

Automating the Dispute Resolution in a Task Dependency Network

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Abstract

When perturbation or unexpected events do occur, agents need protocols for repairing or reforming the supply chain. Unfortunate contingency could increase too much the cost of performance, while breaching the current contract may be more efficient. In our framework the principles of contract law are applied to set penalties: expectation damages, opportunity cost, reliance damages, and party design remedies, and they are introduced in the task dependency model [13].

1 Introduction

The formation of the supply chain is grounded in three key technologies: a) the decision-making mechanism of an individual business entity; b) a coordination mechanism for the allocation of contracts; c) the representation of capabilities and services. In this paper we focus on the second aspect: contract allocation. Flexibility and risk sharing in supply contracting is a main issue when confronted to the uncertain nature of the environment. Contracts aim at improving flexibility, while preserving the interests of both parties. Our interest relies on remedies for breach of contracts. An economic analysis of remedies models their effects on behavior. The remedies imposed by law affect the agents' behavior [3] by: (1) searching for trading partners; (2) negotiating exchanges; (3) drafting the stipulations in contracts; (4) keeping or breaking promises; (5) taking precaution against breach causing events;

(6) acting based on reliance on promises; (7) acting to mitigate damages caused by broken promises; (8) settle disputes caused by broken promises. In the supply chain context a contract breach can be propagated over the entire chain. The damages imposed by legal institutions can positively influence breach propagation. Usually, a contract breach appears when some perturbation arises on the market¹. Therefore, proper rules imposed by law help agents to manage perturbations in supply chain. Each agent has more than one way to respond to a perturbation. The question is how can we change the strategic environment so that the resulting behavior of the involved agents is efficient? More exactly, what types of contracts or market structure can impose this mutually acceptable solution if such a solution exists and, at the same time, these contracts do not have to force the agents to act irrationally when a mutual solution does not exist. Our goal is to find which of the following remedies are adequate for an efficient functionality of the supply chain: expectation damages D_e , opportunity cost D_o , reliance damages D_r , and party designed damages D_p .

The main contribution of this paper consists in introducing penalties in the task dependency network model. It also investigates the agents' decision to breach or perform the contract when they face different levels of information sharing.

In the next section we introduce contracts within the task dependency network model and in section 3

¹For instance, the market price of a raw material could rise so much that, for the agent who had planned to achieve it in order to produce an item, is more efficient to breach the contract with its buyer.

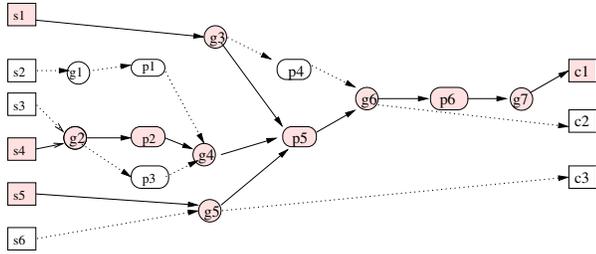


Figure 1. Task dependency network: goods are indicated by circles, suppliers and consumers are represented by boxes, while producers by curved boxes.

we describe the four types of remedies used in the market. The section 4 discusses how breach decision is influenced by information sharing between firms and in section 5 the functions used by the market for penalties are implemented. Sections 6 and 7 detail future experiments and related work.

2 Problem specification

2.1 Task Dependency Network

We adapted the task dependency network model [13] used in the analysis of the supply chain as follows. The task dependency network is a directed, acyclic graph, (V, E) , with vertices $V = G \cup A$, where: G is the set of goods, $A = S \cup P \cup C$ is the set of agents, S is the set of suppliers, P is the set of producers, C = the set of consumers, and a set of edges E connecting agents with their input and output goods. With each agent $a \in A$ we associate an input set I_a and an output set O_a : $I_a = \{g \in G \mid \prec g, a \succ \in E\}$ and $O_a = \{g \in G \mid \prec a, g \succ \in E\}$. Agent a is a supplier if $I_a = \emptyset$, a consumer if $O_a = \emptyset$, and a producer in all other cases. With no loss of generalization, we consider that a consumer $c \in C$ needs a single item ($|I_c| = 1$) and every supplier $s \in S$ or producer $p \in P$ need one single item ($|O_s| = 1$ and $|O_p| = 1$).

An agent must have a contract for all of its input goods in order to produce its output, named *presumable*² and denoted by \hat{p} . If we note $n_p = |I_p|$, the agent has to sign $n_p + 1$ ³ contracts in order to be a member in the supply chain. For each input good $g_k \in I_p$ the agent p bids its own item valuation v_p^k . The auction for the good g_k sets the transaction price at p_k .

²Note that when someone breaches a contract with a presumable agent it has to pay more damages.

³Suppliers and consumers have to sign one contract only.

The agent's investments are $I_p = \sum_{k=1}^{n_p} p_k$ where k are the winning input goods. We note by I_p^g the agent's investments but without considering the investments made for the current good g . Similarly, we note all bid values submitted by the agent p as $V_p = \sum_{k=1}^{n_p} v_p^k$ and this value without the bid for good g as V_p^g . For the output good, the agent p signs a contract at reliance price R_p .

We assume no production costs and when perturbation or unexpected events occur, agents need protocols for repairing or reforming the supply chain. "Allowing decommitment without remedies rises the question of how to enforce that agents decommit only when they are in dead ends, and also does not address the fact that unilateral decisions for decommitment can potentially break the (possibly desirable) contracts of many other downstream producers" [13]. Introducing remedies can reduce aggressive bidding and mitigate the potential problems.

2.2 Contracts

The goods are transacted using the (M+1)st price auction protocol [14], which has the property to balance the offer and the demand at each level in the supply chain (otherwise the supply demand equilibrium cannot be achieved globally). It provides a uniform price mechanism: all contracts determined by a particular clearing are signed at the same price. In the contract

$$C = \langle a_s, a_b, g_i, P_c, t_{issue}, t_{maturity} \rangle$$

a_s represents the seller agent, a_b the buyer agent, g_i the good or the transaction subject, P_c the contract price, t_{issue} is the time when the contract is signed and $t_{maturity}$ is the time when the transaction occurs. During experiments, a contract can be in one of the following states: active (between t_{issue} and $t_{maturity}$ and no breach), violated (at the time of breach $t_{issue} \leq t_{breach} \leq t_{maturity}$) or performed (if no party breaches until $t_{maturity}$).

3 Remedies

According to [12], there are five different philosophies of punishment from which all punishment policies can be derived: deterrence, retribution, incapacitation, rehabilitation and restoration. Retribution is most adequate for multi-agent systems [9], as it considers that the contract breach should be repaired by a remedy as severe as the wrongful act⁴. The remedies described in

⁴Courts call a term "liquidated damages" when it stipulates damages that do not exceed the actual harm. When the stip-

this section try to equal the victim's harm. In the first three cases⁵, the system estimates the harm according to current market conditions, while in the last case, the agents themselves compute the damages and generate their own penalties.

3.1 Expectation Damages

The courts reward damages that place the victim of breach in the position it would have been in if the other party had performed the contract [3]. Therefore, in an ideal situation, the expectation damages do not affect the potential victims, whether the contract is performed or breached. Ideal expectation damages remain constant when the promisee relies on the performance of the contract more than it is optimal.

3.2 Reliance Damages

Reliance increases the loss resulting from the breach of the contract. Reliance damages put the victim in the same position after the breach as if it had not signed a contract with the promisor or anyone else [3]. In an ideal situation, the reliance damages do not affect the potential victims, whether the contract is breached or there was no initial contract. No contract provides a baseline for computing the injury. Using this baseline, the courts may reward damages that place victims of breach in the position that they would have been, if they had never contracted with another agent. Reliance damages represent the difference between profit if there is no contract and the current profit.

3.3 Opportunity Cost

Signing a contract often entails the loss of an opportunity to choose an alternative. The lost opportunity provides a baseline for computing the damage. Using this baseline, the courts reward damages that place victims of breach in the position that they would have been if they had signed the contract that would have been the best alternative to the one that was breached [3]. In the ideal situation, the opportunity cost damages do not affect the potential victims, whether the contract is breached or the best alternative contract is performed⁶. If breach causes the injured party to purchase a substitute item, the opportunity

ulated damages exceed the actual harm caused by breach, the remedies are called penalties.

⁵Expectation damages, reliance damages and opportunity cost are analyzed from an economical point of view in [3, 6].

⁶Opportunity cost and expectation damages approach equality as markets approach perfect competition.

cost formula equals the difference between the best alternative contract price available at the time of contracting and the price of the substitute item obtained after the breach.

3.4 Party-Designed Remedies

The contract might stipulate a sum of money that the breaker will pay to the party without guilt. These "leveled commitment contracts" [10] allow self-interested agents to face the events that unfolded since the contract started. A rational person damages others whenever the benefit is large enough to pay an ideal compensation and have some profit, as required to increase efficiency. Game theoretic analysis has shown that leveled committed contracts increase the Pareto efficiency of contracts. One contract may charge a high price and offer to pay high damages if the seller fails to deliver the goods, while another contract may charge a low price and offer to pay low damages, the types of contracts separating the set of buyers and allowing "price discrimination."

4 Efficient breach

Breaching is more efficient than performing when the costs of performing exceed the benefits to all parties. The costs of performing exceed the benefits when a contingency materializes so that it makes the needed resources for performance more valuable in an alternative usage. Two types of contingencies reorder the value of resources: unfortunate contingency increases the cost of performance (an unpredictable strike) or fortunate contingency makes nonperformance even more profitable than performance (the seller discovers a buyer who values the product even more).

The literature distinguishes between *a priori* and *a posteriori* decided sanctions. According to [9], we consider that a posteriori decided penalties should be avoided in agent-based modeling, since they do not allow agents to reason about when to respect their commitments. Therefore, all the above remedies D_e , D_r , D_o , and D_p are common knowledge and settled a priori. Nevertheless, only the D_p penalty fully reveals the amount of money the agents will pay in case of breach. In the other cases, more information is needed for an agent in order to anticipate how high remedies it has to pay. Hence, the potential victim could advertise how much it will lose depending on the types of remedies imposed by the market (see table 1). This approach stresses the relation between legal rules, communication and common knowledge. We define three levels of information sharing as in [17] (no share, share to each

Remedy	Information shared
D_e	expected profit
D_o	provided by the market
D_r	investments made
D_p	known from contract

Table 1. Dependence of shared information

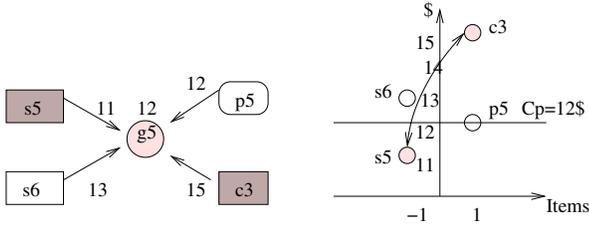


Figure 2. Supplier-Consumer contract

neighbor, and broadcast sharing) and analyze the social welfare in each case. The market should provide incentives for information sharing. In our case, hiding such information in order to collect more penalties should not be encouraged by the rules for remedies.

The conclusions are: (i) The amount of expectation damages must place the victim in the same position as if the actual contract had been performed ⁷(ii) The amount of reliance damages must place the victim in the same position as if no contract had been signed; (iii) The amount of opportunity-cost damages must place the victim in the same position as if the best alternative contract had been performed; (iv) Party designed remedies specify themselves the amount of damages in case of a breach.

5 Case Analysis

5.1 No substitute

5.1.1 Supplier-Consumer

First, we analyze the simplest case in which a contract is signed between a supplier and a client. Recall that a supplier is an agent who does not have any input good in task dependency network model, while the consumer is an agent who does not have any output good.

The consumer breaches the contract: In fig. 2 the suppliers s_5 and s_6 want to sell good g_5 at price 11

⁷We assume that the rate of breach is low. Otherwise, it can be anticipated to some extent, and so the promisee can plan for breach, just as airlines and hotels plan for "no-shows [3]."

and respectively 13, while the agents p_5 and c_3 try to buy it at prices 12 and 15. According to (M+1)st price protocol the transaction price is $P_c = 12\$$. The auction clears at every round. A single contract is signed: $C_{g_5}^1 = \langle s_5, c_3, g_5, 12, t_{issue}, t_{maturity} \rangle$ Consider that c_3 breaches the contract. In this case, the remedies will be:

Expectation damages: if the agent c_3 performs, the s_5 's estimated profit is the difference between the contract price $P_c = 12$ and its own valuation⁸ $v_{a_6}^{g_5} = 11$ (victim valuation). The remedies compensate this value:

$$D_e = P_c - v_a^g$$

Opportunity damages: first, the auctioneer has to compute the opportunity cost P_o , which is the transaction cost in case the breacher was absent from the auction. If agent c_3 is not present $P_o = 11$. The s_5 's bid is one who wins. The contract would be $C_{g_5}^1 = \langle s_5, p_5, g_5, 11, t_{issue}, t_{maturity} \rangle$ and the agent's profit would be $P_o - v_a^g$. But, when there is no contract for agent s_5 , his profit would be null. The opportunity damages should reflect this. We define opportunity cost damage D_o which is received by the agent a as:

$$D_o = \max(P_o - v_a^g, 0)$$

Reliance damages: if the victim does not have any input good, the supplier's investments in performing are null: $D_r = 0$.

Party-designed remedies: the remedies may be a fraction from the contract price ($D_p = \alpha \cdot P_c$) or a fraction from the expected profit ($D_p = \alpha \cdot D_e$) or constant ($D_p = C$). In each of the following cases, this type of remedies is computed in the same manner.

The supplier breaches the contract: Consider that s_5 breaches contract $C_{g_5}^1$.

Expectation damages: $D_e = v_a^g - P_c$.

Opportunity damages: if the breacher had not bid and the victim had signed a contract at the opportunity price P_o , than it's profit would have been $v_a^g - P_o$. If the victim has no contract when the breacher is not bidding, it receives no damages. Hence

$$D_o = \max(v_a^g - P_o, 0)$$

In the depicted case, if the agent s_5 had not existed, c_3 would have signed a contract with s_6 for an opportunity cost $P_o = 12$. Therefore, $D_o = 3$.

Reliance damages: because the client does not produce any output goods, it's reliance is null: $D_r = 0$.

⁸(M+1)st price auction has the following property: the dominant strategy for each agent is to reveal its real valuation.

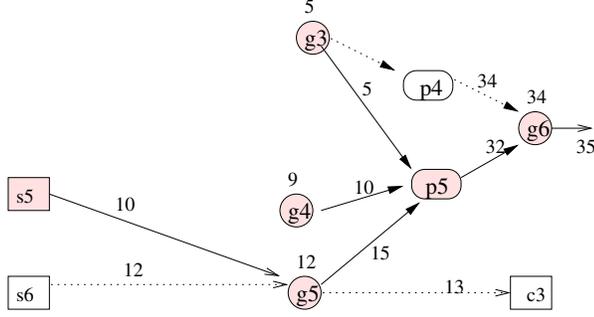


Figure 3. Supplier-Producer contract

5.1.2 Supplier-Producer

The supplier breaches the contract: Consider $C_{sp} = \langle s_5, p_5, g_5, 12, t_{issue}, t_{maturity} \rangle$ in figure 3.

Expectation damages: Observe that the victim is a presumable agent because it has contracts for all its input goods. Its investments are $I_p = 5 + 9 + 12 = 26$ and $I_p^{g_5} = 9 + 5 = 14$. The producer p_5 has also a contract for its output item, so $R_{p_5} = 34$. Its profit is $R_{p_5} - I_p = 8$. When bad contracts have been signed this value can be negative, therefore no damages are imposed. Otherwise, expectation damages are the difference between its bid and the contract price:

$$D_e = \begin{cases} \max(R_p - I_p, 0), & \hat{p}, \exists R_p \\ v_p^g - P_c, & \text{otherwise} \end{cases}$$

Recall that \hat{p} means that agent p is presumable.

Opportunity cost: one seller less implies $P_o \geq P_c$.

$$D_o = \begin{cases} \max(R_p - I_p^g - P_o, 0), & \hat{p}, \exists R_p, \exists P_o \\ v_p^g - P_o, & \neg \hat{p}, \exists R_p, \exists P_o \\ 0, & \neg \exists P_o \end{cases}$$

which is equivalent to:

$$D_o = \begin{cases} \max(R_p - I_p^g - P_o, 0), & \hat{p}, \exists R_p, \exists P_o \\ \max(v_p^g - P_o, 0), & \text{otherwise} \end{cases}$$

Reliance damages:

$$D_r = \begin{cases} V_p^g - I_p^g + R_p - v_p^{g_o}, & \hat{p}, \exists R_p \\ V_p^g - I_p^{g_k}, & \text{otherwise} \end{cases}$$

Here g_o is the output good of the agent p and $I_p^{g_k}$ represents all k contracts signed for input goods, where $k < n_p$. In the depicted case p_5 is presumable and there is a contract with a buyer. Therefore, it has to receive, as a victim, the next reliance damages $D_r = V_{p_5}^{g_5} - I_{p_5}^{g_5} + R_{p_5} - v_{p_5}^{g_6} = (10 + 5) - (9 + 5) + 34 - 32 = 3$.

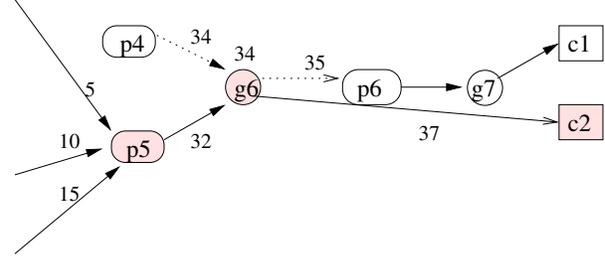


Figure 4. Producer-Consumer contract

In some cases damages can be higher than the contract value itself ($D_r \geq P_c$). According to current practice in law, these damages are the right ones if the victim gives a previous notification about the risks faced by the potential breacher. This a clear situation when information propagation improves the supply chain performance. In the light of the above facts, their reliance damages should remain the ones mentioned if the victim has notified its partner, but should be no more than P_c .

$$D'_r = \begin{cases} D_r, & \text{breacher receives a notice} \\ \min(D_r, P_c), & \text{otherwise} \end{cases}$$

5.1.3 Producer-Consumer

The consumer breaches the contract: Consider the contract $C_{pc} = \langle p_5, c_2, g_6, 34, t_{issue}, t_{maturity} \rangle$ in figure 4, where c_2 breaches.

Expectation damages:

$$D_e = \begin{cases} \max(P_c - I_p^g, 0), & \hat{p} \\ P_c - v_p^g, & \text{otherwise} \end{cases}$$

In this case, p_5 is presumable and $D_e = 34 - (12 + 9 + 5) = 8$. Suppose the agent p_5 does not have any contract for one input good. Therefore, it is not presumable and it will receive $D_e = 34 - 32$.

Opportunity cost: one buyer less implies $P_o \leq P_c$

$$D_o = \begin{cases} \max(P_o - I_p^g, 0), & \hat{p}, \exists P_o \\ P_o - v_p^g, & \neg \hat{p}, \exists P_o \\ 0, & \exists \overline{P_o} \end{cases}$$

which is equivalent to:

$$D_o = \begin{cases} \max(P_o - I_p^g, 0), & \hat{p}, \exists P_o \\ \max(P_o - v_p^g, 0), & \text{otherwise} \end{cases}$$

Reliance damages: $D_r = V_p - I_p$.

5.2 Substitute

The common law requires the promisee to mitigate damages. Specifically, the promisee must take reasonable actions to reduce losses occurred by the promisor's breach. The market can force the victim to find substitute items, in this case the imposed damages reflect only the difference between original contract and substitute contract. With a substitute contract, the victim signs for the identical item, with the same deadline or $t_{maturity}$, but at a different price. Let P_s be the value of the substitute contract⁹. For the general case *Producer-Producer*, when **the buyer breaches the contract**, the equations follow.

Expectation damages:

$$D_e = \begin{cases} \max(P_c - I_p^g, 0), & \hat{p}, \neg\exists P_s \\ P_c - v_p^g, & \hat{p}, \neg\exists P_s \\ \max(P_c - P_s), & \exists P_s \end{cases}$$

Opportunity cost:

$$D_o = \begin{cases} \max(P_o - I_p^g, 0), & \hat{p}, \exists P_o, \neg\exists P_s \\ \max(P_o - v_p^g, 0), & \neg\hat{p}, \exists P_o, \neg\exists P_s \\ \max(P_o - P_s, 0), & \exists P_s \end{cases}$$

Reliance damages:

$$D_r = \begin{cases} V_p - I_p, & \neg\exists P_s \\ \max(P_c - P_s, 0), & \exists P_s \end{cases}$$

6 Planned experiments

First, the framework can be used as a tool for automated online dispute resolution (ODR) with three situations. (i) The market may have substantial authority, hence *one remedy is imposed to all agents*. In this case, the amount of penalties can be automatically computed within this framework. (ii) Consistent with party autonomy, *the agents may settle on different remedies at contracting time*. This approach increases the flexibility and efficiency, because the agents are the ones who know what type of remedy protects better their interests. (iii) *All the above remedies influence the amount of penalties*: in this approach the role of the framework is to monitor the market and collect data such as the expected profit, the opportunity cost, the amount of investments made, if there is a substitute at t_{breach} . Argumentation when the dispute is arbitrated [11] will be used in an architecture which combines rule base

⁹ P_s comes from "spot market" while the original contract value refers to "future market".

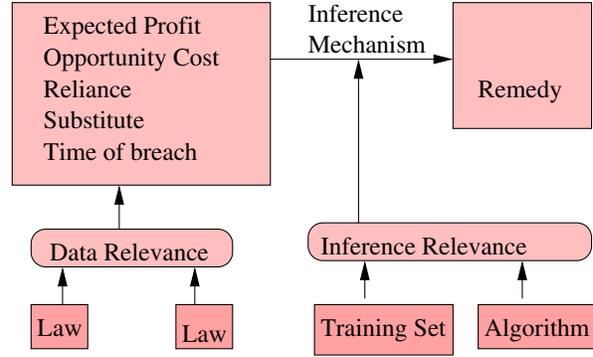


Figure 5. Toulmin argument structure

reasoning (laws) and case base reasoning (training set) as shown in figure 5.

Second, knowing the bids, the actual contracts, the amount of potential remedies, and the available offers on the market, the framework can identify situations in which for both agents is more profitable to breach the contract when a fortunate or an unfortunate contingency appears. It provides pairs of suggestions, helping to increase total welfare towards the Pareto frontier.

Third, as a simulation tool, the market designer may obtain results regarding the following questions: what types of remedies assure flexibility in the supply chain? or how information sharing influences total revenues or can be used to compute optimum reliance? In the prototype developed we are currently making experiments with different types of agents: low-high reliance, breach often-seldom, sharing information-don't share, risk seeking-averse. When agents are risk averse, the penalties do not need to be so high to make breachers behave appropriately.

7 Related Work

The task dependency network model was proposed [13] as an efficient market mechanism in achieving supply chain coordination. However, this approach is rather a timeless-riskless economy. On real markets a firm seldom signs contracts with its buyers and its suppliers simultaneously. Moreover, the breach of a contract implies no penalties, which is an unrealistic assumption in the real world. In contrast, in our model we use auctions, which end independently, and we introduce penalties in case of contract breaching. We have made less strict the assumption that the producer places its first output offer only after receiving the first price quotes for all its inputs. One objective is to compute how high these penalties should be in order to

maintain efficiency in the supply chain.

Whether selfish companies have individual incentive to use information sharing for reducing the bull-whip effect [8] has been studied considering three levels of information sharing: not share, share to each neighbor, and broadcast sharing. Instead, we have used the same levels of information sharing in order to help agents decide when to breach. The agents in our framework sign simple formal contracts, but more complex contracts need semantic interpretation for automated ODR [7].

The role of sanctions in multi-agent systems [9] is the enforcement of a social control mechanism for the satisfaction of commitments. We focus only on material sanctions and we do not include social sanctions which affect trust, credibility or reputation. Moreover, we have applied four types of material remedies in a specific domain. In the same spirit of computing penalties according to the level of harm produced, the amount of remedies may depend on the time when the contract was breached [5]. Expectation damages, reliance damages, and opportunity have also been studied [4, 3, 6] and how contracts influence the supply chain coordination or strategic breach appear in [2, 10].

The Toulmin argument structure was used in a framework for computing the distribution of matrimonial property [1]. The domain was modeled by extracting the relevant variables with the help of experts and a neural network was used as inference mechanism. We apply principles of contract law to determine the amount of remedies and, in our business scenario, data used for argumentation can be automatically extracted from the task dependency network.

8 Conclusions

The design of punishment policies applied to specific domains linking agent actions to material penalties is an open research issue [9]. The contribution of our paper is twofold. On the one hand, we apply the principles of contract law in the task dependency network model [13]. As a result, we enrich that model by including different types of penalties when agents breach, thus bringing the model closer to the real world.

On the other hand, in our work we consider penalties that ensure a higher welfare for the supply chain affected by perturbations, with three levels of information sharing for each type of remedy. This framework is useful for automated ODR. The data obtained can be used as arguments in a mediated dispute or the remedies can be computed in real time when the agents agree with the market policy.

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