee.

² Truster is the word used in the literature that refers to a person who establishes a trust relationship. Truster is the trust source also mentioned in the literature as "trustor" (Jøsang et al., 2006).

³ Trustee is the word used in the literature that refers to a person who receives trust from a truster. Trustee is the trust target (Jøsang et al., 2006).

Uncertainty is the lack of observations about a solution supplier. The higher the customer uncertainty about a solution supplier, the lower the customer's willingness to close a deal⁴.

A-priori trust determines the initial trust placed on a member of the community in the absence of any positive or negative observations.

Two hypotheses are advanced to examine whether or not providing additional observations on a solution supplier's ability, integrity, and benevolence help decrease customer's uncertainty and increase customer's belief about the supplier's solution.

Hypothesis 1. Additional observations on a solution supplier's ability, integrity, and benevolence decrease customer's uncertainty about the supplier's solution.

Hypothesis 2. Additional observations on a solution supplier's ability, integrity, and benevolence increase customer's belief about the supplier's solution.

To test the two hypotheses and answer the research question, we use trust network analysis with subjective logic (TNA-SL). TNA-SL enables the operationalization of a model to measure and analyze trust opinion values about information on solutions published in a marketplace.

The Eclipse Marketplace website (<http://marketplace.eclipse.org>) is the source of the data used in this research.

⁴ A deal is a successful business transaction between a customer and a solution supplier.

This research uses 621 observations on members and suppliers' solutions inferred from information collected from the Eclipse Marketplace website. Observations are about 232 members, and 16 solutions drawn from 2 solution categories in the Eclipse Marketplace named: documentation and team development.

1.2 Deliverables

This research delivers:

1. A model to measure trust in suppliers' solutions offered in a marketplace.
2. An approach to automatically calculate trust values of solutions offered in a marketplace.
3. Insights on ways to increase belief and decrease a customer's uncertainty about a solution offered in a marketplace.

1.3 Contribution

The results of this research are expected to provide the following benefits:

1. Benefits of results of thesis
 - a) Expand Jøsang's (2006) trust network analysis model by incorporating research carried out by Mayer et al. (1995).
2. Future potential benefits
 - a) Reduce costs of transactions among members who access a marketplace
 - b) Increase the number of deals closed by marketplace customers

Transaction costs can be reduced by providing trust opinion values. The trust opinion values add information that potential customers can use to close deals in a marketplace.

Increased trust values reduce uncertainty for customers about suppliers' solutions and foster the number of deals being closed in the marketplace.

Jøsang's trust network analysis model is expanded by deriving trust opinions based on observations on suppliers' ability, integrity, and benevolence. These are the three trust dimensions proposed by Mayer et al. (1995).

1.4 Relevance

This research is relevant to marketplace members because it provides an approach to calculate trust opinion values of the solutions offered in the marketplace operated by the keystone. These trust opinion values are visible and may be able to reduce members' search and information costs.

This research is relevant to operators of keystones for two reasons. First, the research can guide a keystone to help its members increase trust in their solutions. Second, the research shows how the keystone can increase the trust that organizations place on the solutions offered in its marketplace.

This research is also relevant to academics for two reasons. First, the research provides concrete examples of how to calculate trust opinion values in a real marketplace. Second, this research brings together two separate literature streams:

trust network analysis with subjective logic model proposed by Jøsang et al. (2006) and the trust dimensions analysis by Mayer et al. (1995).

1.5 Organization

This thesis is organized into six chapters. The first chapter is the introduction. The second chapter reviews the literature on trust. The third chapter describes the method and simulation model used in this research. The fourth chapter presents the results of the simulation. The fifth chapter discusses the research findings. Finally, chapter six provides the conclusions, research limitations and suggestions for future research.

2 LITERATURE REVIEW

2.1 Trust

Chapter 2 is organized into two sections. Section 2.1 presents a literature review on the definition, importance, dimension, and transitivity of trust. Section 2.2 presents the lessons learned from the literature review.

2.1.1 Definition of trust

Trust has been conceptualized in at least five ways. Table 1 identifies the five conceptualizations found in the literature.

Table 1: Trust conceptualizations

Conceptualization of trust as:	Researchers
Willingness to take risk	Pardue et al., 2008; Svensson & Wood, 2004; Levin et al., 2006; Mcknight et al., 1998; Shoorman et al., 2007; Das & Bing-Sheng Teng, 1998; Jøsang et al., 2006; Mayer et al., 1995
Confidence	Klein, 2001; Ring & Van de Ven, 1992; Ring & Van de Ven, 1994
Belief	Dirks & Ferrin, 2001; Shi et al., 2004; Mouzas et al., 2007; Pavlou & Dimoka, 2006; Huang & Nicol, 2009
Psychological state	Huang & Nicol, 2009; Huang & Fox, 2006; Dirks & Ferrin, 2001
Multi-faceted concept	Ratnasingam, 2005; Nooteboom, 2004; Olekalns & Smith, 2007

Mayer et al. (1995) describe trust as “the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the truster, irrespective of the ability to monitor or control that other party”. The definition of trust proposed by Mayer et al. (1995) is accepted by many authors (Pardue et al., 2008; Svensson & Wood, 2004; Levin et al., 2006; Mcknight et al., 1998; Shoorman et al., 2007; Das & Bing-Sheng Teng, 1998; Jøsang et al., 2006).

A second group of researchers conceptualize trust as the level of confidence on another’s goodwill (Klein, 2001; Ring & Van de Ven, 1992; Ring & Van de Ven, 1994).

A third group of researchers conceptualize trust as a belief (Dirks & Ferrin, 2001; Shi et al., 2004; Mouzas et al., 2007; Pavlou & Dimoka, 2006; Huang & Nicol, 2009). Table 2 provides a list of trust beliefs found in the literature.

Table 2: Trust beliefs

“Belief that one can rely upon another person’s actions and words and/or that the person has good intentions toward oneself”	Dirks, K. T. & Ferrin, D. L. (2001)
“Belief that the actions of another may be relied upon, without explicit guarantee, to achieve a goal in a risky situation”	Shi, J., & Bochmann, G. v., & Adams, C. (2004)
“Belief or sentiment that the other party will act benevolently”	Mouzas, S., & Henneberg, S., & Naudé, P. (2007)
“Belief that a transaction with a seller will occur in a manner consistent with her confident expectations”	Pavlou, P. A., & Dimoka, A. (2006)
“[Belief] that the expected behavior occurs, based on the evidence of the trustee’s competence and goodwill”	Huang, J., & Nicol, D. (2009)

Huang and Nicol (2009), Huang and Fox (2006), and Dirks and Ferrin (2001) define trust as a psychological state comprising three elements: expectancy, belief, and willingness to be vulnerable. Such definition is aligned with the definition of trust advanced by Mayer et al. (1995).

A last group of researchers defines trust as a multi-faceted configuration. Ratnasingam (2005) conceptualizes trust as comprised of technological, economic, behavioural, and organizational perspectives. Nooteboom (2004) and Olekalns and Smith (2007) consider the behavioural facet of trust and divide it in two main aspects: competence trust and good-will or intentional trust. Competence trust is derived from a trustee's ability or competence. Good-will or intentional trust is derived from a trustee's intention, benevolence and integrity.

2.1.2 Importance of trust

Trust is considered to be the most important phenomenon that contributes to the strength and maintenance of fruitful personal and business relationships (Svensson & Wood, 2004). It facilitates conclusion of transactions by diminishing the necessity of undesired mechanisms of control. It can be a "low-cost substitutes for police, regulators, and court actions" (Yandle, 2010).

As trust is built and maintained there is no need for constant on-going verification of another party's trustworthiness. Trust is fundamental to the development and sustainability of a market (Iansiti & Levien, 2004). When significant demands for trust verification are in place, "the transaction costs are increased to a level that makes much cooperation less rewarding, and some is inhibited" (Tullberg, 2008).

Trust can help reduce transaction costs of an exchange (Poel, 2005; Ratnasingam, 2005). Poel (2005) argues:

“Trust can reduce transaction costs (Chiles & McMackin, 1996 in Poel, 2005).

When there is a high level of trust between two parties, contract costs are lower because it is not necessary to include all kinds of costly safeguards. Moreover, negotiation costs are lower because when people trust each other they are more willing to cooperate with each other and they do not have to find out whether the other is a trustworthy person. Furthermore, the monitoring costs are reduced, because it is no longer necessary to check every time whether the other is really doing what he promised to do.”

Lack of trust results in a pay-off of zero for all players and prevents society from achieving outcomes (Klein, 2001). Figure 2 represents the trust decision tree as proposed by Klein (2001). If a truster makes a decision not to trust a promise the result is 0 for both truster and promiser. If the truster decides to trust and the promiser keeps its promise both players win.

Figure 2: Klein's (2001) trust decision tree

2.1.3 Dimensions of trust

Trust dimensions include the perception of someone's ability, integrity, and benevolence (Mayer et al., 1995; Levin et al., 2006; Shoorman et al., 2007; Olekalns & Smith, 2007; Pardue et al., 2008). These factors are also defined as good-will and reliability (Das & Teng, 1998); good-will and competence (Huang & Nicol, 2009); and as integrity or good-will (Ring & Van de Ven, 1994).

Mcknight et al. (1998) distinguish between trusting intention and trusting beliefs and identify three trusting beliefs: benevolence, competence, and honesty or predictability. Olekalns and Smith (2007) also list reliability, predictability, benevolence and integrity as relational risks drawn from theories of interpersonal perception, social exchange and trust. Pavlou and Dimoka (2006) list benevolence and credibility.

Nooteboom 's multi-faceted concept of trust has ability as a dimension of competence trust and dedication plus benevolence as dimensions of intentional trust (Nooteboom, 2004).

Shoorman et al. (2007) noted that "just as perceptions about an individual's ability, benevolence, and integrity will have an impact on how much trust the individual can garner, these perceptions also affect the extent to which an organization will be trusted."

Table 3 provides the dimensions of trust identified in the literature and their associated concepts.

Table 3: Summary of trust dimensions

Mayer et al. (1995) trust dimensions	Associated concepts
Ability	Competence (Huang & Nicol, 2009; Ratnasingam, 2005)
Integrity	Reliability (Das & Teng, 1998) Honesty (Mcknight et al., 1998) Predictability (Mcknight et al., 1998; Olekalns & Smith, 2007; Ratnasingam, 2005) Credibility (Pavlou & Dimoka, 2006)
Benevolence	Goodwill (Das & Teng, 1998; Ring & Van de Ven, 1994; Pavlou & Dimoka, 2006; Ratnasingam, 2005) Willingness (Mouzas et al., 2007) Confidence (Das & Teng, 1998) Intentionality (Ratnasingam, 2005)

2.1.3.1 Ability

Ability can be defined as the truster's belief that a trustee is able to deliver a given product or service in a given manner. The trustee has competence to deliver what is in the scope of the transaction.

2.1.3.2 Integrity

Integrity is the truster's belief that the trustee adheres to a set of common accepted principles (Pardue et al., 2008).

While ability "only assures that the supplier could perform. This does not mean that it will perform, and, therefore, the supplier will not necessarily be trusted. The perception that the supplier has integrity suggests that it will fulfill agreements as promised." (Shoorman et al, 2007)

2.1.3.3 Benevolence

Benevolence is "the extent to which a party is believed to want to do good for the trusting party, aside from an egocentric profit motive" (Shoorman et al., 2007).

When applying it to online marketplaces, benevolence can be defined as "the buyer's belief that a seller has beneficial motives, is genuinely concerned about the buyers' interests, and will act in a goodwill manner beyond short-term profit expectations" (Pavlou & Dimoka, 2006).

Benevolence is the truster's belief that the trustee wants to do what is good to the truster beyond egocentric profit motives (Pardue et al., 2008).

2.1.4 A-priori trust

Initial trust depends on the truster predisposition to trust (basic or a-priori trust) and in the evidence he or she has to trust the other party (direct and indirect trust).

Basic trust is comprised of all past experiences of the truster (Marsh, 1994; Shi et al., 2004). Jøsang et al. (2006) call it a-priori trust. Figure 3 illustrates. Value of a-priori trust ranges between 0 and 1, where 0 means that the truster A has no pre-disposition at all to trust party B, and 1 means that, even in the lack of any evidence, truster totally trusts party B.

Figure 3: Levels of a-priori trust

2.1.5 Trust transitivity

Trust can be direct or indirect (Jøsang et al., 2006; Shi et al., 2004; Pardue et al., 2008).

Direct trust is established from the truster direct experiences with another party, while indirect trust is derived from recommendations made by others (Jøsang et al., 2006; Shi et al., 2004; Pardue et al., 2008).

Indirect trust is established by deriving trust from someone else's trust. "Derive trust" refers to a truster formulating a trust opinion based on other's trust opinions.

Trust transitivity is the use of indirect trust in trust networks (Lifen, 2008; Jøsang et al., 2006).

There are situations where one can't rely solely in past experience and direct observations to make a trust decision. For example, when someone has no expertise on a specific domain, then relying on opinions of experts and on the reputation of the trust object is a totally acceptable way of compiling information that would help the process of decision-making. The weight applied to such opinions will depend in how much the truster also trusts the source of those opinions. Consequently, even though he or she won't take the provided trust opinion as a final value for his or her decision, that opinion will collaborate with a certain degree of influence in his final decision.

Ring and Van de Ven (1992) recognize that reputation is necessary for trust. Trust is more likely to be extended to an organization when that organization earns a reputation

for following norms of equity. However, reputation is not the only factor that affects trust (Ring and Van de Ven, 1992).

Yandle (2010) examined the trust lost due to the financial collapse of 2007-2009.

Yandle argues that mechanisms that ensure trust include “the reputational capital of the service firm or owner, and recommendations from other customers of repair services that can be assessed directly only through experience”.

Pardue et al. (2008) state that “trustors communicate their perceptions of the trustworthiness of a trustee to other trustors in online reputation systems”. However, interestingly they also noted that most of these communications tend to make reference to the trustor's perception of the trustee's ability and integrity. The benevolence dimension had only a small number of references.

Jøsang et al. (2006) propose that trust transitivity can be measured using trust network analysis with subjective logic. In a trust network, trust opinions expressing someone's belief, disbelief and uncertainty about a trustee in a given situation can be derived from a combination of other parties' trust opinions when they are in the same trust path.

A trust path is a sequence of trustors and trustees on a given trust scope. For example, A trusts B that trusts C is a trust path between A and C.

Chandrasekharan and Esfandiari (2000) affirm that “formally, the trust relation is not transitive”. But they recognize the potential transitivity of trust when they propose that “however, trust is considered weakly transitive, in the following sense: there is a probability that A might trust C, if B recommends C to A for action X”. That is in the

sense that A will use B's observations as part of the parameters to formulate its own trust level about C, which is compatible with Jøsang et al. (2006).

2.1.6 TNA-SL

Trust opinion values can be calculated using trust network analysis with subjective logic (TNA-SL). In a trust network, people, organizations and software agents can derive indirect trust in other parties from the members of the trust network. Jøsang et al. (2006) describe an approach to measure derived indirect trust opinion values. TNA-SL consists of the following elements:

1. A concise notation to represent trust transitivity in a trust network
2. A method for simplifying complex trust networks so that they can be expressed in a concise form
3. Trust measures expressed as opinions, so that derived indirect trust can be automatically and securely computed using subjective logic

A trust network is comprised of participants that can derive trust from other participants in the same trust path. A trust path is a set of trust arcs between two parts.

A trust arc establishes the relationship between two parties: the truster and the trustee. The truster is a person or a group that makes a trust decision. The trustee can be a person, group, company, product or service.

A trust path can be direct or indirect. A direct trust path means that the truster trusts the trustee directly from experience with him. Direct trust paths have a single trust arc. An indirect trust path means that the truster is using one or more parties as referral to the trustee. Indirect trust paths have multiple trust arcs.

Derived trust measures are obtained using other parties' trust opinions in an indirect trust path.

Figure 4 illustrates that Alice has derived indirect functional trust (if-trust) in Charlie. Alice trusts Bob as someone that can refer her to a good mechanic who can repair her car. Bob trusts Charlie as a good mechanic. Figure 4 shows that Alice has direct trust in Bob, who has direct trust in Charlie. Consequently, Alice can derive from Bob indirect trust in Charlie. That is possible because the trust that Alice has in Bob is specific to the scope of being a referral for a good mechanic.

Scope is defined as “the specific type(s) of trust assumed in a given trust relationship” (Jøsang et al., 2006). The direct trust that Alice has in Bob is an example of direct referral trust. The direct trust Bob has in Charlie is an example of direct functional trust.

The scope of a trust arc defines what the truster trusts the trustee. One may trust another party as a really good professor, but may not trust that same party for piloting an airplane or executing a cyrurgic intervention. It is based on what exactly the trustee is promising to deliver.

Figure 4: Example of a single path

It is also possible to combine multiple referrals in a parallel trust combination. Let's say Alice knows both Bob and David. Both of them had recommended Charlie as a good mechanic. Therefore, now there is a combination of two possible trust paths from Alice to Charlie, one being derived from Bob and another one being derived from David. Assuming Alice trusts both, this additional trust path would help increase her indirect trust in Charlie.

Figure 5 represents the two parallel trust paths.

Figure 5: Example of two parallel trust paths

In TNA-SL, canonical expressions are used to define trust paths. Canonical expressions are representations “of a trust graph in structured notation where every arc only appears once” (Jøsang et al., 2006).

2.1.6.1 Belief, Disbelief, and Uncertainty

Huang and Nicol (2009) had established a relationship between the dichotomy belief-disbelief with trust-distrust. An additional element to such relationship is the uncertainty attribute (Jøsang et al., 2006).

Belief

Belief in subjective logic refers to the amount of belief in support of the affirmation “A trusts B about S” as being true (Jøsang, 2009). Using the example illustrated in Figure 6, it would be Alice’s belief that Charlie is a good mechanic.

Disbelief

Disbelief in subjective logic refers to the amount of belief in support of the affirmation “A trusts B about S” as being false (Jøsang, 2009). Using the example from Figure 5, disbelief refers to Alice’s belief on Charlie as a not good mechanic.

Uncertainty

Uncertainty refers to a situation where there is no evidence to support of the affirmation “A trusts B about S” as being true or false. In Figure 5, uncertainty refers to Alice’s uncertainty that Charlie is a good mechanic.

According to Das and Teng (1996) “trust is instrumental in reducing uncertainty”.

2.1.6.2 Trust Opinions

In TNA-SL, a trust opinion expresses the belief that the truster has about a given scope based on the evidence that he or she has available. A trust opinion is a vector of values ranging from 0 to 1 representing belief, disbelief, uncertainty, and the a-priori trust value.

A trust opinion is based on evidence that the truster has and that leads the truster to believe that the trustee will deliver what is being promised. It is only when one party has evidence to trust another party that the trust relation is established. The evidence can be based on observations from the direct experience between the parties (direct trust), or on observations of other parties about the trustee (indirect trust). Even when there is no apparent reason or evidence for trusting another party in an initial relationship, it is actually the truster’s past experience and disposition to trust (a-priori trust) that will guide a final decision on whether or not to trust (McKnight et al., 1998; Marsh, 1994).

2.1.6.3 Computing Transitivity

Trust opinion values on direct trust relationships are computed based on the number of positive observations from one party to another (represented by the letter r), and the number of negative observations from one party to another (represented by the letter s).

A trust opinion for an indirect derived trust is computed in TNA-SL using two methods: discounting and consensus.

Discounting

Discounting refers to the method to calculate a trust opinion that results from a transitive indirect trust path. Figure 6 illustrates discounting. The symbol $\otimes$ is used to represent discounting.

Figure 6: Example of discounting

Alice derives her trust opinion about Charlie through Bob. Alice's trust opinion about Bob is used to discount Bob's trust opinion about Charlie.

Consensus

Consensus is a combination of different trust opinions about the same trustee and in the same scope. Consensus represents a consensual derived trust opinion. As a result, the consensus operator amplifies belief and/or disbelief and reduces uncertainty. Figure 7 illustrates how consensus is obtained. The symbol $\oplus$ is used to represent consensus.

Figure 7: Example of consensus

Alice derives her trust opinion about Charlie through Bob and David. Alice's trust opinion about Bob is used to discount Bob's trust opinion about Charlie. Alice's trust opinion about David is used to discount David's trust opinion about Charlie. The two discounted trust opinions are brought together by the consensus operator.

2.1.6.4 Risk

Risk is the variable used by the truster to take the final decision to trust or not trust the trustee. The truster first will take in consideration the reasons he or she has to trust the trustee and then decides whether or not to involve the trustee regarding the particular scope.

2.2 Lessons learned

The lessons learned from the literature review are:

- Trust is an important element in relationships. Lack of trust results in a pay-off of zero for customers and suppliers. Lack of trust prevents society from achieving outcomes.
- Trust has three main trust dimensions: ability, integrity and benevolence
- Transitive trust values can be measured using trust network analysis with subjective logic (TNA-SL). Subjective Logic offers a way to easily represent transitivity in trust networks and calculate trust opinion values that will represent a degree of belief, disbelief, and uncertainty in a transaction.
- Transitivity is an important concept to understand reputation systems and to measure trust opinion values in a marketplace.
- Negative and positive observations about trustees can be used to calculate trust opinion values.
- Multiple trust opinions in a same trust path can be combined using the consensus and discounting operators provided by TNA-SL.

- Literature doesn't provide the connection between trust dimensions and trust transitivity. Jøsang's trust network analysis model can be used to calculate trust opinions based on observations on the three trust dimensions proposed by Mayer et al. (1995): ability, integrity, and benevolence.
- Without trust transaction costs increase (Tullberg, 2008).
- Trust is a low-cost substitute for police, regulators, and court actions, and can reduce transaction cost (Yandle, 2010). Negotiation costs are lower when people trust each other. Monitoring costs are reduced, because constant check on other party trustworthiness is no longer necessary (Poel, 2005).
- Trust is essential to good market operation. A well-trusted marketplace spends less in attracting customers and in managing their interactions (Iansiti & Levien, 2004).
- The number of deals can be increased as increased trust reduces uncertainty for customers about suppliers' solutions. Trust is instrumental in reducing uncertainty (Das & Teng, 1996).

3 RESEARCH METHOD

Chapter 3 describes the method used to carry out this research. It is organized into three sections. Section 3.1 describes the research approach. Section 3.2 provides the research design. Section 3.3 describes the steps undertaken to carry out the research.

3.1 Research approach

Information is collected from the Eclipse Marketplace and used to infer observations about members and solutions.

Observations are used to calculate trust opinion values (belief, disbelief, and uncertainty) in direct trust arcs in a trust network.

Table 4 presents the trust model that anchors the hypotheses to be advanced.

Table 4: Trust model

Independent variables	Dependent Variables		
Positive and negative observations on solution supplier's trust dimensions (Mayer et al., 1995):	ω (trust opinion values) (Jøsang et al., 2006)		
Ability + Integrity + Benevolence	Uncertainty value	Belief value	Disbelief value

The following two Hypotheses are advanced:

Hypothesis 1. Additional observations on a solution supplier's ability, integrity, and benevolence decrease customer's uncertainty about the supplier's solution.

Hypothesis 2. Additional observations on a solution supplier's ability, integrity, and benevolence increase customer's belief about the supplier's solution.

As belief, uncertainty, and disbelief sum to 1, in this research we test only the first two of these three trust opinion values. It's not necessary to test the third opinion value.

Software comprised of three packages was developed.

The first package establishes a connection with a database created to store the research data.

The second package is a web-crawler used to collect data from the Eclipse Marketplace and save it to the database.

The third package uses trust network analysis with subjective logic (Jøsang et al., 2004) to calculate benchmark trust opinion values (ω -benchmark), and generates simulated observations on solution suppliers' ability, integrity, and benevolence.

After simulated observations are generated, trust opinion values are re-calculated (ω -simulation).

The simulated trust opinion values (ω -simulation) are compared to benchmark trust opinion values (ω -benchmark) to test Hypotheses 1 and 2, and answer the research question.

Table 5 shows how trust opinion values are compared to test Hypotheses 1 and 2.

Table 5: Test of hypotheses

	H1 is rejected if	H2 is rejected if
Simulated observations on solution supplier's:	Uncertainty value on	Belief value on
Ability + Integrity + Benevolence	$\begin{matrix} (\omega\text{-simulation}) \\ > \\ (\omega\text{-benchmark}) \end{matrix}$	$\begin{matrix} (\omega\text{-simulation}) \\ < \\ (\omega\text{-benchmark}) \end{matrix}$

Table 5 shows that if the uncertainty value of the simulated trust opinion is higher than the uncertainty value of the benchmark trust opinion then Hypothesis 1 is rejected.

Hypothesis 1 is rejected because the uncertainty value (between 0 and 1) of a trust opinion should decrease when simulated observations on solution supplier's ability, integrity, and benevolence are added.

If the belief value of the simulated trust opinion values is lower than the belief value of benchmark trust opinion values then Hypothesis 2 is rejected.

Hypothesis 2 is rejected because the belief value (between 0 and 1) of a trust opinion should increase when simulated observations on solution supplier's ability, integrity, and benevolence are added.

Figure 8 shows the relation between observations on the keystone, members, and solution suppliers and the calculation of trust opinion values in a transitive trust network.

Figure 8: Relation between observations and trust opinion values (ω)

Figure 8 shows that the customer's opinion about the keystone (ω_1) has its trust opinion values (belief, disbelief, and uncertainty) calculated based on observations about the keystone. The keystone's opinion about the marketplace members (ω_2) has its trust opinion values calculated based on observations about marketplace members. The marketplace members' opinions about a solution (ω_3) have their trust opinion

values calculated based on observations about the supplier's solution. In the indirect trust arc between the customer and the supplier's solution, the customer's opinion about the supplier's solution (ω_4) is calculated using TNAL-SL to combine ω_1 , ω_2 , and ω_3 .

3.2.1 Unit of analysis

The unit of analysis is information on a solution published in the marketplace website operated by the Eclipse Foundation.

For each solution, the information collected is comprised of:

1. Solution name
2. Solution category
3. Indication of whether or not the solution is tagged with the Eclipse Foundation
Member logo
4. List of members that selected the solution as their favourite
5. Reviews provided by members about the solution

3.2.2 Source of data

The source of data for this research is the Eclipse Marketplace website available at:
<http://marketplace.eclipse.org/>.

3.2.3 Time period

Data was collected during the months of April and June of 2010.

3.2.4 Sample selection

The solutions included in the sample were selected using three steps:

1. In the Eclipse Marketplace the solution categories that met the following criteria as of June, 21st 2010 were selected:
 - a) Contains at least 25 solutions and no more than 50 solutions
 - b) Contains more than one solution with a review provided by a marketplace member
 - c) Contains more than one solution placed in the list of favorite solutions of marketplace members
2. Randomly select two solution categories from the list of categories that fit the criteria defined on step 1.
3. For each of the two categories, select the first eight solutions identified within the marketplace website with the highest number of marketplace members that had selected the solution as their favourite.

Information about 16 solutions was collected (2 categories x 8 solutions per category).

3.3 Research steps

Table 6 outlines the steps undertaken to complete this research.

Table 6: Research steps

Step	Dominant activity undertaken	Deliverable
1 Develop model	Develop a trust model to test Hypotheses 1 and 2 based on three trust dimensions identified in the literature review and trust network analysis with subjective logic	Trust model
2 Operationalize the model	<p>2.1 Develop a database schema to store information on the solutions in the sample</p> <p>2.2 Develop a web-crawler to collect information about the 16 solutions in the sample</p> <p>2.3 Develop software to represent a trust network and compute trust opinion values (belief, disbelief, and uncertainty) to use as benchmarks.</p> <p>2.4 Develop software to generate additional simulated observations about solution supplier's ability, integrity, and benevolence</p>	Details about the operationalized model
3 Data acquisition	<p>Acquire data following three steps:</p> <p>3.1 Select two solution categories to collect data</p> <p>3.2 Launch the web-crawler developed on step 2.2 to collect and store in a database information about solutions published in the Eclipse Marketplace</p> <p>3.3 For each solution, code each review published by a member as positive, negative, or neutral based on the content of the review.</p>	Database on solutions

4 Benchmark	Execute software developed in step 2.3 to calculate benchmark trust opinion values using data acquired from step 3.2 and 3.3	Table with benchmark trust opinion values (belief, disbelief, and uncertainty)
5 Ability Simulation	<p>5.1 Execute software developed in step 2.4 to generate additional simulated observations pertinent to a solution supplier's ability.</p> <p>5.2 Execute software developed in step 2.3 to re-calculate trust opinion values using data acquired from step 3.2 and 3.3 plus simulated data generated on step 5.1</p>	Table with simulated trust opinion values after additional simulated observations on solution supplier's ability are added to the database
6 Benevolence Simulation	<p>6.1 Execute software developed in step 2.4 to generate additional simulated observations pertinent to a solution supplier's benevolence.</p> <p>6.2 Execute software developed in step 2.3 to re-calculate trust opinion values using data acquired from step 3.2 and 3.3 plus simulated data generated on step 6.1</p>	Table with simulated trust opinion values after additional simulated observations on solution supplier's benevolence are added to the database
7 Integrity Simulation	<p>7.1 Execute software developed in step 2.4 to generate additional simulated observations pertinent to a solution supplier's integrity.</p> <p>7.4 Execute software developed in step 2.3 to re-calculate trust opinion values using data acquired from step 3.2 and 3.3 plus simulated data generated on step 7.1</p>	Table with simulated trust opinion values after additional simulated observations on solution supplier's integrity are added to the database

8 Combined simulation	Execute software developed in step 2.3 to re-calculate trust opinion values using data acquired from step 3.2 and 3.3 plus simulated data generated on steps 5.1, 6.1, and 7.1 (ability, integrity and benevolence simulations)	Table with simulated trust opinion values combining simulated observations on solution supplier's ability, integrity, and benevolence
9 Test Hypotheses	Compare trust opinion values belief and uncertainty from the results of simulations with the trust opinion values belief and uncertainty of the benchmark	Compare results of simulations with benchmark

3.3.1 Step 1 – Develop model

A model to test Hypotheses 1 and 2 is developed. It uses three trust dimensions as independent variables (suppliers' ability, integrity, and benevolence) and two dependent variables (customer's uncertainty and belief about a supplier's solution).

The model posits that a higher number of observations of a solution supplier's ability, integrity, and benevolence (independent variables) decreases customer's uncertainty about the supplier's solution, and increases customer's belief about the same supplier's solution (dependent variables).

3.3.2 Step 2 – Operationalize the model

The model is operationalized by developing a database schema to store information about solutions and by implementing web crawler software to collect data from the Eclipse marketplace, compute trust opinions, and generate additional simulated observations.

3.3.3 Step 3 – Data acquisition

The web-crawler is used to collect information on 16 solutions from two randomly selected solution categories. The list of solution categories is provided in Appendix D.

The following information is collected:

1. Solution name
2. Solution category
3. Indication of whether or not the solution is tagged or not with the Eclipse Foundation Member logo
4. List of members that selected the solution as their favourite
5. Reviews provided by members about the solution

Based on the information collected from the marketplace we infer observations that a customer can use to decide whether or not to trust solutions and members.

Observations were coded as positive, negative, or neutral.

Negative and positive observations were used to compute trust opinion values using TNA-SL. Neutral observations were not used.

Observations about solutions related to reviews provided by members were examined by the researcher and based on his judgement coded as positive, negative, or neutral

The presence of the Eclipse Foundation Member logo (icon:) associated with a solution was coded as a positive observation about the solution.

An observation about a member was coded as positive if the member publishes a comment and/or selects a solution as a favourite solution.

The submission of a solution to the Eclipse Marketplace is also considered as a positive observation.

3.3.4 Step 4 - Benchmark

The method to calculate trust opinions embodied in the software is executed providing a customer with parameterized a-priori trust value and the number of positive and negative observations about the keystone.

The software receives the following parameters: customer a-priori trust value (real number between 0 and 1) denoted (a), number of positive observations that the customer has about the keystone denoted (r), number of negative observations that the customer has about the keystone denoted (s).

The initial trust that would be put in any member of the community in the absence of any positive and negative observations must be a number between 0 and 1. We assume a default a-priori trust value of 0.5, as it is the average value to represent initial trust.

We assume that the member has at least one positive observation about the Eclipse Foundation (that could be the availability of the marketplace itself). And we assume that the member had no negative observations about the Eclipse Foundation.

The TNA-SL model uses subjective logic probability and it doesn't rely on Bayesian probability recommendations for parameter sensitivity or confidence interval determination. The parameters were defined by inference based on the facts assumed about the Eclipse Foundation and the members.

Therefore the initial parameters to run the software are:

$$a = 0.5$$

$$r = 1$$

$$s = 0$$

The software is then launched using data acquired from Eclipse Marketplace.

Benchmark trust opinion values (belief, disbelief, and uncertainty) are returned for all solutions collected by the web-crawler and stored in the database.

After the benchmark execution of the software, the software methods to generate additional simulated observations pertinent to a solution supplier's ability, integrity, and benevolence are executed.

Two simulation passes were performed. The first pass was performed with solutions from category #1. The second pass was performed with solutions from category #2.

The second pass was used to corroborate the findings of the first pass.

3.3.5 Step 5 - Ability simulation

To provide additional observations about a solution supplier's ability, we simulate a system where members are invited to rate the solution with 1, 2, or 3 stars. One star means that the solution is not able to deliver what is promised, two stars means that the solution delivers what is promised with an average performance as any other solution; three stars means that the solution delivers what is promised better than average.

For a member that had reviewed a solution the simulation rates as:

- 1 star if the member had provided negative feedback about the solution.
- 2 or 3 stars if the member had provided positive feedback about the solution.

For a member that had selected a solution as favourite, the simulation randomly assigns 2 or 3 stars.

If the same member had provided a review and also selected the solution as favourite the simulation assigns a single random rate of 2 or 3 stars.

A simulated 1 star is considered as a negative observation.

A simulated 2 stars is considered as a neutral observation and is not computed.

A simulated 3 stars is considered as a positive observation.

3.3.6 Step 6 - Benevolence simulation

A benevolent behavior of a solution supplier can be verified by the level of engagement it has with the community and on how much information it shares without expecting anything in return.

In order to simulate observations about the benevolence of a solution supplier we assume that the keystone provides them with a space in the marketplace where they can share free whitepapers with relevant content about their expertise with the community members. The greater the number of whitepapers they share, the more benevolent they are. The simulation randomly generates an integer number between 0 and 2 for the simulated number of whitepapers of each solution supplier.

A simulated number of 0 whitepapers is considered as a negative observation.

A simulated number of 1 or 2 whitepapers is considered as a positive observation.

3.3.7 Step 7 - Integrity simulation

Integrity is derived from the perception that the solution supplier adheres to a set of common accepted principles. The main source of observations for such behaviour relies on the reviews provided by other users. For the purpose of this simulation we add observations about integrity that are derived from an hypothetical “Integrity Seal” awarded by the Keystone to selected solutions suppliers that had hypothetically

followed a set of established norms and principles. The simulation randomly applies the “Integrity Seal” to 25% of the solution suppliers.

The simulated presence of an “Integrity Seal” is considered as a positive observation.

3.3.8 Step 8 - Combined simulation

After the additional simulated observations on a solution supplier’s ability, integrity, and benevolence are generated, the simulation software is re-executed to re-calculate trust opinion values using data acquired from Eclipse Marketplace plus simulated data that were generated. Updated trust opinion values (belief, disbelief, and uncertainty) are returned for all solutions collected by the web-crawler and stored in the database.

4 BENCHMARK, SIMULATIONS, AND RESULTS

This chapter is divided into six sections. Section 4.1 presents the trust research model developed. Section 4.2 describes the implementation of the software to calculate the benchmark trust opinion values and generate simulated observations. Section 4.3 describes the data collection. Section 4.4 describes the software execution to calculate the benchmark trust opinion values. Section 4.5 describes the software execution to generate the simulations. Section 4.6 compares the simulations' results with the benchmark results.

4.1 Step 1 - Develop model

Table 7 illustrates the trust research model used to test Hypotheses 1 and 2.

Table 7: Trust research model

	Customer's trust opinion (ω) about supplier's solution	
	H1	H2
Additional observations on solution supplier's:	Uncertainty value on ω -simulation in relation to ω -benchmark	Belief value on ω -simulation in relation to ω -benchmark
+Ability +Integrity +Benevolence

In Table 7 the independent variables are observations on solution supplier's ability, integrity, and benevolence. The dependent variables are customer's belief and uncertainty about a supplier's solution.

We expect that adding observations on solution supplier's ability, integrity, and benevolence decreases customer uncertainty about a supplier's solution and increases customer belief on a supplier's solution.

4.2 Step 2 – Operationalize the model

In this step we create the database to store information about solutions, develop the trust model software containing a web-crawler to collect data from selected solution categories of the Eclipse Foundation Marketplace website, implement classes to represent a trust network and compute trust opinion values, and implement methods to generate additional simulated observations about solution suppliers.

4.2.1 Trust model software packages

The software consists of three main packages: 1. a database wrapper; 2. a web-crawler to collect the data; and 3. a set of classes to a) represent the trust network and compute trust opinion values, and b) generate additional simulated data about observations on solution suppliers.

Table 8 describes the classes implemented in the software.

Table 8: Classes implemented in the software

Package 1: trustmodel.db	
Class	Description
Wrapper.java	Class to establish the connection with database used to store data collected by the web-crawler from the Eclipse marketplace. It is used by other classes to perform insert, update, and delete operations in the database Tables.
Package 2: trustmodel.util	
Class	Description
Web.java	Class to collect data from Eclipse marketplace (web-crawler)
Package 3: trustmodel.trust	
Class	Description
Arc.java	Class to represent and compute trust opinion values on direct and indirect trust paths
IndirectArc.java	Class to represent indirect trust paths
Nodes.java	Class to represent the parties involved in the trust network
Observation.java	Class to represent observations about the trust parties
Opinion.java	Class to represent trust opinions
Scope.java	Class to represent the scope of the trust network

4.2.2 Database schema

A database schema is created to store the information about solutions retrieved from the marketplace.

Table 9 describes the database Tables used by the classes implemented in the simulation software.

Table 9: Database tables used to collect and analyze data

Database Table	Description
Directarcs	Arcs from direct trust paths collected from Eclipse marketplace
Indirectarcs	Arcs from indirect trust paths collected from Eclipse marketplace
Nodes	All trust parties involved in the Eclipse marketplace trust network
Observations	Observations collected from Eclipse marketplace
Scope	Scope of solutions collected from Eclipse marketplace
Variants	Scope variants of trust arcs (customer, keystone, reviewer, or solution)

The first package implemented in the software makes the database available to the simulation through the wrapper class.

4.2.3 Web-crawler

Package 2 has a web-crawler developed to browse the Eclipse Marketplace website and list all solution categories available. The researcher is then able to select categories to collect data. The crawler reads and interprets HTML content from the URL <http://marketplace.eclipse.org> looking for information about the solutions of the selected categories, finds the information and saves the collected data to a set of tables in the database connected with the first package.

The following entries are considered as valid observations and collected by the web-crawler: reviews from members about solutions; list of members that have put the solutions in their favourites list; solutions tagged with Eclipse Foundation Member icon.

The observations are coded as positive, negative, and neutral as outlined in section 3.3.3 Step 3 – Data acquisition.

Table 10 describes the main methods of the class Web.java (methods' parameters were omitted):

Table 10: Methods implemented in the class Web.java

Method	Description
getComments()	Reads comments made by marketplace members about a given solution
getSolutions()	Reads a list of solutions available on the marketplace for a given scope
getSolutionDetails()	Reads the details about a given solution and get the list of members that had selected the solution as their favourite
loadPage()	Reads the html content from a page of the marketplace website (crawler)
recordNode()	Stores information about a member or solution in the database
recordTrustArc()	Stores information about the trust relationship between members and solutions in the database

4.2.4 Trust network representation and computation of trust opinion values

The class Arc.java is used to represent and compute trust opinion values for all direct and indirect arcs of the trust paths between the customer and the solution. It is used to calculate benchmark trust opinion values and it is also used to calculate simulated trust opinion values after the additional simulated observations are added to the database.

Table 11 describes the main methods of the class Arc.java:

Table 11: Methods implemented in the class Arc.java

Method	Description
buildTransitiveTrustNetwork()	Reads and computes all trust arcs collected by the web crawler to build the transitive trust network canonical expressions
calcConsensus(List of Arcs)	Performs a consensus calculation of a given list of trust arcs
calcDiscounting(List of Arcs)	Performs a discounting calculation of a given list of trust arcs

In this research we use a slightly modified version of the notation proposed by Jøsang et al. (2006) to represent a transitive trust network. This notation is described in Appendices A and B.

Appendix A describes the notation used in the software to express trust arcs and trust paths.

Appendix B describes the notation used in the software to express and calculate trust opinions.

Appendix C describes the notation and formulas used to represent and calculate discounting and consensus.

The method buildTransitiveTrustNetwork() of the class Arc.java uses the notation outlined in appendices A and B to generate a representation of all trust arcs involved in

the trust path between the customer and each solution, and uses the formulas presented in appendix C to compute trust opinion values for each trust arc.

The method `buildTransitiveTrustNetwork()` is first executed using data collected from Eclipse marketplace before additional simulated observations are added to the database to calculate benchmark trust opinion values. It is re-executed later, after the ability, integrity, and benevolence simulations, to calculate the simulated trust opinion values.

The method `buildTransitiveTrustNetwork()` generates trust paths and computes trust opinion values for the following direct and indirect trust arcs:

- a) Direct trust arc between customer and the keystone: **[customer, keystone-code, dr.KEY.scope-code]**
- b) Direct trust arc between keystone and members: **[keystone-code, member-code, dr.REV.scope-code]**
- c) Direct trust arc between a member and a solution: **[member-code, solution-code, df.SOL.scope-code]**
- d) Direct trust arc between the keystone and a solution: **[keystone-code, solution-code, df.SOL.scope-code]**
- e) Indirect trust arc between the keystone and a solution: **[keystone-code, solution-code, if.SOL.scope-code]**
- f) Indirect trust arc between customer and solution: **[customer, solution-code, if.SOL.scope-code]**

Table 12 describes the scope variants used in the representation of the trust arcs.

Table 12: Scope variants used to build the transitive trust network

Scope variant	Description
dr.KEY	Direct referral trust in a keystone
dr.REV	Direct referral trust in a reviewer (marketplace member)
df.SOL	Direct functional trust in a solution
if.SOL	Indirect functional trust in a solution

Figure 9 presents the formula using TNA-SL to achieve the final customer's trust opinion values about a solution.

$$\begin{aligned}
 \omega[\text{customer}, \text{solution-code}, \text{if.SOL.scope-code}] = & \\
 & \omega[\text{customer}, \text{keystone-code}, \text{dr.KEY.scope-code}] \otimes \\
 & (\omega[\text{keystone-code}, \text{solution-code}, \text{df.SOL.scope-code}] \oplus \\
 & (\omega[\text{keystone-code}, \text{member-code}, \text{dr.REV.scope-code}] \otimes \\
 & (\omega[\text{member}_1\text{-code}, \text{solution-code}, \text{df.SOL.scope-code}] \oplus \\
 & \omega[\text{member}_n\text{-code}, \text{solution-code}, \text{df.SOL.scope-code}])))
 \end{aligned}$$

Figure 9: Customer's trust opinion values formula

The trust opinion values in each direct trust arc are computed based on the number of positive (r) and negative (s) observations from the truster about the trustee.

Table 13 shows how the parameters r and s are defined for each different type of direct trust arc on the calculation of the benchmark trust opinion values and simulated trust opinion values.

Table 13: Parameters r and s used for trust opinion values calculation

Direct trust arc	Parameters to calculate benchmark trust opinion values	
	r	s
[customer, keystone]	Manually entered as a software parameter. Default = 1	Manually entered as a software parameter. Default = 0
[keystone, solution]	Based on: 1. Submission of a solution 2. Presence of Eclipse Foundation Member logo	Default = 0
[keystone, member]	Based on: 1. Member activity on the marketplace	Default = 0
[member, solution]	Based on: 1. Content of reviews submitted by members coded as positive 2. List of members that had selected the solution as their favourite	Based on: 1. Content of reviews submitted by members coded as negative
Direct trust arc	Parameters to calculate simulated trust opinion values	
	r	s
[customer, keystone]	Same as benchmark	Same as benchmark
[keystone, solution]	Same as benchmark plus simulated observations	Same as benchmark plus simulated observations
[keystone, member]	Same as benchmark	Same as benchmark
[member, solution]	Same as benchmark plus simulated observations	Same as benchmark plus simulated observations

Table 13 shows that for the direct trust arc between the customer and the keystone, the parameters r and s are manually entered at the moment of the software execution. To calculate the benchmark and simulated trust opinion values we considered that the customer had at least one positive observation about the keystone and no negative observations.

For the direct trust arc between the keystone and the solution, the parameter r is defined based on the presence or not of the Eclipse Foundation logo on the solution's listing in the marketplace. The submission of the solution to the marketplace is also considered as a positive observation, which is made to consider that the keystone has at least one positive observation about the solution. Additional positive and negative observations from the keystone about the solutions are generated by the simulation and used to calculate simulated trust opinion values.

For the direct trust arc between keystone and members, the parameter r is defined based on the activity of the member within the marketplace. Each feedback provided by the member (reviews and selection of solutions as favorites) is considered as a positive observation about the member. No negative observations were collected or simulated about members.

For the direct trust arc between the member and the solution, the parameters r and s are defined based on the content of reviews provided by members and on the number of members that had selected the solution as their favorite. Reviews are considered as positive, negative, or neutral based on the judgement of the researcher. The selection of the solution as favorite by member is considered as a positive observation about the

solution. Additional positive and negative observations from the member about the solutions are generated by the simulation used to calculate simulated trust opinion values.

Section 4.2.5 describes how the additional simulated observations are generated.

The trust opinion values of the **indirect** trust arcs between customer, keystone, and solution are computed based on discounting and consensus of the trust opinion values of the **direct** trust arcs in the trust path as shown in figure 11.

The final result of the operations performed by `buildTransitiveTrustNetwork()` is the customer's trust opinion values comprising belief, disbelief, and uncertainty about each solution.

The output of `buildTransitiveTrustNetwork()` method for each solution is displayed using a template described in appendix J.

4.2.5 Generate simulated observations

The class `Observation.java` is used to represent observations about solutions and members, count the number of positive and negative observations, and generate simulated observations.

Table 14 describes the main methods of the class `Observation.java`:

Table 14: Methods implemented in the class Observation.java

Method	Description
countRS()	Counts the number of positive (r) and negative (s) observations about a given solution or member
getObsbyArc()	Reads all observations related to a given trust arc
simulateAbility()	Generates simulated observations about a solution supplier's ability as outlined in section 3.3.5
simulateBenevolence()	Generates simulated observations about a solution supplier's benevolence as outlined in section 3.3.6
simulateIntegrity()	Generates simulated observations about a solution supplier's integrity as outlined in section 3.3.7

After executing the methods `simulateAbility()`, `simulateBenevolence()`, and `simulateIntegrity()` of the class `Observation.java`, the researcher is then able to re-execute `buildTransitiveTrustNetwork()` method of the class `Arc.java` to analyze the impact of the simulation on the customer's trust opinion values.

4.3 Step 3 – Data acquisition

The `web.java` class (web-crawler) is executed to collect information about solutions from the Eclipse Marketplace from two selected categories denoted Documentation and Team development.

Figure 10 shows that the Eclipse Marketplace website provided information on 1,000 solutions as of June 12, 2010.

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The Barracuda Eclipse Plugins are complete development for the programming language JPL - JPL as part of the Panther development

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Barracuda JPL/Panther development environment
The Barracuda Eclipse Plugins are complete development for the programming language JPL - JPL as part of the Panther development

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Language IDE

New and Updated Solutions

Figure 10: Eclipse Marketplace

Table 15 list the top 8 solutions with most observations acquired from category “Documentation” (scope code S5).

Table 15: List of top 8 solutions with the most observations - scope S5

SolutionCode	# observations
umlet-uml-tool-fast-uml-diagrams	60
Wireframesketcher	30
rcp-developer	18
mylyn-wikitext	15
Jautodoc	7
Eclox	6
Jdoceditor	5
Texlipse	5

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Table 16 list the top 8 solutions with most observations acquired from category “Team Development” (scope code S15).

Table 16: List of top 8 solutions with most observations - scope S15

SolutionCode	# observations
Subclipse	52
subversive-svn-team-provider	29
mercurialeclipse-was-hgeclipse	24
pulse-download-manage-and-maintain-eclipse-tools	21
atlassian-connector-eclipse	15
collabnet-desktop-eclipse-edition	6
amazon-s3-browser	3
mintjams-content-management	3

In total 321 observations about the 16 solutions were inferred from the data collected from Eclipse Marketplace involving: the submission of the 16 solutions; 18 solution reviews by marketplace members; 282 selections of solutions as favourite by marketplace members; 5 solutions tagged with the Eclipse Foundation member logo.

The solution reviews by marketplace members (18 in total) were individually analysed to be considered as positive, negative, or neutral. All the other observations about solutions were by default considered as positive.

Figure 11 displays examples of reviews retrieved from the Eclipse Marketplace website.

Reviews

[Add a Review](#)

Posted on 19/03/2010

WireFrameSketcher is really useful

By **KAPT**

We are working on WebApps design and development. We were used to sketch our future screens on basic tool such as a PowerPoint-like application. We tried WireframeSketcher to design a new service for SmartPhones and we were pleasantly surprised that was fine! even for SmartPhones screens design. And it is really convenient since we don't have to get off Eclipse.
Good Job, we recommend it!

[Login](#) or [register](#) to post comments

Posted on 06/03/2010

Great Prototyping Plugin

By **hoffmann**

Really great tool. I've tried several prototyping tools, such as Balsamiq Mockups, Axure RP or Mockup Screens and my favorite was Balsamiq Mockups. But WireframeSketcher is a must-have plugin for everyone who works with Eclipse.

Many thanks!

[Login](#) or [register](#) to post comments

Figure 11: Example of reviews in Eclipse Marketplace

Figure 12 displays a list of members that had selected a specific as their favourite.

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Markets

≈

1,001 Solutions and counting

Favorited By

All

[Peter Severin](#)
[Holger Voormann](#)
[Todd E. Williams](#)
[Mark Phippard](#)
[Bruce Doan](#)
[Burkhard Vogel](#)
[bgr](#)
[J. Brun](#)
[hoffmann](#)
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[Peter S. Phip](#)
[Holger Voormann](#)
[Todd E. Williams](#)
[Mark Phippard](#)
[Bruce Doan](#)
[Burkhard Vogel](#)
[bgr](#)

[Full](#)

Figure 12: Example of a list of members that have “favorited” a solution

4.4 Benchmark and simulations

The software is executed for three purposes: 1. calculate benchmark trust opinion values; 2. generate simulated observations; and 3. calculate simulated trust opinion values.

4.4.1 Step 4 - Benchmark calculation

The software class to build the transitive trust network with subjective logic (method `buildTransitiveTrustNetwork()` of the class `Arc.java`) is executed to generate a representation of all transitive trust paths for each solution followed by all necessary calculus that result in the final trust opinion values for the main trust arc: [customer, solution, if.scope].

The benchmark execution is performed without any additional simulated observations on the database but using only observations collected from the Eclipse Marketplace website.

The result of this execution is exemplified on appendix H with the solution code 'texlipse'.

Figure 13 displays how the parameters are passed to the software.

Figure 13: Execution of the software

The output of this benchmark execution for the solution 'texlipse' is displayed on appendix G.

4.4.1.1 Benchmark results

The initial results for the customer's trust opinion on this benchmark calculation execution for all 16 solutions (eight from each category) using observations collected from the marketplace and not adding any simulated observations are displayed in Table 16.

By comparing the benchmark results on Table 17 with the output of the simulations it will be possible to identify whether the simulated observations on a solution supplier's ability, integrity, and benevolence will increase belief and decrease uncertainty.

Table 17: Benchmark results using only observation from the marketplace website

Solution Code	Scope Code	Customer's trust opinion values about the solution		
		Belief	Disbelief	Uncertainty
umlet-uml-tool-fast-uml-diagrams	S5	0.293475051668142	0.00442869796279893	0.702096250369058
wireframesketcher	S5	0.273453093812375	0	0.726546906187625
rcp-developer	S5	0.261261261261261	0	0.738738738738739
mylyn-wikitext	S5	0.260869565217391	0	0.739130434782609
Jautodoc	S5	0.211009174311926	0	0.788990825688073
Eclox	S5	0.198653198653198	0	0.801346801346801
jdoceditor	S5	0.194444444444444	0	0.805555555555556
Texlipse	S5	0.182389937106918	0	0.817610062893082
Subclipse	S15	0.296650508755841	0	0.703349491244159
subversive-svn-team-provider	S15	0.277310924369748	0	0.722689075630252
mercurialeclipse-was-hgeclipse	S15	0.267326732673267	0	0.732673267326733
pulse-download-manage-and-maintain-eclipse-tools	S15	0.26241134751773	0	0.73758865248227
atlassian-connector-eclipse	S15	0.244444444444444	0	0.755555555555556
collabnet-desktop-eclipse-edition	S15	0.221288515406162	0	0.778711484593837
amazon-s3-browser	S15	0.168724279835391	0	0.831275720164609
mintjams-content-management	S15	0.168724279835391	0	0.831275720164609

4.4.2 Generation of simulated observations

In the second round of execution we added simulated observations about the solution supplier's ability, integrity, and benevolence as outlined in sections 3.3.4.2, 3.3.4.3, and 3.3.4.4.

4.4.3 Step 5 - Ability simulation

The method `simulateAbility()` of the class `observation.java` was used to generate simulated observations on solution supplier's ability. The simulated observations were generated as described in section 3.3.4.2 Ability.

The simulated trust opinion values resulted after the use of the method `simulateAbility()` are displayed in Table 18.

Table 18: Simulation results with simulated observations about the solution supplier's ability

Solution Code	Scope Code	Simulated trust opinion values about the solution		
		Belief	Disbelief	Uncertainty
umlet-uml-tool-fast-uml-diagrams	S5	0.299200866856291	0.00568874441284031	0.695110388730868
wireframesketcher	S5	0.284098235742336	0	0.715901764257664
rcp-developer	S5	0.274509803921568	0	0.725490196078431
mylyn-wikitext	S5	0.275145469659185	0	0.724854530340815
jautodoc	S5	0.229706390328152	0	0.770293609671848
Eclox	S5	0.211752786220871	0	0.788247213779129
jdoceditor	S5	0.211752786220871	0	0.788247213779129
Texlipse	S5	0.191990577149588	0	0.808009422850412
subclipse	S15	0.302842208428618	0	0.697157791571382
subversive-svn-team-provider	S15	0.283889575607746	0	0.716110424392254
mercurialeclipse-was-hgeclipse	S15	0.281182094741417	0	0.718817905258583
pulse-download-manage-and-maintain-eclipse-tools	S15	0.270440251572327	0	0.729559748427673
atlassian-connector-eclipse	S15	0.262032085561497	0	0.737967914438503
collabnet-desktop-eclipse-edition	S15	0.237179487179487	0	0.762820512820513
amazon-s3-browser	S15	0.18407960199005	0	0.81592039800995
mintjams-content-management	S15	0.178893178893179	0	0.821106821106821

4.4.4 Step 6 - Benevolence simulation

The method `simulateBenevolence()` of the class `observation.java` was used to generate simulated observations on solution supplier's benevolence. The simulate observations were generated as described in section 3.3.4.3 Benevolence.

The simulated trust opinion values resulted after the use of the method `simulateBenevolence ()` are displayed in Table 19.

Table 19: Simulation results with simulated observations about solution suppliers' benevolence

Solution Code	Scope Code	Simulated trust opinion values about the solution		
		Belief	Disbelief	Uncertainty
umlet-uml-tool-fast-uml-diagrams	S5	0.295486403139893	0.00420521446593775	0.700308382394169
wireframesketcher	S5	0.250915750915751	0.0274725274725275	0.721611721611722
rcp-developer	S5	0.268292682926829	0	0.731707317073171
mylyn-wikitext	S5	0.26797385620915	0	0.73202614379085
jautodoc	S5	0.178294573643411	0.0516795865633075	0.770025839793282
Eclox	S5	0.165266106442577	0.0560224089635855	0.778711484593837
jdoceditor	S5	0.218390804597701	0	0.781609195402299
Texlipse	S5	0.21025641025641	0	0.78974358974359
subclipse	S15	0.298563682271617	0	0.701436317728383
subversive-svn-team-provider	S15	0.281653746770026	0	0.718346253229974
mercurialeclipse-was-hgeclipse	S15	0.273273273273273	0	0.726726726726727
pulse-download-manage-and-maintain-eclipse-tools	S15	0.237179487179487	0.0320512820512821	0.730769230769231
atlassian-connector-eclipse	S15	0.215686274509804	0.0392156862745098	0.745098039215686
collabnet-desktop-eclipse-edition	S15	0.237410071942446	0	0.762589928057554
amazon-s3-browser	S15	0.201320132013201	0	0.798679867986799
mintjams-content-management	S15	0.201320132013201	0	0.798679867986799

4.4.5 Step 7 - Integrity simulation

The method `simulateIntegrity()` of the class `observation.java` was used to generate simulated observations on solution supplier's integrity. The simulated observations were generated as described in section 3.3.4.4 Integrity.

The simulated trust opinion values resulted after the use of the method `simulateIntegrity ()` are displayed in Table 20.

Table 20: Simulation results with simulated observations about solution suppliers' integrity

Solution Code	Scope Code	Simulated trust opinion values about the solution		
		Belief	Disbelief	Uncertainty
umlet-uml-tool-fast-uml-diagrams	S5	0.295486403139893	0.00420521446593775	0.700308382394169
wireframesketcher	S5	0.273453093812375	0	0.726546906187625
rcp-developer	S5	0.261261261261261	0	0.738738738738739
mylyn-wikitext	S5	0.260869565217391	0	0.739130434782609
jautodoc	S5	0.211009174311926	0	0.788990825688073
Eclox	S5	0.198653198653198	0	0.801346801346801
jdoceditor	S5	0.194444444444444	0	0.805555555555556
texlipse	S5	0.182389937106918	0	0.817610062893082
subclipse	S15	0.298563682271617	0	0.701436317728383
subversive-svn-team-provider	S15	0.277310924369748	0	0.722689075630252
mercurialeclipse-was-hgeclipse	S15	0.267326732673267	0	0.732673267326733
pulse-download-manage-and-maintain-eclipse-tools	S15	0.26241134751773	0	0.73758865248227
atlassian-connector-eclipse	S15	0.254901960784314	0	0.745098039215686
collabnet-desktop-eclipse-edition	S15	0.221288515406162	0	0.778711484593837
amazon-s3-browser	S15	0.168724279835391	0	0.831275720164609
mintjams-content-management	S15	0.201320132013201	0	0.798679867986799

4.4.6 Step 8 - Combination of all simulations

Table 21 presents the combination of all simulated observations related to solutions' supplier ability, benevolence, and integrity.

Simulated customer's trust opinion values are updated with the combined results of the methods `simulateIntegrity()`, `simulateBenevolence()`, and `simulateAbility()` of the class `observation.java`.

Table 21: Simulation results combining simulated observations on ability, benevolence, and integrity

Solution Code	Scope Code	Final simulated trust opinion values about the solution		
		Belief	Disbelief	Uncertainty
umlet-uml-tool-fast-uml-diagrams	S5	0.301884437788593	0.00524148259078996	0.692874079620616
wireframesketcher	S5	0.264559794771028	0.0229245128541019	0.71251569237487
rcp-developer	S5	0.279279279279279	0	0.720720720720721
mylyn-wikitext	S5	0.279816513761468	0	0.720183486238532
jautodoc	S5	0.19880418535127	0.0448430493273543	0.756352765321375
Eclox	S5	0.179091688089117	0.051413881748072	0.769494430162811
jdoceditor	S5	0.230505569837189	0	0.769494430162811
texlipse	S5	0.216715257531584	0	0.783284742468416
subclipse	S15	0.305397585553227	0	0.694602414446772
subversive-svn-team-provider	S15	0.287303413885692	0	0.712696586114308
mercurialeclipse-was-hgeclipse	S15	0.284965739621121	0	0.71503426037888
pulse-download-manage-and-maintain-eclipse-tools	S15	0.247126436781609	0.0287356321839081	0.724137931034483
atlassian-connector-eclipse	S15	0.245227606461087	0.0293685756240823	0.725403817914831
collabnet-desktop-eclipse-edition	S15	0.249299719887955	0	0.750700280112045
amazon-s3-browser	S15	0.211382113821138	0	0.788617886178862
mintjams-content-management	S15	0.227792436235708	0	0.772207563764292

4.5 Step 9 – Comparing results of simulations and benchmark

This section presents the absolute and relative impact of the simulations implemented in section 4.4, and provides an indication on whether belief and uncertainty increased or decreased as a result of the different simulations.

Table 22 show the impact of the simulations on customer's belief about the solution in absolute numbers.

Table 22: Belief values

Solution Code	Scope Code	Benchmark belief value	Belief after ability simulation	Belief after benevolence simulation	Belief after integrity simulation	Belief with all simulations combined
umlet-uml-tool-fast-uml-diagrams	S5	0.29347505	0.2992009	0.295486403	0.2954864	0.30188444
Wireframesketcher	S5	0.27345309	0.2840982	0.250915751	0.27345309	0.26455979
rcp-developer	S5	0.26126126	0.2745098	0.268292683	0.26126126	0.27927928
mylyn-wikitext	S5	0.26086957	0.2751455	0.267973856	0.26086957	0.27981651
Jautodoc	S5	0.21100917	0.2297064	0.178294574	0.21100917	0.19880419
Eclox	S5	0.1986532	0.2117528	0.165266106	0.1986532	0.17909169
jdoceditor	S5	0.19444444	0.2117528	0.218390805	0.19444444	0.23050557
Texlipse	S5	0.18238994	0.1919906	0.21025641	0.18238994	0.21671526
subclipse	S15	0.29665051	0.3028422	0.298563682	0.29856368	0.30539759
subversive-svn-team-provider	S15	0.27731092	0.2838896	0.281653747	0.27731092	0.28730341
mercurialeclipse-was-hgeclipse	S15	0.26732673	0.2811821	0.273273273	0.26732673	0.28496574

pulse-download-manage-and-maintain-eclipse-tools	S15	0.26241135	0.2704403	0.237179487	0.26241135	0.24712644
atlassian-connector-eclipse	S15	0.24444444	0.2620321	0.215686275	0.25490196	0.24522761
collabnet-desktop-eclipse-edition	S15	0.22128852	0.2371795	0.237410072	0.22128852	0.24929972
amazon-s3-browser	S15	0.16872428	0.1840796	0.201320132	0.16872428	0.21138211
mintjams-content-management	S15	0.16872428	0.1788932	0.201320132	0.20132013	0.22779244

Table 23 shows the impact of the simulation on customer's belief about the solution in relative values. It uses the symbols ↑ and ↓ to indicate whether belief increased or decreased.

Table 23: Relative impact on belief after simulation

Solution Code	Scope Code	Benchmark belief value	% Belief change after ability simulation	% Belief change after benevolence simulation	% Belief change after integrity simulation	% Belief change with all simulations combined
umlet-uml-tool-fast-uml-diagrams	S5	0.2934751	1.95% ↑	0.69% ↑	0.69% ↑	2.87% ↑
Wireframesketcher	S5	0.2734531	3.89% ↑	-8.24% ↓	0.00%	-3.25% ↓
rcp-developer	S5	0.2612613	5.07% ↑	2.69% ↑	0.00%	6.90% ↑
mylyn-wikitext	S5	0.2608696	5.47% ↑	2.72% ↑	0.00%	7.26% ↑

Jautodoc	S5	0.2110092	8.86% ↑	-15.50% ↓	0.00%	-5.78% ↓
Eclox	S5	0.1986532	6.59% ↑	-16.81% ↓	0.00%	-9.85% ↓
jdoceditor	S5	0.1944444	8.90% ↑	12.32% ↑	0.00%	18.55% ↑
Texlipse	S5	0.1823899	5.26% ↑	15.28% ↑	0.00%	18.82% ↑
subclipse	S15	0.2966505	2.09% ↑	0.64% ↑	0.64% ↑	2.95% ↑
subversive-svn-team-provider	S15	0.2773109	2.37% ↑	1.57% ↑	0.00%	3.60% ↑
mercurialeclipse-was-hgeclipse	S15	0.2673267	5.18% ↑	2.22% ↑	0.00%	6.60% ↑
pulse-download-manage-and-maintain-eclipse-tools	S15	0.2624113	3.06% ↑	-9.62% ↓	0.00%	-5.82% ↓
atlassian-connector-eclipse	S15	0.2444444	7.19% ↑	-11.76% ↓	4.28% ↑	0.32% ↑
collabnet-desktop-eclipse-edition	S15	0.2212885	7.18% ↑	7.29% ↑	0.00%	12.66% ↑
amazon-s3-browser	S15	0.1687243	9.10% ↑	19.32% ↑	0.00%	25.28% ↑
mintjams-content-management	S15	0.1687243	6.03% ↑	19.32% ↑	19.32% ↑	35.01% ↑

Tables 24 show the impact of the simulations on uncertainty values.

Table 24: Uncertainty values

Solution Code	Scope Code	Benchmark uncertainty values	Uncertainty after ability simulation	Uncertainty after benevolence simulation	Uncertainty after integrity simulation	Uncertainty with all simulations combined
umlet-uml-tool-fast-uml-diagrams	S5	0.7020963	0.6951104	0.7003084	0.7003084	0.6928741
Wireframesketcher	S5	0.7265469	0.7159018	0.7216117	0.7265469	0.7125157
rcp-developer	S5	0.7387387	0.7254902	0.7317073	0.7387387	0.7207207
mylyn-wikitext	S5	0.7391304	0.7248545	0.7320261	0.7391304	0.7201835
Jautodoc	S5	0.7889908	0.7702936	0.7700258	0.7889908	0.7563528
Eclox	S5	0.8013468	0.7882472	0.7787115	0.8013468	0.7694944
jdoceditor	S5	0.8055556	0.7882472	0.7816092	0.8055556	0.7694944
Texlipse	S5	0.8176101	0.8080094	0.7897436	0.8176101	0.7832847
Subclipse	S15	0.7033495	0.6971578	0.7014363	0.7014363	0.6946024
subversive-svn-team-provider	S15	0.7226891	0.7161104	0.7183463	0.7226891	0.7126966
mercurialeclipse-was-hgeclipse	S15	0.7326733	0.7188179	0.7267267	0.7326733	0.7150343
pulse-download-manage-and-maintain-eclipse-tools	S15	0.7375887	0.7295597	0.7307692	0.7375887	0.7241379
atlassian-connector-eclipse	S15	0.7555556	0.7379679	0.745098	0.745098	0.7254038
collabnet-desktop-eclipse-edition	S15	0.7787115	0.7628205	0.7625899	0.7787115	0.7507003
amazon-s3-browser	S15	0.8312757	0.8159204	0.7986799	0.8312757	0.7886179
mintjams-content-management	S15	0.8312757	0.8211068	0.7986799	0.7986799	0.7722076

Table 25 shows the impact of the simulation on customer's uncertainty about the solution in relative values. It uses the symbols ↑ and ↓ to indicate whether uncertainty increased or decreased. In the column "Belief after integrity simulation" NA means that no simulated observations on integrity were applied to the solution.

Table 25: Percentage change on uncertainty values after simulation

Solution Code	Scope Code	Benchmark uncertainty value	% Uncertainty change after ability simulation	% Uncertainty change after benevolence simulation	% Uncertainty change after integrity simulation	% Uncertainty change with all simulations combined
umlet-uml-tool-fast-uml-diagrams	S5	0.7020963	-1.00% ↓	-0.25% ↓	-0.25% ↓	-1.31% ↓
Wireframesketcher	S5	0.7265469	-1.47% ↓	-0.68% ↓	NA	-1.93% ↓
rcp-developer	S5	0.7387387	-1.79% ↓	-0.95% ↓	NA	-2.44% ↓
mylyn-wikitext	S5	0.7391304	-1.93% ↓	-0.96% ↓	NA	-2.56% ↓
Jautodoc	S5	0.7889908	-2.37% ↓	-2.40% ↓	NA	-4.14% ↓
Eclox	S5	0.8013468	-1.63% ↓	-2.82% ↓	NA	-3.97% ↓
Jdoceditor	S5	0.8055556	-2.15% ↓	-2.97% ↓	NA	-4.48% ↓
Texlipse	S5	0.8176101	-1.17% ↓	-3.41% ↓	NA	-4.20% ↓
Subclipse	S15	0.7033495	-0.88% ↓	-0.27% ↓	-0.27% ↓	-1.24% ↓
subversive-svn-team-provider	S15	0.7226891	-0.91% ↓	-0.60% ↓	NA	-1.38% ↓
mercurialeclipse-was-hgeclipse	S15	0.7326733	-1.89% ↓	-0.81% ↓	NA	-2.41% ↓
pulse-download-manage-and-maintain-eclipse-tools	S15	0.7375887	-1.09% ↓	-0.92% ↓	NA	-1.82% ↓

atlassian-connector-eclipse	S15	0.7555556	-2.33% ↓	-1.38% ↓	-1.38% ↓	-3.99% ↓
collabnet-desktop-eclipse-edition	S15	0.7787115	-2.04% ↓	-2.07% ↓	NA	-3.60% ↓
amazon-s3-browser	S15	0.8312757	-1.85% ↓	-3.92% ↓	NA	-5.13% ↓
mintjams-content-management	S15	0.8312757	-1.22% ↓	-3.92% ↓	-3.92% ↓	-7.11% ↓

5 RESULTS AND DISCUSSION

This chapter is organized into two sections. The first section provides the simulation results. The second section discusses the results.

5.1 Results

Customer uncertainty decreases with additional observations.

Results in Tables 24 and 25 show that customer uncertainty decreases in all simulation scenarios. In Table 24, uncertainty values in the columns “Uncertainty after ability simulation”, “Uncertainty after benevolence simulation”, “Uncertainty after integrity simulation”, and “Uncertainty with all simulations combined” are lower than the corresponding uncertainty values in the column “Benchmark uncertainty values”. Table 25 provides the percentage uncertainty is lower on each simulation.

Belief does not necessarily increase or decrease with additional observations.

Results in Table 23 show that belief doesn’t necessarily just increase or decrease with additional observations. Customers can use additional observations to decrease uncertainty by increasing disbelief if the observations are not positive. The column “% Belief change after benevolence simulation” show that a solution supplier perceived as non-benevolent can have its belief values decreased.

Results in Tables 18 and 23 show that in the ability simulation all solutions had their belief value increased. Figure 14 show that solutions with lower initial belief had the most relative benefit from the simulation results.

Figure 14: Relative impact of ability simulation on belief value

Results in Tables 19 and 23 show that in the benevolence simulation, by having the keystone allowing solution suppliers to post whitepapers it was possible to identify that belief decreased for solution suppliers that didn't collaborate sharing their knowledge and increased for suppliers that shared their knowledge.

Results in Table 23 also show that, from the solution suppliers that had their belief values decreased, the solution suppliers with lower initial belief were the most

negatively impacted by the results of the simulation. By the other hand, solution suppliers with higher initial belief didn't benefit too much from the simulation.

5.2 Results discussion

The simulation results allow us to assess how the numbers of observations about solution supplier's ability, benevolence, and integrity affect customer's uncertainty and belief on a solution.

Results suggest that customer uncertainty can be decreased with additional observations on solution suppliers. All simulation scenarios show that uncertainty decreases when additional information about a solution supplier's ability, integrity, and benevolence are made available. On average, uncertainty values decrease 3.23% when 309 observations are added (average of 19.3 additional observations per solution).

Keystone operators can take advantage of this finding by providing as much information as possible about their members and about the solutions announced in their marketplaces.

Providing additional observations on solutions suppliers does not necessarily increases the belief in a solution. Belief increases or decreases based on the judgment made about such observations to identify them as positive or negative.

Providing ways to allow solution supplier's to share knowledge (e.g., whitepapers) with marketplace members makes it possible for potential customers to identify which

suppliers share and which suppliers do not share information with the community.

While the first group that shares their knowledge would have their belief value increased, the second group identified as not willing to share would have their belief decreased.

Keystone operators seeking the best interest of their customers can provide suppliers with as many mechanisms as possible to allow them to show their benevolence. It is on the suppliers' hands to use such mechanisms to gain customers' belief in their solutions. Information that shows a solution suppliers' benevolence should always be made public on a marketplace website (e.g., suppliers participating in organizations that advocate customers' agenda, suppliers' statements that their success depends on their customers' success).

Observations that show a solution suppliers' ability help to increase customer's belief. Solution suppliers should provide as much evidence as possible about their ability to deliver a solution. An average increase of 5.51% on belief was observed in the ability simulation.

Keystone operators can enable solution suppliers to show their integrity to potential customers by providing them with ways that attest their correctness to deliver what they said they would deliver.

6 CONCLUSIONS, LIMITATIONS, AND FUTURE RESEARCH

This chapter is organized into three sections. The first section provides the conclusions of this research. The second section provides the limitations of this research. The third section provides opportunities for future research.

6.1 Conclusions

This research integrates two literature streams: (i) trust dimensions and (ii) trust network analysis with subjective logic.

Based on the results of this research I conclude that:

The results of this research led us to the following conclusions:

- Trust opinion values decrease customers' uncertainty about a supplier's solution.
- Adding observations on a solution supplier's ability, integrity, and benevolence does not necessarily increase belief in the solution. The belief value of a trust opinion is dependent on the quality of each observation. Marketplaces and solution suppliers seeking to increase trust in the published solutions should seek quality instead of quantity of observations about solutions made available to potential customers.

- We can expand Jøsang's trust network analysis model by calculating trust opinion values based on observations on suppliers' ability, integrity, and benevolence.

6.2 Limitations

This research has at least two limitations:

1. Marketplace member's reviews were analyzed based on the researcher's judgement. It was possible because from the 321 observations only 18 were member's reviews. An automated method to interpret the content of marketplace member's reviews should be considered when looking at a larger amount of observations.
2. Benevolence simulation was based on solution supplier's sharing their knowledge with the marketplace community by preparing and posting white-papers. Other better ways to assess a solution suppliers' benevolence should be considered on different simulation scenarios.

6.3 Future research

This research identifies three opportunities for future research:

1. As adding observations on a solution supplier's ability, integrity, and benevolence does not necessarily increase belief, other methods to increase belief on a solution announced in a marketplace should be considered in a future research.

2. The conclusions were taken based on the combination trust opinions of three trust arcs in a trust network (ω_1 , ω_2 , and ω_3) using TNA-SL. A new study could also investigate the implications and impact of each trust dimensions for each trust opinion of each trust arc of a marketplace separately.
3. Examine evidence of benevolence with different ways to assess a solution suppliers' benevolence.

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APPENDIX A – Notation for trust arcs and trust paths

In this research we will use a slightly modified version of the notation proposed by Jøsang et al. (2006). A simple trust relationship is expressed as follow:

$$[A, B]$$

In the example above we have the trust arc $[A, B]$ meaning that A trusts B.

Scope is expressed using the symbol σ . The variants of the scope (referral trust or functional trust) are represented by the letters r and f. The distinction between direct and indirect trust is represented by the letters d and i. The possible combinations are exemplified below:

$[A, B, dr.\sigma]$ A has direct referral trust in B about σ

$[A, B, ir.\sigma]$ A has indirect referral trust in B about σ

$[A, B, df.\sigma]$ A has direct functional trust in B about σ

$[A, B, if.\sigma]$ A has indirect functional trust in B about σ

A transitive trust path is represented using the symbol “:”. A transitive trust path from node A to node C through node B can be expressed as follow:

$$([A, C, if.\sigma]) = ([A, B, dr.\sigma] : [B, C, df.\sigma])$$

Parallel trust paths can be expressed by the symbol “ $\diamond$ ”. An example for two trust transitive paths between A and C, one through B and another through D, can be expressed as follow:

$$([A, C, \text{if}.\sigma] = (([A, B, \text{dr}.\sigma] : [B, C, \text{df}.\sigma]) \diamond ([A, D, \text{dr}.\sigma] : [D, C, \text{df}.\sigma])))$$

Jøsang et al. (2006) also presents a method about how complex transitive trust networks can be simplified. Simplification of trust networks is not in the scope of this present research.

In this research when expressing trust arcs, the symbol σ is substituted with a scope code associated with a solution code.

The pattern to represent for trust arcs used in this research is:

[truster, trustee, scope variant.scope code]

Example:

[customer, texlipse, if.SOL.S5]

The scope variants and scope codes used in this research are:

dr.KEY	Direct referral trust in a keystone
dr.REV	Direct referral trust in a reviewer (marketplace member)
df.SOL	Direct functional trust in a solution
if.SOL	Indirect functional trust in a solution

The scope codes and scope codes used in this research are:

S5	Documentation
S15	Team development

APPENDIX B – Notation for trust opinions

Trust opinions are expressed with the following notation:

$$\omega [A,B, \sigma] = (b, d, u, a)$$

Where:

$\omega [A,B, \sigma]$ represents then opinion of A about B regarding σ

(b, d, u, a) represents (belief, disbelief, uncertainty, and a-priori trust)

In an opinion the values of belief, disbelief, and uncertainty sum to 1. Increasing any one of these parameters will decrease one or both other parameters.

$$b + d + u = 1$$

Trust opinion values belief, disbelief, and uncertainty are calculated based on the number of positive (r) and negative (s) observations from the truster about the trustee.

Belief is calculated with the following formula:

$$b = r / (r + s + 2)$$

Disbelief is calculated with the following formula:

$$d = s / (r + s + 2)$$

Uncertainty is calculated with the following formula:

$$u = 2 / (r + s + 2)$$

The a-priori trust value (a) is defined by the predisposition that the truster has to establish an initial trust in a trustee even in the absence of any evidence.

In this research when expressing a trust opinion, we follow the pattern:

$$(\omega[\text{truster, trustee, scope variant.scope code}] = \{b, d, u, a\})$$

Example:

$$(\omega[\text{EF,user3708,dr.REV.S5}] = \{0.5, 0.0, 0.5, 0.5\})$$

APPENDIX C – Notation for discounting and consensus

Discounting is represented by following notation:

$$\omega [A,C, \sigma] = \omega [A,B, \sigma] \otimes \omega [B,C, \sigma]$$

A discounted opinion is calculated by applying the following formulas:

Having:

$$\omega_d = \omega [A, C, \sigma]$$

$$\omega_1 = \omega [A, B, \sigma]$$

$$\omega_2 = \omega [B, C, \sigma]$$

Therefore:

$$\omega_d = \omega_1 \otimes \omega_2$$

Where:

$$\omega_d(b) = \omega_1(b) \times \omega_2(b)$$

$$\omega_d(d) = \omega_1(b) \times \omega_2(d)$$

$$\omega_d(u) = \omega_1(d) + \omega_1(u) + (\omega_1(b) \times \omega_2(u))$$

$$\omega_d(a) = \omega_1(a)$$

Consensus is represented by the following notation:

$$\omega [A\Diamond B,C, \sigma] = \omega [A,C, \sigma] \oplus \omega [B,C, \sigma]$$

A consensual opinion is calculated by applying the following formulas:

Having:

$$\omega_c = \omega [A\Diamond B, C, \sigma]$$

$$\omega_1 = \omega [A, C, \sigma]$$

$$\omega_2 = \omega [B, C, \sigma]$$

Therefore:

$$\omega c = \omega 1 \otimes \omega 2$$

Where:

$$\omega c(b) = (\omega 1(b) \cdot \omega 2(u) + \omega 2(b) \cdot \omega 1(u)) / (\omega 1(u) + \omega 2(u) - \omega 1(u) \times \omega 2(u))$$

$$\omega c(d) = (\omega 1(d) \cdot \omega 2(u) + \omega 2(d) \cdot \omega 1(u)) / (\omega 1(u) + \omega 2(u) - \omega 1(u) \times \omega 2(u))$$

$$\omega c(u) = (\omega 1(u) \cdot \omega 2(u)) / (\omega 1(u) + \omega 2(u) - \omega 1(u) \times \omega 2(u))$$

$$\omega c(a) = \omega 1(a)$$

APPENDIX D – List of solution categories from Eclipse Marketplace

Category name (number of solutions)

Application Management (48)
Application Server (19)
BIRT (5)
Build and Deploy (69)
Code Management (56)
Database (39)
Database Persistence (9)
Documentation (29)
Editor (106)
Entertainment (8)
Graphics (18)
IDE (133)
J2EE Development Platform (33)
J2ME (10)
Languages (60)
Logging (5)
Modeling Tools (75)
Mylyn Connectors (15)
Network (9)
Other (36)
Process (21)
Profiling (12)
Reporting (12)
Rich Client Applications (27)
SCM (18)
Search (9)
Source Code Analyzer (55)
Systems Development (18)
Team Development (46)
Testing (66)
Tools (250)
UI (54)
UML (40)
Web (47)
Web Services (20)
XML (22)

APPENDIX E – List of all solutions from the category “Documentation”

SolutionCode	SolutionName	ScopeCode
instinctools-ditaworks-documentation-tool	*instinctools DITAworks Documentation Tool	S5
mylyn-wikitext	Mylyn WikiText	S5
rcp-developer	RCP Developer	S5
agilej-structureviews	AgileJ StructureViews	S5
amazon-s3-browser	Amazon S3 Browser	S5
apt-editor	APT Editor	S5
dtp-cheat-sheet-eclipse-34	DTP Cheat Sheet for Eclipse 3.4	S5
eclipse-code-recommenders	Eclipse Code Recommenders	S5
eclipse-help-topics	eclipse help topics	S5
Eclox	Eclox	S5
feature-working-sets	Feature Working Sets	S5
fx2doc	Fx2Doc	S5
Gluebox	Gluebox	S5
i-net-doqua	i-net Doqua	S5
Jautodoc	JAutodoc	S5
jboss-seam-eclipse-help-plugin	JBoss Seam Eclipse Help Plugin	S5
Jdoceditor	JDocEditor	S5
jindent-source-code-formatter-javacc	Jindent - Source Code Formatter for Java/C/C++	S5
mintjams-content-management	MintJams Content Management	S5
nqdoc-document-processor	nqDoc Document Processor	S5
relations-0	Relations	S5
rss-view	RSS View	S5
se-editor	SE-Editor	S5
source-code-search-engine	Source Code Search Engine	S5
texlipse	TeXlipse	S5
tip-day	Tip Of The Day	S5
umlet-uml-tool-fast-uml-diagrams	UMlet - UML Tool for Fast UML Diagrams	S5
wireframesketcher	WireframeSketcher	S5
yep-apt-editor	YEP APT Editor	S5

APPENDIX F – List of all solutions from the category “Team Development”

SolutionCode	SolutionName	ScopeCode
collabnet-desktop-eclipse-edition	CollabNet Desktop - Eclipse Edition	S15
pulse-download-manage-and-maintain-eclipse-tools	Pulse Download, manage and maintain Eclipse tools	S15
solution-blueprint-community-edition	Solution Blueprint - Community Edition	S15
subversive-svn-team-provider	Subversive - SVN Team Provider	S15
accurev-accubridge-eclipse-plug	AccuRev AccuBridge for Eclipse Plug-In	S15
annotate-add-ibm-rational-clearcase-scm-adapter	Annotate Add-On for the IBM Rational ClearCase SCM Adapter	S15
atlassian-connector-eclipse	Atlassian Connector for Eclipse	S15
bazaar-plugin-eclipse	Bazaar plugin for Eclipse	S15
boneclipse-cvsgrapher	boneclipse-cvsgrapher	S15
ceno	Ceno	S15
code-collaborator	Code Collaborator	S15
codebeamer-eclipse-studio	codeBeamer Eclipse Studio	S15
codebeamer-plugin-eclipse	codeBeamer Plugin for Eclipse	S15
commit-20	Commit 2.0	S15
cruise-control-eclipse-plugin	Cruise Control Eclipse Plugin	S15
eclipse-subversion-plugin-integrated-total-alm-solution-easyflow	Eclipse-Subversion Plugin integrated with a total ALM solution - Easy!Flow	S15
ganttchart-clearquest	GanttChart for ClearQuest	S15
magicdraw	MagicDraw	S15
mercurial-eclipse	Mercurial Eclipse	S15
mercurialeclipse-was-hgeclipse	MercurialEclipse (was: HgEclipse)	S15
plastic-scm-eclipse-plug	Plastic SCM Eclipse Plug-In	S15
project-set-plugin	Project Set Plugin	S15
projectcards	ProjectCards	S15
projectkoach-premium	ProjectKoach Premium	S15
projectkoach-team	ProjectKoach Team	S15
remote-project-properties-plug	Remote Project Properties Plug-in	S15
remote-workspace-preferences-plug	Remote Workspace Preferences Plug-in	S15
remove-tag-tool	Remove Tag Tool	S15
reviewclipse	ReviewClipse	S15
roundTable-team	RoundTable Team	S15
saros-distributed-collaborative-editing-and-pair-programming	Saros - Distributed Collaborative Editing and Pair Programming	S15
snipper-code-sharing-service	Snipper - Code Sharing Service	S15

sourcegear-fortress-plugin-eclipse	SourceGear Fortress Plugin for Eclipse	S15
sourcegear-vault-plugin-eclipse	SourceGear Vault Plugin for Eclipse	S15
spectrumscm-plugin-eclipse	SpectrumSCM Plugin for Eclipse	S15
subclipse	Subclipse	S15
svn-reporter-plugin	SVN Reporter Plugin	S15
svnadmin	SvnAdmin	S15
synergy-alm	Synergy ALM	S15
trackclipse-track-issue-tracker	Trackclipse for Track+ Issue Tracker	S15
twikle	Twikle	S15
xpairtise-pair-programming-eclipse	XPairtise - Pair Programming for Eclipse	S15

Appendix G – Results of building a transitive trust network from customer to solution textlipse

TNA-SL

1. Indirect Trust Arc

[customer, textlipse, if.SOL.S5]

2. Transitive Trust Paths

[customer,EF] : [EF,user3708] : [user3708,textlipse]
[customer,EF] : [EF,user1295] : [user1295,textlipse]
[customer,EF] : [EF,user1474] : [user1474,textlipse]
[customer,EF] : [EF,user1624] : [user1624,textlipse]

3. Canonical Expression

$([customer, textlipse]) = ([customer, EF]) : (([EF, user3708] : [user3708, textlipse]) \diamond ([EF, user1295] : [user1295, textlipse]) \diamond ([EF, user1474] : [user1474, textlipse]) \diamond ([EF, user1624] : [user1624, textlipse]))$

4. Discounting: (keystone : members) $\otimes$ (members : solution)

$(\omega[EF, user3708, dr.REV.S5] = \{0.5, 0.0, 0.5, 0.5\}) \otimes$
 $(\omega[user3708, textlipse, df.SOL.S5] = \{0.5, 0.0, 0.5, 0.5\}) = \{0.25, 0.0, 0.75, 0.5\}$

$(\omega[EF, user1295, dr.REV.S5] = \{0.3333333333333333, 0.0, 0.6666666666666667, 0.5\}) \otimes$
 $(\omega[user1295, textlipse, df.SOL.S5] = \{0.3333333333333333, 0.0, 0.6666666666666667, 0.5\}) =$
 $\{0.1111111111111088, 0.0, 0.8888888888888891, 0.5\}$

$(\omega[EF, user1474, dr.REV.S5] = \{0.3333333333333333, 0.0, 0.6666666666666667, 0.5\}) \otimes$
 $(\omega[user1474, textlipse, df.SOL.S5] = \{0.3333333333333333, 0.0, 0.6666666666666667, 0.5\}) =$
 $\{0.1111111111111088, 0.0, 0.8888888888888891, 0.5\}$

$(\omega[EF, user1624, dr.REV.S5] = \{0.3333333333333333, 0.0, 0.6666666666666667, 0.5\}) \otimes$
 $(\omega[user1624, textlipse, df.SOL.S5] = \{0.3333333333333333, 0.0, 0.6666666666666667, 0.5\}) =$
 $\{0.1111111111111088, 0.0, 0.8888888888888891, 0.5\}$

5. Consensus: ω [member1 $\diamond$ membern, solution]

$$\begin{aligned} &(\omega[\text{EF}, \text{user3708}, \text{dr.REV.S5}] : [\text{user3708}, \text{texlipse}, \text{df.SOL.S5}] = \{0.25, 0.0, 0.75, 0.5\}) \oplus \\ &(\omega[\text{EF}, \text{user1295}, \text{dr.REV.S5}] : \\ &[\text{user1295}, \text{texlipse}, \text{df.SOL.S5}] = \{0.11111111111111088, 0.0, 0.8888888888888891, 0.5\}) \oplus \\ &(\omega[\text{EF}, \text{user1474}, \text{dr.REV.S5}] : \\ &[\text{user1474}, \text{texlipse}, \text{df.SOL.S5}] = \{0.11111111111111088, 0.0, 0.8888888888888891, 0.5\}) \oplus \\ &(\omega[\text{EF}, \text{user1624}, \text{dr.REV.S5}] : \\ &[\text{user1624}, \text{texlipse}, \text{df.SOL.S5}] = \{0.11111111111111088, 0.0, 0.8888888888888891, 0.5\}) = \\ &\{0.41463414634146306, 0.0, 0.5853658536585369, 0.5\} \end{aligned}$$

6. Consensus: ω [keystone.solution.if $\diamond$ keystone.solution.df, solution]

$$\begin{aligned} &(\omega[\text{EF}, \text{texlipse}, \text{df.SOL.S5}] = \{0.3333333333333333, 0.0, 0.6666666666666667, 0.5\}) \oplus \\ &(\omega[\text{EF}, \text{texlipse}, \text{if.SOL.S5}] = \{0.41463414634146306, 0.0, 0.5853658536585369, 0.5\}) = \\ &\{0.5471698113207543, 0.0, 0.45283018867924557, 0.5\} \end{aligned}$$

7. Discounting: (customer : keystone) $\otimes$ (keystone : solution)

$$\begin{aligned} &(\omega[\text{customer}, \text{EF}] = \{0.3333333333333333, 0.0, 0.6666666666666667, 0.5\}) \otimes \\ &([\text{EF}, \text{texlipse}, \text{if} \oplus \text{df.SOL.S5}] = \{0.5471698113207543, 0.0, 0.45283018867924557, 0.5\}) = \\ &\{0.1823899371069181, 0.0, 0.8176100628930818, 0.5\} \end{aligned}$$

8. Trust opinion values

Belief = 0.1823899371069181

Disbelief = 0.0

Uncertainty = 0.8176100628930818

Appendix H – Results of building a transitive trust network from customer to solution textlipse with simulated observations on ability, benevolence, and integrity

TNA-SL

1. Indirect Trust Arc

[customer, textlipse, if.SOL.S5]

2. Transitive Trust Paths

[customer,EF] : [EF,user3708] : [user3708,textlipse]
[customer,EF] : [EF,user1295] : [user1295,textlipse]
[customer,EF] : [EF,user1474] : [user1474,textlipse]
[customer,EF] : [EF,user1624] : [user1624,textlipse]

3. Canonical Expression

([customer, textlipse]) = ([customer, EF]) : (([EF,user3708] : [user3708,textlipse]) $\diamond$
([EF,user1295] : [user1295,textlipse]) $\diamond$ ([EF,user1474] : [user1474,textlipse]) $\diamond$ ([EF,user1624] :
[user1624,textlipse]))

4. Discounting: (keystone : members) $\otimes$ (members : solution)

(ω [EF,user3708,dr.REV.S5]={0.5,0.0,0.5,0.5}) $\otimes$
(ω [user3708,textlipse,df.SOL.S5]={0.5,0.0,0.5,0.5}) = {0.25,0.0,0.75,0.5}

(ω [EF,user1295,dr.REV.S5]={0.3333333333333333,0.0,0.6666666666666667,0.5}) $\otimes$
(ω [user1295,textlipse,df.SOL.S5]={0.3333333333333333,0.0,0.6666666666666667,0.5}) =
{0.1111111111111111,0.0,0.8888888888888889,0.5}

(ω [EF,user1474,dr.REV.S5]={0.3333333333333333,0.0,0.6666666666666667,0.5}) $\otimes$
(ω [user1474,textlipse,df.SOL.S5]={0.5,0.0,0.5,0.5}) =
{0.1666666666666665,0.0,0.8333333333333335,0.5}

(ω [EF,user1624,dr.REV.S5]={0.3333333333333333,0.0,0.6666666666666667,0.5}) $\otimes$
(ω [user1624,textlipse,df.SOL.S5]={0.5,0.0,0.5,0.5}) =
{0.1666666666666665,0.0,0.8333333333333335,0.5}

5. Consensus: ω [member1 $\diamond$ membern, solution]

$$\begin{aligned} &(\omega[\text{EF}, \text{user3708}, \text{dr.REV.S5}] : [\text{user3708}, \text{texlipse}, \text{df.SOL.S5}] = \{0.25, 0.0, 0.75, 0.5\}) \oplus \\ &(\omega[\text{EF}, \text{user1295}, \text{dr.REV.S5}] : \\ &[\text{user1295}, \text{texlipse}, \text{df.SOL.S5}] = \{0.1111111111111111088, 0.0, 0.8888888888888891, 0.5\}) \oplus \\ &(\omega[\text{EF}, \text{user1474}, \text{dr.REV.S5}] : \\ &[\text{user1474}, \text{texlipse}, \text{df.SOL.S5}] = \{0.1666666666666665, 0.0, 0.8333333333333335, 0.5\}) \oplus \\ &(\omega[\text{EF}, \text{user1624}, \text{dr.REV.S5}] : \\ &[\text{user1624}, \text{texlipse}, \text{df.SOL.S5}] = \{0.1666666666666665, 0.0, 0.8333333333333335, 0.5\}) = \\ &\{0.46188340807174866, 0.0, 0.5381165919282513, 0.5\} \end{aligned}$$

6. Consensus: ω [keystone.solution.if $\diamond$ keystone.solution.df, solution]

$$\begin{aligned} &(\omega[\text{EF}, \text{texlipse}, \text{df.SOL.S5}] = \{0.5, 0.0, 0.5, 0.5\}) \oplus \\ &(\omega[\text{EF}, \text{texlipse}, \text{if.SOL.S5}] = \{0.46188340807174866, 0.0, 0.5381165919282513, 0.5\}) = \\ &\{0.6501457725947521, 0.0, 0.3498542274052479, 0.5\} \end{aligned}$$

7. Discounting: (customer : keystone) $\otimes$ (keystone : solution)

$$\begin{aligned} &(\omega[\text{customer}, \text{EF}] = \{0.3333333333333333, 0.0, 0.6666666666666666, 0.5\}) \otimes \\ &([\text{EF}, \text{texlipse}, \text{if} \oplus \text{df.SOL.S5}] = \{0.6501457725947521, 0.0, 0.3498542274052479, 0.5\}) = \\ &\{0.21671525753158405, 0.0, 0.783284742468416, 0.5\} \end{aligned}$$

8. Trust opinion values

Belief = 0.21671525753158405

Disbelief = 0.0

Uncertainty = 0.783284742468416

Appendix I – Template used in the output of results of building a transitive trust network from customer to a solution

Placeholders for data collected by the web-crawler are represented in *italics*:

TNA-SL

1. Indirect Trust Arc

[customer, *solution-code*, if.SOL.*scope-code*]

2. Transitive Trust Paths

[customer, EF] : [EF, *member1-code*] : [*member1-code*, *solution-code*]
 [customer, EF] : [EF, *membern-code*] : [*membern-code*, *solution-code*]

3. Canonical Expression

(([customer, *solution-code*]) = ([customer, EF]) : (([EF, *member1-code*] : [*member1-code*, *solution-code*]) $\diamond$ ([EF, *membern-code*] : [*membern-code*, *solution-code*]))

4. Discounting: (keystone : members) $\otimes$ (members : solution)

(ω [EF, *member1-code*, dr.REV.*scope-code*] = { b_{x1} , d_{x1} , u_{x1} , a_{x1} }) $\otimes$ (ω [*member1-code*, *solution-code*, df.SOL.*scope-code*] = { b_{y1} , d_{y1} , u_{y1} , a_{y1} }) = { b_l , d_l , u_l , a_l }

(ω [EF, *membern-code*, dr.REV.*scope-code*] = { b_{xn} , d_{xn} , u_{xn} , a_{xn} }) $\otimes$ (ω [*membern-code*, *solution-code*, df.SOL.*scope-code*] = { b_{yn} , d_{yn} , u_{yn} , a_{yn} }) = { b_n , d_n , u_n , a_n }

5. Consensus: (member₁) $\oplus$ (member_n)

$$(\omega[\text{EF}, \text{member1-code}, \text{dr.REV.S5}] : [\text{member1-code}, \text{solution-code}, \text{df.SOL. scope-code}] = \{b_1, d_1, u_1, a_1\}) \oplus (\omega[\text{EF}, \text{membern-code}, \text{dr.REV. scope-code}] : [\text{membern-code}, \text{solution-code}, \text{df.SOL. scope-code}] = \{b_n, d_n, u_n, a_n\}) = \{b, d, u, a\}$$
6. Consensus: (keystone.solution.if) $\oplus$ (keystone.solution.df)

$$(\omega[\text{EF}, \text{solution-code}, \text{df.SOL. scope-code}] = \{b_{df}, d_{df}, u_{df}, a_{df}\}) \oplus (\omega[\text{EF}, \text{solution-code}, \text{if.SOL. scope-code}] = \{b_{if}, d_{if}, u_{if}, a_{if}\}) = \{b_{df \oplus if}, d_{df \oplus if}, u_{df \oplus if}, a_{df \oplus if}\}$$
7. Discounting: (customer : keystone) $\otimes$ (keystone : solution)

$$(\omega[\text{customer}, \text{EF}, \text{dr.KEY. scope-code}] = \{b_{dr}, d_{dr}, u_{dr}, a_{dr}\}) \otimes [\text{EF}, \text{solution-code}, \text{if} \oplus \text{df.SOL. scope-code}] = \{b_{df \oplus if}, d_{df \oplus if}, u_{df \oplus if}, a_{df \oplus if}\}) = \{b, d, u, a\}$$
8. Trust opinion values

Belief = b

Disbelief = d

Uncertainty = u

In the template used for the output content of buildTransitiveTrustNetwork() method shown in this appendix I we have the following parts:

1. **Indirect trust arc:** a representation of the indirect trust arc between the customer and the solution. The notation used follows the pattern [truster, trustee, scope variant.scope].
2. **Transitive trust paths:** a list of all possible paths between the customer and the solution considering the keystone and all marketplace members that had provided some feedback about the solution. EF is the keystone-code for Eclipse.

3. **Canonical expression:** the canonical expression for all transitive trust paths between the customer and the solution.
4. **Discounting: (keystone : members) $\otimes$ (members : solution):** a discounting operation for each transitive trust path between the keystone and the solution. The result of each operation is a discounted trust opinion ($\omega = \{\text{belief, disbelief, uncertainty, a-priori trust}\}$) for each transitive trust path
5. **Consensus: (member₁) $\oplus$ (member_n):** a consensus operation is made for all discounted opinions. The result of this operation is a new consensual opinion derived from the opinion of all members in the transitive trust paths between the customer and the solution.
6. **Consensus: (keystone.solution.if) $\oplus$ (keystone.solution.df):** a second consensus operation is made, now between the keystone direct functional trust opinion about the solution (based on the direct observations of the keystone to the solution) and the consensual opinion derived from the opinion of all members (result of previous consensus operation)
7. **Discounting: (customer : keystone) $\otimes$ (keystone : solution):** a second discounting operation is made, now between the opinion of the customer about the keystone and the consensual opinion of the keystone about the solution (result from previous step).
8. **Trust opinion values:** The result of all steps is the trust opinion values for belief, disbelief, and uncertainty of the customer about the solution.

Appendix J – Transitive Trust Network Model

The key features of a transitive trust network model for a marketplace operated by a keystone are:

- a. A keystone operates the marketplace where members can announce their solutions
- b. Customers find about members through the marketplace
- c. Customers go to the marketplace because they have some level of initial trust on the keystone
- d. Other members provide their views about announced solutions
- e. The customer can, therefore, derive indirect trust to the solution from the keystone and from members

Figure 15 illustrates the high level visualization of the trust path between the customer and a solution in the marketplace.

Figure 15: Trust path between customer and a solution in a marketplace

The keystone trusts marketplace members and offers them a space to

announce solutions and review other members' solutions. Marketplace members work as referrals by providing their views about solutions published. The keystone also works as a referral to marketplace members and their solution.

The indirect trust from the customer to the solution is derived from observations about the ability, integrity and benevolence of the solution supplier.

Figure 16 illustrates the relationship between the three trust dimensions and the transitivity of a trust opinion. It uses the same trust path customer : keystone : marketplace members : solution.

Figure 16: Detailed trust model for a marketplace

The trust model in Figure 16 illustrates the following:

- a) Customer arrives with its own initial a-priori trust on the keystone.
- b) Customer goes to the marketplace looking for information about "Solution".
- c) Keystone and marketplace members provide observations about "Solution".
- d) "Solution" is the trust scope.
- e) Observations from the marketplace's keystone and members about the solution supplier's ability, integrity, and benevolence are used as indirect trust evidence to compute a derived trust opinion.
- f) A final customer's trust opinion that will define the level of belief, disbelief, and uncertainty of the customer on the solution can be calculated.