Formal Aspects of a Generic Model of Trust for Electronic Commerce

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Abstract

In this paper we describe how an agent's trust in transactions is a combination of an agent's trust in the other party and the trust in the control mechanisms for the successful performance of the transaction. This distinction is in particular relevant for international business-to-business electronic commerce, where trading partners often do not know each other before the trading takes place. We argue also that the agent's understanding of a control mechanism is essential for the agent's trust in that control mechanism. We give a formal analysis of the understanding that is required for control mechanisms to work, and for determining the subjective level of trust in control mechanisms in electronic commerce.

1. Introduction
1.1 Trust in Electronic Commerce

With the advent of Electronic Commerce many people have become interested in trust issues. Most people agree that electronic commerce can only become a success if the general public trusts the virtual environment. Trust in electronic commerce is therefore an important issue to investigate.[1] In this paper we focus on transaction trust, i.e. the trust that is needed to engage in a transaction. We investigate the determinants of trust in electronic commerce, and we present different methods to increase the level of this trust in a transaction.

The basic assumption of our generic trust model is that an individual only engages in a transaction if his level of trust exceeds his personal threshold. This personal threshold depends on the type of transaction and the other parties involved in the transaction. For example, the threshold will be high if the value of the transaction is high, and the threshold will be low if the agent shares a long history of satisfactory trade transactions with his trading partner. Figure 1 gives a graphical representation of the generic trust model. In the center of this figure is the trustor's transaction trust; i.e. the mental state of the trustor that determines whether he has sufficient trust to engage in a transaction. The determinants of the trustor's trust threshold are represented in the lower half of Figure 1. Several determinants for a person's threshold can be distinguished. The potential profit for the person, the risk involved, the person's attitude towards risk or risk propensity, i.e. risk seeking, risk neutral, risk averse are examples of such determinants. The upper half of Figure 1 represents the trust determinants such as the trust that the counter party in a transaction induces in the trustor, and the trust that control mechanisms induce in the trustor. By a control mechanism we mean procedures and protocols that monitor and control the successful performance of a transaction. There are basically two ways to enable a specific electronic trade transaction; either by decreasing the personal threshold of the potential actor with respect to this transaction, or to increase his trust level related to this transaction. Here we focus on methods to increase trust levels.

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[1] See, for example, the special issue on trust in organizations of the journal *Academy of Management Review,* Vol. 20, No 3, 1998.

In this paper we present a formal analysis of several aspects of the control procedures and protocols that can be used to increase trust. In particular, we analyse the so-called evidence rules and the understanding the agents have about these rules. Evidence rules are rules that state that a certain document reliably indicates that a certain world fact has happened. For example, the receipt you receive in a supermarket reliably indicates the existence of a contract of sale between you and
the supermarket. The receipt is not the contract of sale itself. It only evidences that such a (perhaps implicit) contract of sale exists. Because the source (issuer) of the document is important for the evidence relations, we also show how to model the reliability of information sources.
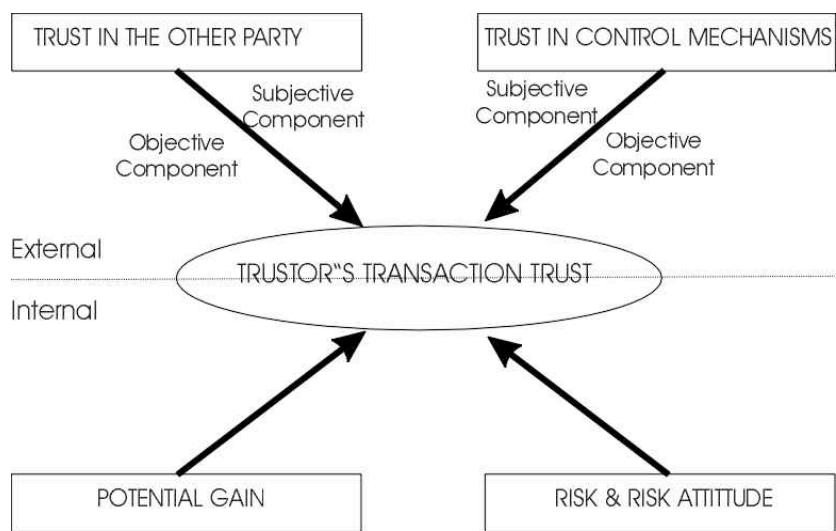

Figure 1. Generic Trust Model

1.2 Why is Electronic Commerce not trusted?
Why is it that people would not trust electronic commerce in the first place? It has been argued that trust is needed only in risky situations [KK70], and to trust essentially means to take risks and leave oneself vulnerable to the actions of trusted others [H95]. The electronic commerce environment is obviously an environment with risk. Many types of risks can be explained by looking at the information available to the parties in a transaction. We can distinguish three typical situations. The situation of perfect information in which all parties know everything that is relevant for a transaction. The situation of complete ignorance where none of the parties has information relevant for a transaction. And the intermediary situation of information asymmetry in which one party has information that the other party does not have. This situation of information asymmetry is the most interesting one, because it may give rise to opportunistic behavior. Williamson [W75][W85] describes opportunism as 'self interest seeking with guile' and as making 'self disbelieved statements'. In other words, opportunism is trying to exploit the information asymmetry to your own advantage. The textbook example of opportunism is the situation of a used-car market. The seller knows the quality of the car, while the buyer does not. The seller can try to exploit this information asymmetry by claiming a higher than actual quality and thus asking a higher price.

A distinction can be made between the case where the information problem arises before the parties agree to transact, *ex ante*, or the case where the problem arises after the transaction has been agreed, *ex post*. In the first case the problem is called *hidden information* and in the second case the problem is called *hidden action*. Hidden action can, for instance, occur when an insurance company has agreed to insure someone against damage to his house caused by fire. The insured could set his house on fire and then claim damages from the insurance company. The insurance company does not know who has set the house on fire and that information asymmetry harms her interests. That the insurance company does not know who has set the house on fire illustrates the importance of (un)observability. Unobservability is a major cause for the occurrence of information asymmetries. In our view

unobservability plays an even more important role for electronic commerce than it does for more traditional commerce. The reason is that in electronic commerce direct observation, "with your own eyes and ears", is often more difficult than in a traditional environment. As a consequence indirect observation, e.g. by means of statements from other parties about the present situation, becomes more important for reducing information asymmetries. It seems reasonable to assume that most people have more confidence in their own direct observations than in the indirect observations, which were made by others and communicated to them. Trust in electronic commerce is therefore more difficult to achieve.

Clearly, people will have to take a certain risk when they engage in electronic commerce transaction. However, the risks must be below their personal threshold before they are actually prepared to take the risk, i.e., before they trust sufficiently to transact in the virtual trade environment.

2. The Determinants of Trust

2.1 Party Trust
In the literature many different definitions for trust have been proposed. We discuss some of those definitions. Mayer *et al.* define trust as "The willingness of a party to be vulnerable to the actions of another party based on the expectation that the other party will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party" [MDS95, 712]. Gambetta [G88] defines trust as "Trust is the subjective probability by which an individual A expects that another individual B performs a given action on which its welfare depends". Both definitions are based on a subjective interpretation of trust. The first definition refers to "the willingness of a party", and the second one refers to the "subjective probability". Just as we said that the level of trust threshold is different for each individual, the level of actual trust in a certain situation is different for each person. Another element that both definitions have in common is the action perspective. The definitions use phrases like "perform a particular action" and "perform a given action". This action perspective contrasts with the information perspective. Just as we can trust someone with respect to the performance of a particular action, we can also trust someone with respect to certain information provided. The information perspective is included in the definition of trust by Cook and Wall [CW80] "The extent to which one is willing to ascribe good intentions to and have confidence *in the words* and actions of other people".

The kind of trust the authors define in the above definitions is what we call 'trust in the other party', or briefly 'party trust'. We can see from the definitions that it is important to note that 'party trust' is subjective and that both an action and an information perspective should be distinguished. The definitions also show that trust is commonly seen as an interpersonal relation. One person trusts another person.

2.2 Trust and control
An important concept in international trade is the duality between trust and control (see e.g. [GLF88], [HL98] and [L79]). In a specific situation the trading parties can either trust each other, or rely on functionally equivalent control mechanisms, i.e. procedures and protocols that monitor and control the successful performance of a transaction. If we do not trust someone, then we want to use control mechanisms instead. The relation between trust and control is usually taken to be a substitution or complementary relation. The assumption of a substitution relation is, for example, clear in the quote that "legalistic remedies have been described as weak, impersonal substitutes for trust" [SR93]. The general idea is that the stronger the trust is, the weaker the control can be, and vice versa. This idea is also expressed by Beamish when he said that "to reach a minimum level of confidence in cooperation, partners can use trust and control to complement each other" [B88]. This means in our model that if the level of trust is below the threshold, then trust should be complemented by control to reach the threshold level.

In contrast with this complementary relationship view is the idea of Das and Bing-Sheng Teng [DB98] that trust and control are parallel concepts. They state "We believe that this restrictive complementary relationship needs reassessment, because an open-ended supplementary one would more appropriately capture the nature of trust and control as parallel concepts". In our opinion the

following example clearly illustrates that trust and control are indeed parallel concepts. Assume that your video recorder is not working properly, and you take it to a repair center. When you hand over your video recorder, the repair center will prepare an intake form that you have to sign. One of the questions on this form is "Is there any visible damage?" The idea behind this question is obvious. The repair center wants to avoid a possible accusation that they damaged the product while being repaired. This question on the form that you have to sign is a control that the repair center uses. The restrictive complementary relationship would lead to the conclusion that the repair center does not have sufficient trust in you and therefore uses the control to complement the trust. However, it is very probable that the repair center did not even assess whether they trust you not to falsely accuse them of damaging your video recorder. They simply applied the control mechanism without assessing their trust in you. Their level of trust in the control mechanism is sufficient to engage in the transaction irrespective of whether they trust or distrust you personally. This control mechanism is clearly not a substitute or complement for a lack of trust in you, because the trust in you is unknown.

In internal auditing it is often assumed that people behave opportunistically whenever they can. Therefore, control mechanisms are designed to detect, or prevent, all opportunistic behavior and (unintentional) errors without any reliance on trust. "According to Starreveld, internal control is needed when an organization has a delegated task structure which allows agents to establish commitments on behalf of the organization, to employ certain funds, goods or products or to store such items. The principal that has delegated such activities will have the *evident* need to control the agent that performs these activities." [Bons97, p46] However, using a no-trust assumption does not mean that there is no trust!

2.3 Control trust
In the discussion of party trust we mentioned that most scientists use a subjective interpretation of trust. Different individuals can have different levels of trust in identical situations. An individual's level of trust in a situation depends among others on previous experiences and trust propensity, which are clearly subjective. However, when it comes to control mechanisms an objective view is often taken. For example, Bons [Bons97, p41] defines a trustworthy trade procedure as "a trade procedure that governs a transaction in which the risk of opportunistic behavior by one or more parties is present, but which provides sufficient inter-organizational controls to limit this risk". Although 'sufficient' could be interpreted as a subjective measure Bons continues with "this will result in a set of design principles for trade procedures, which specify in detail when a certain trade procedure has sufficient controls." The set of design principles is clearly intended to be an objective measure for the trustworthiness of trade procedures.
The consensus seems to be that controls, whether considered a complement or supplement to trust, are objective. If there is not enough party trust in a certain situation, then some control mechanism is prescribed. For example, if you do not trust someone to pay for goods you consider supplying, then you can use a Letter of Credit. The Letter of Credit control procedure is supposed to supplement everybody's party trust in such a way that everybody's threshold is exceeded. However, I might not trust letters of credit, e.g. because I have the personal experience that letters of credit can be falsified. Therefore, they do not help me to exceed my threshold. So it is not the control that supplements my party trust, but it is the trust in the control, control trust for short, which supplements my party trust.

Besides personal experiences we believe that the understanding of a control is an important determinant of control trust. The underlying idea is that if you fully understand a control mechanism, then you can evaluate the effectiveness of the control mechanism yourself, and by doing so convince yourself that it really works to protect your interests. In that case you can reach a higher level of trust than when you cannot evaluate the effectiveness yourself, because you don't understand the control mechanism. For example, when you try to determine your level of trust in the SET protocol for electronic payments it is important for you to understand the SET protocol. If you understand the SET protocol you can get useful information by evaluating the protocol. The additional information can increase your level of trust in the SET protocol. If you do not understand the SET protocol, then you cannot get any additional information that might increase your level of trust and you can only select a minimal level of trust based on this factor. (Note that other factors, such as public experience, might still give you a higher than minimal level of trust in the SET protocol).

We argued that trust and control are parallel concepts that supplement each other. We also argued that it is not control in itself that is important, but that the trust in a control mechanism is important. We define transaction trust as party trust supplemented with control trust, which is expressed in the following equation.

$$\textit{Party Trust} + \textit{Control Trust} = \textit{Transaction Trust}$$

The level of transaction trust that a person has should be above his personal threshold. The upper part of figure 1 shows the transaction trust broken down into the constituents, party trust and control trust.

2.4 The Objective and Subjective Aspects of Party Trust and Control trust

In addition to the fundamental difference between party trust and control trust, a more subtle distinction is made in Figure 1 between objective and subjective aspects of party trust as well as control trust. An aspect is objective if it depends on inter-subjective methods that are widely accepted by most people. We illustrate this notion with some examples.

Party Trust:
Objective aspects:
- Social signs: uniforms of police officers and doctors etc. You trust someone's medical advice, because he wears a doctor's uniform and/or a stethoscope.

Subjective aspects;
- 'Good vibrations'; e.g. you trust a person without any earlier experience or interaction, simply because he gives you good vibrations. Some people will call this intuition.
- Personal experience; e.g. you trust a person based on a history of previous interactions and positive experiences. In none of these interactions the person deceived you.
- Communality; e.g. you trust the opinion of an expert, because others trust him too. (Typically, you are not expert enough to assess the quality of his opinion yourself, so you have to rely on your trust in the expert.)

Control Trust:
Objective aspects:
- Quality assessment of control; e.g. you trust the controls, because you assessed them using widely accepted auditing principles and your assessment was positive.

Subjective aspects:
- Understanding of controls; e.g. you trust a control system (e.g. the SET protocol for electronic credit card transactions), because you understand how it works.
- Communality; e.g. you assume that a control system protects you against fraud, because everybody around you is relying on the system to do this.

3. Modeling trust in control mechanisms

3.1 Evidence relations and understanding
In the previous section we argued that the trust an agent has in a control mechanism is an important determinant of the agent's transaction trust. In our opinion the trust an agent has in a control mechanism is largely based on his understanding of the control mechanism. The idea is that if you do not understand a control mechanism, then it is of little value to you. Your trust in the control mechanism is then merely based on an assessment by another agent. Moreover, understanding the procedure is of course also important simply for the proper functioning of the procedure. If agents do not understand a control mechanism, they cannot comply with it. In this section we formalize what it means to understand a control procedure for trust.

Let us start with discussing in some detail an example of a control mechanism, namely the Bill of Lading. The Bill of Lading is one of the most important documents in a so-called Letter of Credit Procedure. Banks to solve the following problem in international trade introduced the letter of credit procedure. Suppose we have a seller in Hong Kong and a buyer in the Netherlands. The agents are geographically far apart, and the goods have to be transported by a carrier from the seller to the buyer (we assume by sea). On the one hand the seller does not want to ship the goods onto the carrier's vessel (and thereby lose control over them) without first receiving payment from the buyer. On the other hand the buyer does not want to pay the seller (and thereby lose control over the money) before the goods have been shipped. In other words, the agents prefer a simultaneous exchange of the shipment of the goods in return for the money. To solve this deadlock situation banks introduced the letter of credit, which is an agreement that the bank of the buyer will arrange the payment for the seller as soon as the seller can prove to the bank that he shipped the goods. The bill of lading is issued by the carrier in return for the goods that he received from the seller. The United Nations Convention on International Multimodal Transport of Goods describes this function as follows [UN80]:

Article 10 - *Evidentiary effect of the multimodal transport document*

Except for particulars in respect of which and to the extent to which a reservation permitted under article 9 has been entered:
(a) The multimodal transport document shall be prima facie evidence of the taking in charge by the multimodal transport operator of the goods as described therein; and
(b) Proof to the contrary by the multimodal transport operator shall not be admissible if the multimodal transport document is issued in negotiable form and has been transferred to a third party, including a consignee, who has acted in good faith in reliance on the description of the goods therein.

In other words, the Bill of Lading as multimodal transport document *reliably indicates* that the goods have been shipped in international trade procedures. Note that this article has a normative element. Whether the Bill of Lading is evidence does not depend so much on whether a person is convinced by it, but the law simply stipulates that everybody should consider this document as sufficient evidence. We use the conditional operator $\Rightarrow_P$, which denotes 'reliably indicates', to formalize the following so-called evidence rule:

$$\text{1) BoL} \Rightarrow_P \text{Shipped} \qquad\qquad \text{"evidence rule"}$$

This is read as 'In the context of procedure P, the Bill of Lading reliably indicates that the goods were shipped'. The conditional $\Rightarrow_P$ has the following axioms

[CC] $(A \Rightarrow_P B) \wedge (A \Rightarrow_P C)) \rightarrow (A \Rightarrow_P (B \wedge C))$

[CA] $((A \Rightarrow_P B) \wedge (C \Rightarrow_P B)) \rightarrow ((A \vee C) \Rightarrow_P B)$

and the following inference rules

[RCEC]   If $\vdash A \leftrightarrow B$, then $\vdash (C \Rightarrow_P A) \leftrightarrow (C \Rightarrow_P B)$

[RCEA]   If $\vdash A \leftrightarrow B$, then $\vdash (A \Rightarrow_P C) \leftrightarrow (B \Rightarrow_P C)$

Note that the modus ponens inference rule does not hold for $\Rightarrow_P$, hence it is much weaker than material implication. Our formal representation of this notion of 'reliably indicating' is inspired by the counts-as operator that was introduced by Jones and Sergot in [JS96]. Jones and Sergot proposed a logic of a conditional operator $\Rightarrow_S$, which they interpret as 'counts as'. They illustrate this notion with the example that when a priest declares a couple husband and wife (A), then in many legal systems (S) this counts as creating a marriage (B). Lay people do not have this power. The formal representation of this 'counts as' relation is the formula $A \Rightarrow_S B$. Although our conditional has the same axioms as the counts-as operator, our use is quite different. The typical use that Jones and Sergot make of the formula $A \Rightarrow_S B$ is that A and B are two aspects of the same physical event. In their

paradigmatic example the wedding ceremony performed by the priest gets a special meaning, creating a marriage. In our reading, however, the A and B in $A \Rightarrow_S B$ are usually two different events, which stand in a special evidence relation to each other. Analogously, to smoke which usually signals fire. Note that the evidence relation is not a causal relation. Just as smoke does not cause fire, the bill of lading does not cause shipment.

We described the evidence rule and the procedure in an objective manner, i.e. in terms of objective facts such as 'BoL' and 'Shipped'. For the actual execution of the procedure, however, the mental states of the agents involved are equally important. If one of the agents does not believe the facts, or something went wrong, e.g. an agent did not receive the Bill of Lading, then the procedure does not work. Hence, we cannot simply use objective facts like 'BoL' and 'Shipped' for modeling the mental states of the agents, but we have to use subjective beliefs about such facts to model the mental state of the agents. To model these belief states of agents, we use epistemic operators such as $B_i\varphi$, which denotes that agent i believes φ, and $K_i\varphi$, which denotes that agent i knows φ. If agent b accepts the Bill of Lading, then we represent this by the formula $B_i BoL$, which denotes that the agent i has accepted the document, i.e. the agent believes the content of the document. When an agent has received and read a document, then he decides whether or not to accept the content of the document. This decision depends on whether the agent thinks that the document is forged or not, and whether the document comes from a trustworthy source. Similarly, $B_i Shipped$ means that the agent i believes that shipment of the goods took place. The K_i and B_i operators have the usual axioms and inference rules.

K_i Axioms:
1) $K_i(\varphi \rightarrow \psi) \rightarrow (K_i\varphi \rightarrow K_i\psi)$ (K axiom for K_i)
2) $K_i\varphi \rightarrow \varphi$ (T Axiom)
3) $K_i\varphi \rightarrow K_iK_i\varphi$
4) $\neg K_i\varphi \rightarrow K_i\neg K_i\varphi$

B_i Axioms:
1) $B_i(\varphi \rightarrow \psi) \rightarrow (B_i\varphi \rightarrow B_i\psi)$ (K axiom for B_i)
2) $B_i\varphi \rightarrow \neg B_i\neg\varphi$
3) $B_i\varphi \rightarrow B_iB_i\varphi$
4) $\neg B_i\varphi \rightarrow B_i\neg B_i\varphi$

and the following inference rules:

1) if φ and $\varphi \rightarrow \psi$, then ψ
2) if $\vdash \varphi$, then $\vdash K_i\varphi$ and $\vdash B_i\varphi$ (Necessitation rules)

We model the fact that an agent understands the evidence rule of the procedure with the following formula.

2) $K_i(B_i BoL \Rightarrow_P B_i Shipped)$ "epistemic evidence rule"

This formula says that agent i knows that, if he believes the Bill of Lading, then according to the procedure P he has a good reason to believe that the goods are shipped. We use here the knowledge operator, because procedures or legal texts are non-empirical information (like the rules of a game, or mathematics). In other words, these are not empirical data about which you can make incorrect observations. You either know this or not, but there is nothing in between, while you can get

misleading information about empirical facts such as a bill of lading or shipment. Hence, we use the B_i operator to represent the belief in these facts.

It is a general principle in most legal systems that its norm subjects are supposed to know the norms. This can be represented by an obligation for the norm subjects to 'ought to know', or as an assumption of the legal system. However, if it is an assumption of the legal system, then it is clearly a non-defeasible assumption, because according to Article 10 evidence to the contrary is not taken into account by the legal system. We have taken the first option and represented it as an obligation for the norm subject. The norm in Article 10 expresses that everybody who uses the trade procedure *ought to know* that the Bill of Lading reliably indicates that the goods were shipped is formalized as:

3) $O_iK_i(B_iBoL \Rightarrow_P B_iShipped)$, for all agents i   "obligatory knowledge of the evidence rule"

Where the deontic operator O_i is the standard deontic logic (SDL) operator. We have the usual SDL axioms and inference rules.

    O_i Axioms:
    1) $O_i(\varphi \rightarrow \psi) \rightarrow (O_i\varphi \rightarrow O_i\psi)$ (K axiom for O_i)
    2) $O_i\varphi \rightarrow \neg O_i \neg \varphi$

and the following inference rules:

    1) if φ and $\varphi \rightarrow \psi$, then ψ
    2) if $\vdash \varphi$, then $\vdash O_i\varphi$ (Necessitation rule)

The idea of rule 3 is that an agent cannot use the argument that he did not know rule 2 as justification for violating an obligation. In other words, if agent i has received the Bill of Lading but did not pay for the goods on time, then agent i cannot justify his violation of the obligation to pay for the goods by saying that he did not know that the goods have been already shipped. Agent i ought to have known that receiving the Bill of Lading reliably indicates that the goods were shipped.

There is a technical problem with rule 3. The combination of the O_i operator and the K_i operator leads to a potential paradox.[2] Using the K and T axioms, and the Necessitation inference rule from SDL, we can derive the following theorem.

        4) $O_iK_i\varphi \rightarrow O_i\varphi.$ (SDL Theorem)

In most cases this theorem is counter-intuitive. From the obligation to *know* φ, does not follow that the fact φ itself is obligatory. This is usually illustrated with the following example. If your wife is committing adultery, then you should know about this. However, this does not imply that she should commit adultery. Due to theorem 4, Rule 3 implies $O_i(B_iBoL \Rightarrow_P B_iShipped)$. In other words, from the norm that the evidence rule should be known by everybody, can be inferred that the evidence rule should hold for everybody. However, this is less surprising than the adultery example, because we use the knowledge operator only for non-empirical legal code, and for this type of legal information holds automatically that it is obligatory. Hence, the theorem $O_iK_i\varphi \rightarrow O_i\varphi$ is not counter-intuitive when it concerns knowledge about legal facts φ, and therefore this theorem is not paradoxical in our logic.

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[2] We thank Marek Sergot for pointing out this problem.

The last issue that we have to address is the common knowledge aspect of trust. The letter of credit procedure is only trustworthy for the seller if he knows about all the other parties involved, e.g. the buyer, the buyer's bank etc, that they will accept the bill of lading as proof of shipment. In other words, the seller has to know that the evidence rule is obligatory knowledge for all the other parties. We model this by the following formula

$$5)\ K_i(O_j(K_j(B_jBoL \Rightarrow_P B_jShipped)))\ \text{for all agents}\ j \neq i$$

One of the important conclusions of this analysis of what it means to understand a control procedure for trust is that the axioms of the epistemic operators K_i or B_i are not sufficient to model the actual understanding of the procedure. The rules 2, 3 and 5 of the agent's mental state rather than the S5 or KD45 axioms of the operators Ki and Bi characterize the understanding of the procedure. The understanding of the procedure is modeled by the fact that the rules 2, 3 and 5 are part of the agent's mental state. In other words, B_iBoL does not model that the agent understands the Bill of Lading. It only models that the agent has *accepted* the Bill of Lading. *Understanding* the complete functionality of the Bill of Lading requires a lot more. The agent has to know about all the consequences and functions of the Bill of Lading, and the agent has to know what he and other agents are supposed to know about these consequences.[3]

3.2 Trust in trade procedures

In ([Bons97]) a set of auditing principles is introduced for trustworthy trade procedures in international trade. The difficult thing in international trade is that you often do have very little information about your potential trade partner. The underlying idea is that if trade procedures are compliant with these auditing principles, then these procedures create enough trust for people to trade. An example of such an auditing principle is the following:

> *If Role 1 cannot witness the performance of a counteractivity, another Role 3 should testify the completion of Role 2's activity if the agent playing Role 2 is not trusted by the agent playing Role 1. This document must be received by Role 1 before the execution of its primary activity, and the agent playing Role 3 should be trusted by the agent playing Role 1.*

This general principle can be applied to the earlier example of the seller in Hong Kong and the buyer in the Netherlands. The first condition, that the buyer (Role 1) cannot witness the shipment of the goods, holds. And the second condition that the seller (Role 2) is not trusted by the buyer (Role 1), holds as well. (We said that the buyer does not want to pay before shipment of the goods). The solution that the general auditing principle prescribes is the introduction of a third agent (Role 3) that testifies (using a document) that the goods have been shipped. The buyer (Role 1) should have received this document before the seller is paid.

This general principle, therefore, imposes a constraint on the trade procedure we described in the previous section. It is not enough that the seller informs the buyer of the shipment by sending the buyer the Bill of Lading. The buyer will only accept the content of the Bill of Lading when it is issued by an independent third party. In other words, we only have that B_iBoL is true, if the Bill of Lading was issued by a trusted third party. Because of the importance of the information source we investigate modeling of trusted information sources in the next section.

3.3 Modeling trust in information sources.

In the previous sections we discussed how a belief in a bill of lading should reliably indicate a belief that the goods were shipped. However, the questions still remains open how you can justify your belief that

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[3] Knowing about all the functions of the Bill of Lading is certainly not trivial. For example, the Bill of Lading is evidence of a contract of carriage with a carrier. This contract of carriage states that only the Bill of Lading can be used to claim the goods from the carrier. Receiving the Bill of Lading also means a transfer of ownership.

a specific bill of lading is not a forgery, i.e. to assess whether the formula B_iBoL is actually true. This latter issue can be addressed by assessing the reliability of the source that issued the bill of lading. In [D97] a logic to formalize reliable information sources is presented. The first step is to model that an agent i has asserted a fact p by A_ip. The fact that agent i is considered by agent k to be a reliable source of information regarding a fact p is represented by $RV_{i,k}(p)$, and is defined as:

$$RV_{i,k}(p) =_{def} K_k(A_ip \rightarrow p)$$

We read this as 'the fact that agent k considers agent i to be a reliable source regarding p is defined as agent k knows that if agent i asserts p then p is true'. We could also use the weaker definition:

$$RV_{i,k}(p) =_{def} K_k(B_kA_ip \rightarrow B_k\ p)$$

We read this as 'the fact that agent k knows that agent i is a reliable source regarding p is defined as agent k knows that if he believes that agent i asserts p then he/ believes that p is true.' Instead of saying that agent i is known by agent k to be a reliable source regarding p, we interpret $B_kA_ip \rightarrow B_k\ p$ as representing that agent k trusts agent i. In case the buyer trusts the carrier with respect to the Bill of Lading, we can represent that by $RV_{carrier,buyer}(BoL)$, which is defined as $K_{buyer}(B_{buyer}A_{carrier}BoL \rightarrow B_{buyer}BoL)$. The seller communicates the fact that the carrier asserts that the goods have been shipped to the buyer by sending the Bill of Lading to the buyer.

We modeled the situation in which the buyer trusts the carrier with respect to the Bill of Lading. In actual trade situations, however, it is usually the case that the buyer does not know the carrier selected by the seller. The buyer has no previous experiences, nor does he know the carrier's reputation. In other words, the buyer has no particular reason to trust this specific carrier. In practice the buyer accepts Bills of Lading issued by carriers he does not know. The main reason for this is that the carrier has no vested interest in the purchase contract between the buyer and the seller. In other words, the carrier's independence is important. The buyer trusts the carrier because of the independent role the carrier plays in the procedure. This is an example of trust that the buyer has in the control mechanism. We represent the fact that the buyer considers information from any agent that plays a trustworthy role with the formula:

$$K_k(\forall i((Role(i, R) \wedge A_ip\ ) \rightarrow B_kp)))$$

This formula is read as 'agent k knows that for every agent i holds that, if agent i plays the role R and agent i asserts p, then p is believed to be true.' It is important to note that this is fundamentally different from the formula $K_k(A_ip \rightarrow p)$. The formula $K_k(A_ip \rightarrow p)$ states that agent k knows that if agent i asserts p, then p is true. This is independent from the role agent i performs. This is trust in the other party. On the other hand, $K_k(\forall i((Role(i, R) \wedge A_ip\ ) \rightarrow B_kp)))$, expresses that the agent k trusts certain agents only in the context in which the agent plays a specific role.

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