RISK ANALYSIS FOR INTER-ORGANIZATIONAL CONTROLS

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Abstract: Existing early requirements engineering methods for dealing with governance and control issues do not explicitly support comparison of alternative solutions and have no clear semantics for the notion of a control problem. In this paper we present a risk analysis method for inter-organizational business models, which is based on value modeling. A risk is the likelihood of a negative event multiplied by its impact. In value modeling, the impact of a control problem is given by the missing value. The likelihood can be estimated based on assumptions about trust and about the underlying coordination model. This allows us to model the expected value of a transaction. The approach is illustrated by a comparison of the risks of different electronic commerce scenarios for delivery and payment.

1 INTRODUCTION

New business models are often based on cooperation among companies in a network organization, made possible by information technology (Tapscott et al., 2000). For the development of business models and the subsequent design and implementation of inter-organizational information systems, practitioners need a good understanding of the governance and control of the network. What is the risk that another participant will default? How can we make sure that participants, on whom the joint success depends, will behave as agreed? When participants who do not know each other need to collaborate, initially lack of trust is likely (Gambetta, 1988). To overcome the initial lack of trust, inter-organizational control measures are needed (Williamson, 1979; Bons et al., 1998). Such measures can take the shape of contractual arrangements or supervision by a trusted third party. Governance and control measures affect system requirements and need to be designed and agreed on explicitly. That means that governance and control issues should be addressed during early requirements engineering (Yu, 1997; Mylopoulos et al., 1997).

A recently developed method for modeling inter-organizational control problems and their solutions is e3-control (Kartseva, 2008; Kartseva et al., 2005). The e3-control method is based on e3-value, a technique for representing and reasoning about networked business models with the perspective of economic value (Gordijn and Akkermans, 2003). Networks should respect the principle of *economic reciprocity*: for all services or goods delivered to the network, the network should provide services or goods of equal value in return. The e3-value method is supported by a graphical modeling tool with some reasoning capabilities to determine well-formedness. An alternative would be dependency graphs, as in i* (Yu, 1997). Value models can be translated into dependency graphs (Gordijn et al., 2006).

However, current conceptual modeling tools have several limitations:

1. There are usually many different ways to deal with governance and control. Current conceptual modeling tools offer no support for prioritizing or selecting among those alternative scenarios.
2. The conceptual modeling tools should help to identify governance and control problems (threats or vulnerabilities), represented in e3-control by a dashed arrow. Currently, the notion of a control problem does not have a precise semantics.

We address these limitations by extending the value modeling framework with risk analysis. Generally, risk is modeled as the product of the likelihood and the impact of an event on the proper functioning of

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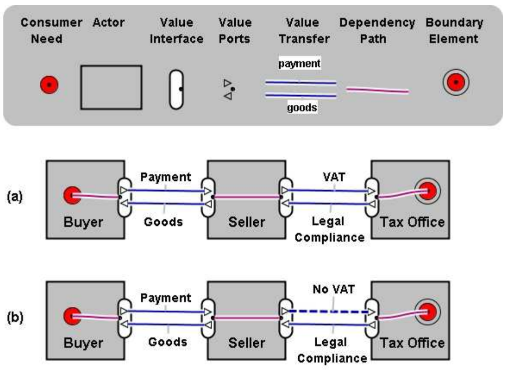


Figure 1: Example of an e3-value model of a purchase with tax payment: (a) ideal situation (b) sub-ideal situation.

an organization: *risk* = *likelihood* × *impact*. In our case, the impact of a missing value transfer is already given by the value model. The likelihood is much harder to identify. We propose to apply existing risk frameworks (e.g. NIST 800-30; ISO/IEC 27005), and organize identified threats and vulnerabilities into a Bayesian network, based on the dependencies implicit in the value model, as well as assumptions about the domain, the participants and the presence or absence of specific control measures. The main contribution of the paper is a re-interpretation of value models, where value transfers are understood as *expected value transfers*. Risk estimates provide a semantics for control problems, and can be used to select or prioritize among control scenarios.

The paper is structured as follows. Section 2 describes e3-value and e3-control. Section 3 presents illustrative scenarios for delivery and payment. Section 4 describes the risk analysis method.

2 VALUE AND CONTROL

An e3-value model provides a conceptual model of the value transfers in a business network, encoded in the e3-value ontology (Gordijn and Akkermans, 2003). Initially we apply the e3-value ontology for the description of organizations that behave in compliance with procedures and regulations. This is called an *ideal situation*. *Sub-ideal situations* resulting from threats or vulnerabilities can be expressed using e3-control, a modification of the e3-value ontology (Kartseva et al., 2005).

The e3-value constructs have a graphical notation. Figure 1(a) shows an example of a buyer who obtains goods from a seller and offers a payment in return. The seller is obliged to pay value-added tax (VAT). This can be conceptualized by the following e3-value constructs (in bold). **Actors**, such as the buyer, seller, and the tax office are economically independent entities. Actors transfer **value objects** (payment, goods, VAT) by means of value transfers, depicted by labeled arrows. A **value interface** models the *principle of economic reciprocity*: actors are only willing to transfer a value in return for some other value object. A value interface consists of **value ports**, to for offering and requesting value objects. Actors may have a **consumer need**, which, following a **dependency path** will result in the transfer of value objects. Transfers are either dependent on other transfers, or lead to a **boundary element**. Dependency paths can be connected by a choice fork (triangle) or parallel execution (bar). Monetary values can be assigned to value transfers, in order to evaluate the relative profitability of a business idea. A tool allows analysts to draw value networks and perform validity checks (www.e3value.com). We consider two requirements for internal validity: (R1) A value interface should have at least one ingoing and at least one outgoing value port. This corresponds to the principle of economic reciprocity. (R2) A dependency path may not contain any cycles.

In e3-value value transfers are assumed to be ‘ideal’, but reality may be sub-ideal: actors commit fraud or make unintentional errors, e.g. participants will not pay, or will not deliver the (right) goods. Often, but not always, this implies violation of the principle of economic reciprocity. All invalid e3-value models indicate a sub-ideal situation, but not all sub-ideal situations correspond to an invalid model: a control problem may be hidden on the coordination level. The specific value transfer which is compromised by a sub-ideal situation – a ‘value leak’ – is graphically represented by a dashed arrow. For example, Figure 1(b) shows a sub-ideal value transfer in which the seller does not pay VAT tax. Currently, dashed arrows are only a notational convention.

The implementation of one value transfer may require several operational and communication activities (Weigand and de Moor, 2003). Value models abstract over the coordination aspects, but the order in which activities take place and the choice of actor performing the activities, forms a crucial part of many control mechanisms (Romney and Steinbart, 2006). So in addition to value models, we need process and coordination models (Wieringa, 2008). We use UML interaction diagrams for this purpose.

3 E-COMMERCE EXAMPLE

The example is concerned with a simple transaction, shown in Figure 2: a buyer and a seller are exchanging money in return for goods. Think of a transaction initiated by eBay or some other electronic marketplace. Delivery will take some time, so at least one of the parties will depend on the other. We assume that participants do not know each other, and have no other reasons to trust one another. Moreover, we assume that initially no additional control measures, such as eBay's reputation mechanism, are in place. Similar scenarios are discussed in the literature on transaction costs and electronic marketplaces (Williamson, 1979; Hu et al., 2004). See (Wieringa, 2008) for coordination models of a similar scenario.

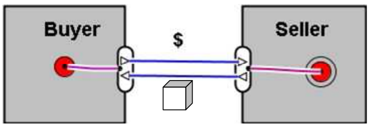
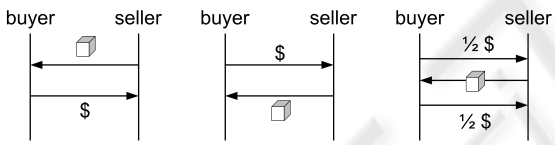


Figure 2: Value model of a generic e-commerce setting

A transaction often consists of several operational activities. By varying the order in which operational activities take place we get different *scenarios*, with different risks for the participants (Figure 3). Which control scenario is selected, generally depends on a multi-party negotiation process.



Scenario 1: pay before delivery | Scenario 2: deliver before paying | Scenario 3: down payment

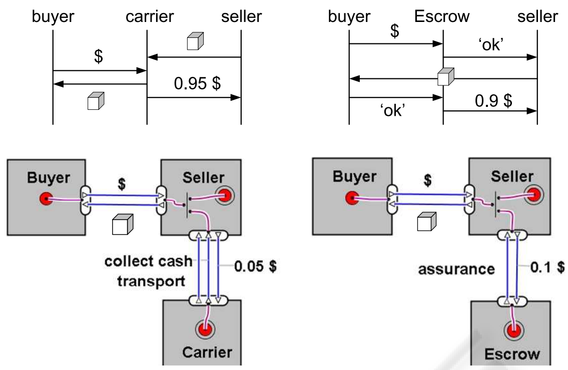
Figure 3: Scenarios for delivery and payment.

1. Pay before Delivery. The buyer must pay before the seller will deliver the goods. This is the preferred option for the seller. The buyer runs the risk that the goods will not be delivered and that the money cannot be recovered.

2. Deliver before Paying. The seller must deliver the goods, before the buyer will pay. This option is preferred by the buyer. The seller runs the risk that the goods will not be paid.

3. Down Payment. A compromise may be reached in the form of a down payment: the buyer will pay for example 50% of the agreed price beforehand. This reduces the risk of the seller of not being paid at all. The additional 50% will be paid after delivery, reducing the risk of the buyer that the goods will not be delivered. Other percentages may be used.

4. Cash on Delivery. The goods are paid to the carrier who delivers the goods. The buyer can inspect the goods before paying, reducing her risks. The carrier acts as a payment guarantee, reducing the risks for the seller. This 'cash collection' can be seen as an additional service. In this version, the service is paid for by the seller. Here we assume the seller will trust the carrier. In practice, the seller will often take additional measures to control the carrier. Think of an obligatory receipt signed by the buyer.



Scenario 4: cash on delivery | Scenario 5: Escrow

Figure 4: Delivery and payment scenarios with third parties.

5. Escrow. Participants hire a trusted third party (the Escrow) to ensure delivery and payment. First the buyer pays the agreed sum to the Escrow. The Escrow notifies the seller that payment has arrived. The seller subsequently delivers the goods. Now the buyer notifies the Escrow of delivery, and thereby releases the payment, with a certain percentage deducted as a fee. The Escrow service may be termed 'assurance'.

Now we will compare the scenarios. We start from the point of view of the seller. Suppose p_b represents the seller's estimate of the likelihood that the buyer will pay beforehand, with $0 < p_b < 1$. This represents the initial trust of the seller in the buyer. When buyers are from a trustworthy community p_b will be relatively high, for example 0.6. But on the internet, p_b could be as low as 0.3. Suppose furthermore that the seller's value for the goods is v_s, with $v_s > 0$, and that the down payment fraction is a, with $0 < a < 1$.

Seller's expected value:
S1: v_s, the agreed price
S2: $p_b v_s$, where p_b is the initial trust
S3: $a v_s + p_b(1-a)v_s$, for 1st and 2nd payment.
S4: $v_s - f$, where f is the carrier's fixed fee.
S5: $v_s - e v_s$, where e is the Escrow fee %.

Regardless of v_s, p_b and a, we have the following ranking: S1 > S3 > S2. So when entering negotiations, the seller will prefer 'payment before delivery'. When that proves impossible, he will try to get the buyer to make a down payment. When the buyer is unwilling to make any down payment, the seller may consider the services of a third party, like a carrier or Escrow. We assume that S4 and S5 guarantee the desired outcome. In practice, an Escrow is probably more certain, but also more expensive. The ranking for S4 and S5 depends on the values for v_s, p_b, a, f and e. Suppose $v_s = 1.0, p_b = 0.6, a = 0.5, f = 0.05$ and $e = 0.1$. In that case: S1 (1) $>$ S4 (0.95) $>$ S5 (0.9) $>$ S3 (0.8) $>$ S2 (0.6).

We can make a similar calculation for the buyer. Let p_s be the buyer's initial trust in the seller. Assume the seller has a reputation to loose, so p_s is 0.9. The price is agreed beforehand, so the buyer's value $v_b = v_s$. The other values remain the same.

Buyer's expected value:
S1: $p_s v_b$
S2: $v_b = 1$,
S3: $v_b - (1 - p_s) a v_b$
S4: $v_b = 1$
S5: $v_b = 1$.

We get the following (partial) ranking for the buyer: {S2 (1), S4 (1), S5 (1)} $>$ S3 (0.95) $>$ S1 (0.9).

Clearly, the first choices do not match. The second choices are closer. What decides the outcome of such a negotiation? Until now we have only made assumptions about trust. But some scenarios will never be the outcome of a negotiation, given the relative *dominance* of players on the market. Suppose that there are many sellers, who compete ferociously. Buyers have a choice, so they can set the trade conditions. In such a market, the cash for delivery scenario is more likely. When there are few sellers, the seller can set the trade conditions. In such cases a down payment scenario is more likely. This kind of setting is traditionally analyzed with game theoretic techniques. For example (Hu et al., 2004) calculate the optimal fee for an Escrow service. Here we do not need full-blown game theory. Crucial is that the assumptions are derived from the scenario and market conditions.

4 VALUE MODELS AND RISK

In this section we describe how to re-interpret value transfers under risk. The general idea is to label value transfers with a probability. To reason with probabilities one often has to make the assumption that they are independent. However, value transfers are usually dependent, because of the principle of reciprocity and the dependency paths. Reciprocity means that one transfer may only take place provided that the other transfer has also taken or will also take place, and vice versa. This is modeled as a mutual conditional probability. For example, the mutual dependency of payment on delivery in Figure 2 should ideally come out as follows: $\text{P}(pay|deliver) = \text{P}(deliver|pay) = 1$ and $\text{P}(pay|\neg deliver) = \text{P}(deliver|\neg pay) = 0$.

In practice, also control measures are faulty. How much investment in controls is acceptable? By combining the two variables we get four possible outcomes, which can be ordered according to their relative acceptability. In general, stake holders tend to prefer a deal to no deal, and prefer no deal to a violation of the principle of reciprocity: $(pay \wedge deliver) > (\neg pay \wedge \neg deliver) > \{(pay \wedge \neg deliver), (\neg pay \wedge deliver)\}$.

The probability that a complete transaction will occur, is a summation of the probabilities for each of the execution paths made possible by the coordination model. We must realize that – by definition – these probabilities are not independent, we cannot simply add or multiply the probabilities. Instead we should use conditional probabilities, using Bayes' rule: $P(a|b) = P(b|a)P(a)/P(b)$.

Interestingly, in e3-value dependency paths are defined as directed acyclic graphs, which model the dependencies between events: one value transfer may only occur provided another value transfer has occurred. We suggest to use these dependency paths to derive a *Bayesian Network*. Formally, a Bayesian Network is also a directed acyclic graph, where nodes correspond to events, and links represent causal dependencies between events (Pearl, 1986). Unconnected nodes are considered to be independent. This reduces the space of possible combinations to consider. Attached to each node is a conditional probability table, which gives the relative strength of the dependency (Figure 5).

Where do we get the data for 'filling' the conditional probability tables? Well, businesses can monitor the business partners and make risk estimates based on historical experience. However, when a new business model is set up, no such data is usually available. This need not be a problem. The point of the example in Section 3 was to show that conditional probabilities can in fact be estimated, given general assumptions about participants and market conditions. Think of assumptions like: 'buyer wants goods', 'seller has a reputation to loose'. In addition, we need the relative strength of the control measures in the coordination model, but such estimates should be available during the design phase.

Starting from an e3-value model we can systematically explore transaction risks, using the dependency paths, assumptions about participants, and the underlying coordination models as a guideline. The method can be summarized as follows.

1. Start with an ideal value model.

2. Start with the consumer need. Follow the dependency path to the boundary element. Generate the skeleton of a Bayesian network, using the value model and dependency path as a guideline.
3. For each value transaction, generate a choice-fork with two (or more) options:
– agent *a* goes first, followed by agent *b*,
– agent *b* goes first, followed by agent *a*,
– either *a* or *b* splits the value transfer,
– either *a* or *b* makes use of a third party.
4. Evaluate the value and likelihood of each of these 'forks' given existing agreements about control measures in the coordination model, and general assumptions about the domain. Now set risk = value × likelihood.
5. To get the risk of a scenario, sum the risk over all choice-forks.

To illustrate the method, we consider the example of down payment (S3). First, we assume participants agree on the down payment interaction protocol. Second, we split the value transfer, and follow the steps in the coordination model (Figure 3), adding non-payment and non-delivery explicitly as events. This would produce a game-tree, with the pay-offs (impact) and likelihoods for each agent based on the assumption from Section 3.

Instead of a game-tree, we can also immediately generate the underlying Bayesian network, as we have done here (Figure 5). The Bayesian network shows that the conditional probabilities are very simple: here they are only based on initial trust, and on the outcome of the previous step in the interaction protocol. We believe this limited complexity is a general property of the e-commerce domain. Otherwise, the effects of interaction protocols could not be explained to practitioners. In the last step, the trust of the seller in the buyer (p_b) is 0.6 without control measures, see the argumentation in Section 3. Similarly, the initial trust of the buyer in the seller (p_s) is 0.9, which determines the second step. There is also a chance that, even after agreeing on the protocol, the buyer does not want to go along with the deal after all, say 0.2. In that case, the seller runs only a little risk, because no goods are being shipped.

Finally, to link these probability estimates to the impact of the various events, we can put the Bayesian Network as it were 'on top of' the e3-control model. This produces a diagram as in Figure 6. In this model, we see the usual dependency paths of e3-value and e3-control, but now annotated with their relative likelihoods. Both the likelihood and impact of the various 'negative events' (buyer does not pay first instalment, seller does not deliver, buyer does not pay the second

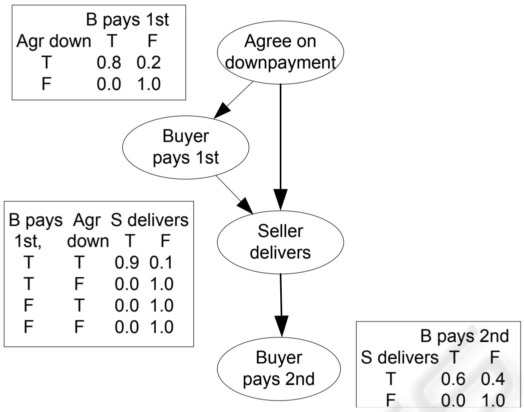


Figure 5: Bayesian Network for Scenario 3 down payment, with conditional probability tables.

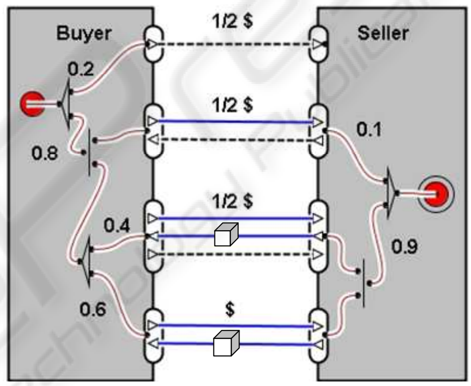


Figure 6: e3-control model with likelihood estimates for scenario 3 down payment

instalment) can now be estimated. In other words, the dashed lines, which until now only indicated a control problem, have been given a proper semantics. The meaning of a 'sub-ideal' dashed line, like that of an 'ideal' value transfer, is the relative size of the risk associated with it. This solves the second limitation of current conceptual modeling techniques like e3-control. Such risk estimates can be made for all possible control solutions, such as the various scenarios discussed here. This makes it possible to compare and prioritize the scenario's. Given assumption about the relative preferences of the participants, we can predict what the most probably outcome of the negotiation about control measures will be. This solves the first limitation of current conceptual modeling techniques.

5 CONCLUSIONS

Governance and control issues of a network organization, determine the design of inter-organizational systems in a business relation. There are various conceptual modeling tools for network organizations. Some model the transfer of objects of value between actors (Gordijn and Akkermans, 2003), whereas others model the dependencies between goals of actors (Yu, 1997). In this paper we extend one of these methods, namely e3-control (Kartseva et al., 2005), with risks. Risk estimates are needed to make informed decisions about implementation of a control measure. A representation of the relative effectiveness of alternative control scenarios should facilitate the negotiation process between network participants.

We propose to replace the meaning of a value transfer by the *expected value*: the probability of the value transfer succeeding, multiplied by the value itself. The risk then becomes the probability of the value transfer not succeeding, multiplied by the missing value. Using an example of different interaction protocols in an e-commerce setting, we have argued that it is feasible to make estimates of such probabilities, based on general assumptions about the participants and the domain.

Moreover, we present a systematic method for generating a Bayesian Network, based on the value model and the execution paths allowed by the underlying coordination model. The Bayesian network provides conditional probabilities for each of the value transfers or dependency paths. The example shows that reasonable conditional probabilities can in fact be estimated, based on available design knowledge and general assumptions.

Extending value models with probabilities solves two limitations of current conceptual modeling tools for dealing with governance and control. First, calculating the net expected value for each scenario, which includes the probability of lost value, provides a nice measure for prioritizing or selecting control scenarios. Second, sub-ideal value transfers (dashed arrows) which represent a control problem, are now provided with a proper semantics. The risk exposure is exactly the meaning of a sub-ideal value transfer.

There is some related research. Asnar et al use an extension of TROPOS with risk assessment, to compare alternative business solutions in a network organization (Asnar et al., 2008). Their work is similar to us, because it uses dependencies to model the network. However, they cannot express the impact of a control problem in terms of the lost value.

Our research has limitations. We showed that our approach is feasible using an example, but we cannot say much about scalability or portability to other domains. Tool support only becomes necessary for complex applications. Future research will have to point out whether our approach is helpful for large cases.

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