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Designing Reputation and Trust Management Systems

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ABSTRACT

This article analyzes the handling of customer complaints after shipping ordered goods by applying automated reputation and trust accounts as decision support. Customer complaints are cost intensive and difficult to standardize. A game theory based analysis of the process yields insights into unfavorable interactions between both business partners. Trust and reputation mechanisms have been found useful in addressing these types of interactions. A reputation and trust management system (RTMS) is proposed based on design theory guidelines as an IS artifact to prevent customers from issuing false complaints. A generic simulation setting for analysis of the mechanism is presented to evaluate the applicability of the RTMS. The findings suggest that the RTMS performs best in market environments where transaction frequency is high, individual complaint-handling costs are high compared to product revenues, and the market has a high fraction of potentially cheating customers.

Keywords: design science; game theory; reputation and trust management system; simulation and modeling IS

INTRODUCTION

The continued demand for automated interorganizational business processes to reduce transaction costs in supply chains has provided a strong demand for extensive information systems (IS) support. While areas for the application of IS in supply chain management are growing rapidly, the management and automation of personal relationships in impersonal electronic business relations is still an area that has not been adequately served by existing IS research and development. In this article, we describe how a reputation and trust management system (RTMS)

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for an automated evaluation of business relationships in supply chains can be designed and implemented. As RTMS research domain, we have chosen the management of customer complaints since it is also a largely unexplored, yet promising application area. While empirical research and data are limited in this area, two cases provide an indication of how much money can be saved by an improved complaint-handling process: Eastman Chemicals saved $2 million after improving its business processes associated with investigating and responding to complaints by cutting expenses for waste removal and rework caused by off-quality products or incorrect paperwork (Hallen & Latino, 2003). The second example provides a more accurate view on the de facto costs of handling customer complaints manually: According to Schilling and Sobotta (1999), a medium-sized enterprise with approximately €5 million annual revenue calculated the average processing costs as €837.47 for each complaint handling process in 1997.

The need for human interaction and decision (e.g., to check complaints or to prevent opportunistic customer behavior) historically has been a major impediment to increasing the degree of automation. Since handling of complaints is costly for both suppliers and customers, only 5% to 10% of all dissatisfied customers decide to complain at all (Tax & Brown 1998). Dissatisfied customers are likely to switch providers, which usually leads to future revenue losses higher than the costs caused by complaints in the first place (Fornell & Wernerfelt, 1987). Therefore, suppliers face two dilemmas: First, they cannot automate or standardize the complaint-handling process, since opportunistic customers may benefit from this lack of human diligence. Second, dissatisfied customers, having switched to another supplier, may never notify the errant supplier, since the manual complaint-handling process is too expensive in comparison to the value of the defective or missing delivery.

This article proposes an RTMS-based complaint-handling solution, not only to provide benefits from the efficiency of computer-based customer complaint management but also to prevent opportunistic behavior and customer losses in relevant market environments. We provide a mechanism that allows increasing the role of automated business processes while concurrently mitigating incentives for opportunistic behavior in business-to- business as well as business-to-consumer relationships. We believe that this approach is a contribution to IS literature, since reputation and trust management research from behavioral science has not yet been expatiated adequately in existing IS research.

After describing the problem relevance, the theoretical background of the article presents foundations of reputation and trust as well as transaction cost theory. Since we strive to contribute to knowledge by following a design science approach, the guidelines provided by Hevner, March, and

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Park (2004) and further IS design science contributions are related to this research in the theoretical section. Next, we detail the (predominantly) existing defective product handling or customer complaint process after receiving defective articles or failing to receive articles. A game-theoretical model of supplier and customer motivations is introduced providing the formal representation and logic for process redesign. Afterward, we modify the customer complaint-handling process by introducing RTMS to minimize the number of manual interactions. To evaluate our solution, results of a simulation model are provided for demonstrating the utility and efficacy of the proposed design artifact. The validity of the sociotechnical approach is discussed and scenarios are identified where this IT artifact may yield higher benefits for suppliers. The article closes with a short summary of our findings and a discussion of the design problems.

THEORETICAL BACKGROUND

The need for efficient relationship management arises whenever independent business partners have to coordinate interdependent activities (Malone & Crowston, 1994). When engineering a rigorous RTMS that meets design science requirements, we must consider reputation and trust as well as economic demands. Both will provide the theoretical foundation upon which this research rests. Before digging deeper into the theoretical foundations, basic guidelines for engineering artifacts according to design science requirements are given.

Design Science and Artifact Engineering

According to Walls, Widmeyer, and El Sawy (1992), design theory is different from grand theories (e.g., as propagated by Popper). Serving human purposes by improving process performance, building and evaluating constructs, models, methods, and instantiations are typical design science research activities (March & Smith, 1995). This differentiates design theory from, for example, grounded theory (Eisenhardt, 1989; Glaser & Strauss, 1967), which uses an empirical inductive approach and qualifies design theory to be part of middle-range theories (Merton, 1968). Nevertheless, design theory is suggested to utilize grand theories deductively as kernel theories. In this article, reputation and trust, as well as economic theories, serve as these so-called kernel theories. According to Merton (1968), emerging disciplines should develop special theories with limited conceptual ranges that function as stepping stones or middle-range theories on the way toward a total conceptualization or grand theory. In this epistemological context of middle-range theorizing, Walls et al. (1992) postulated that "the IS discipline needs to articulate and develop a class of 'design theories' and provide examples where goal-oriented theorizing has successfully led to executive information systems (EIS), management informa-

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tion systems (MIS), decision support systems (DSS) (Walls et al., 1992), or emergent knowledge process systems (EKPS) (Markus, Majchrzak, & Gasser, 2002)." Inspired by the idea of developing theories unique to the IS discipline, Hevner et al. (2004) articulated seven guidelines on how to evaluate and present rigorous design science research. We use these guidelines to create a purposeful RTMS artifact and, more specifically, a method (guideline 1) for the trust and reputation management in customer complaint handling, which, as outlined before, represents a relevant organizational problem (guideline 2). The RTMS was evaluated by applying a simulation approach (guideline 3) to reengineer and automate the customer complaint handling to contribute to a more effective and efficient customer complaint process (guideline 4). Regarding research rigor (guideline 5), the RTMS has been informed by kernel theories, such as theories on reputation and trust and transaction cost economics, and subsequently defined and formally represented as a game theoretical problem. Simulated artificial market scenarios are developed to find the limitations of the RTMS artifact (guideline 6). Finally, the solution is communicated in this article to allow for a thorough discussion in the scientific community (guideline 7). In the following sections, the kernel theories applied in this research to comply with Hevner's fifth guideline are introduced.

Reputation and Trust

In the business world, a supplier's reputation reflects an aggregate ratio incorporating multiple factors: quality of merchandise, reliability of financial transactions, and/or level of customer service. It is often observed that reputation and trust acquire fundamental importance in long-term business-to-business (B2B) relations. According to Mui, Mohtashemi, and Halberstadt (2002), reputation is a "perception that an agent creates through past actions about its intentions and norms" and trust is a "subjective expectation an agent has about another's future behavior based on the history of their encounters." It has been shown that reputation reduces the complexity of the decision process (Wigand, Picot,& Reichwald, 1997) by better estimating the likelihood of failed orders and through a reduction in the number of quality tests needed for a product (Marsh, 1992).

It is important to distinguish between the individual and social dimensions of reputation (Sabater & Sierra, 2002). This article focuses on the individual dimension of reputation relevant for direct interactions between two business partners. Experience of transactions with a partner is directly reflected in an assigned reputation value. The social dimension of reputation relies on intermediates to propagate common reputation assessments and must be aggregated through standardized processes. Due to the specific setting of bilateral supplier-customer relationships, the social

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aspect of reputation can be neglected because, typically, only two partners are involved in the complaint-handling process at hand.

Models of reputation and trust have been developed extensively in agent-based computational economics. A broad overview of approaches to the use of reputation in multiagent systems is provided by Mui, Halberstadt, and Mohtashemi (2002). Sabater and Sierra (2001) introduced a reputation model, taking the individual and social dimension of reputation into account for a multiagent society. Others propose a formalization of reputation for multiagent systems, applying the sociological concept of role fulfillment for establishing a positive reputation and for examining the link between reputation and trust (Carter, Bitting, & Ghorbani, 2002). The role of trust in supply relationships and the underlying implications were addressed by Lane and Bachmann (1996) in an empirical study of business relationships in Germany and U.K. (Lane & Bachmann, 1996). As they pointed out, trust relations are highly dependent on stable social, institutional, and legal structures. Moorman, Zaltman, and Deshpande (1992) investigated the specific relationship between providers and users of market research reports, providing a reasonable introduction to the role of trust in relationships (Moorman et al., 1992).

Das and Teng (1998) argued that trust and control are the two pivotal sources of confidence in the cooperative behavior of business partners in strategic alliances. Both sources of confidence are highly interdependent. A large amount of control reflects a low amount of trust and vice versa. Without any control, the trusting party assumes the risk of the trustee's opportunistic behavior. As described, trust and control are inherently different approaches to business relationships. The costs to control the behavior of business partners can be extremely high. If reputation or trust is not established and the threshold to behave in an undesirable manner is low, the defrauded partner's control costs can be higher than the value of the goods, and consequently one may accept—to a certain degree—some fading in deliveries. Business partners are anticipating that control is difficult (e.g., in the case of defective, low-value goods, where shipping them back to the vendor is more expensive than accepting to discard them by the customer). Such behavior is more likely in new business relations and more anonymous markets, such as electronic marketplaces, where no face-to-face contact is established.

Reputation Mechanisms and Transaction Costs

Increasing the level of control by establishing contracts or mechanisms to prevent opportunistic behavior can result in higher transaction costs so that, in the worst case, the handling of an order might be more costly than the expected benefit. In the context of reputation and trust, ex-post transaction costs are of particular importance (Williamson,

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1975, 1985). Ex-post transaction costs refer to costs that emerge after the order has been shipped and before the transaction cycle is completed. Ex-post transaction costs will increase if the trust level decreases. In other words, the monitoring and enforcement costs to prevent ex-post bargaining will be higher if the incentive for opportunistic behavior increases (Dahlstrom & Nygaard, 1999). For suppliers, such costly uncertainties are based on unanticipated changes in the behavior of business partners (Noordewier, George, & Nevin, 1990). The greater the level of uncertainty, the more difficult it is to formulate, negotiate, and enforce a contract to reduce the risk of being a victim of opportunistic behavior. In long-term relations, expensive tracking and monitoring instruments may be replaced by mutual trust; however, trust and reputation must be effectively managed in an automated way when the number of business partners increases.

A REPUTATION AND TRUST MANAGEMENT SYSTEM FOR CUSTOMER COMPLAINT-HANDLING PROCESSES: DESIGNING AN ARTIFACT

In our RTMS, extensive control in the customer complaint-handling process is replaced by trust to reduce costs for suppliers and customers. A supplier utilizing RTMS assigns individual reputation values to its customers and tracks past actions in complaint issues to assess the probability of future opportunistic behaviors. The supplier can use this reputation measure to decide whether to trust the customer and accept the complaint without validating the claim, or to pursue a detailed investigation. In the following sections, we will elaborate on the proposed automated system in detail and introduce the artifact, referring to Hevner's first guideline for design science.

Customer Complaint Alternatives and Implications

Many business processes are not yet fully automated. In order to discuss the complaint process, both on the customer and supplier sides in more detail, the alternatives and relevant business cases are depicted in the following. Drawing from the *exit, voice, and loyalty* model provided by Hirschman (1970), and the customers *problem impact tree* framework of Rust, Subramanian, and Wells (1992), a problem tree of *voice a complaint or exit without making a complaint* is utilized. According to Hirschman, customers have two potential feedback options: (1) to voice complaints and thereby express the dissatisfaction directly to the supplier or (2) to stop buying and exit the relation. Both options have different but always unfavorable impacts on suppliers, who must respond with adequate defensive strategies to overcome those problems. To elaborate, all possible customer complaints scenarios are first described briefly: After submitting an order and receiving a delivery note from the supplier, the incoming orders are checked

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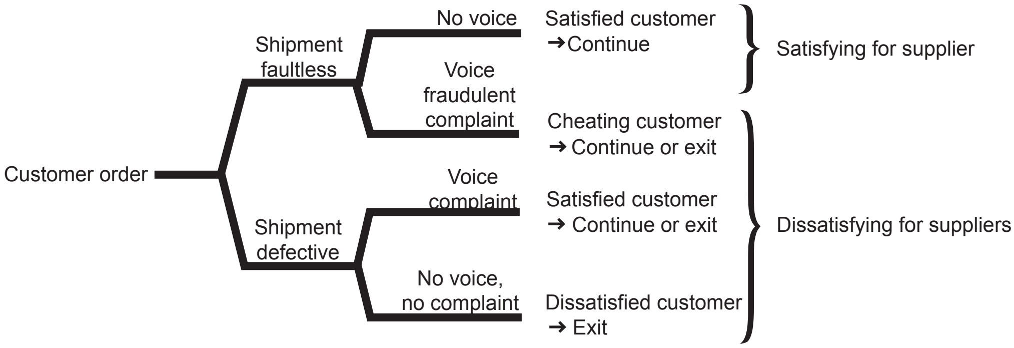
by the customer's receiving department. In the case of a faultless shipment, one expects that customers have no reason to complain (see the upper branch of Figure 1). This is true in nearly all cases: Customers receiving correct deliveries will be satisfied, continue with the supplier, and will not place any complaints. The situation is slightly different if complaints are not too costly and the supplier does not ask for the defective items to be sent back in order to validate the complaint. If customers do not perceive the recall of defective items as a credible threat, then they might be tempted to cheat and complain about faultless shipments. Avoiding such an incentive is a pivotal element when designing an automated customer complaint-handling solution.

In the case of defective or partially missing items in the shipment (see the lower branch of Figure 1), the supplier must be contacted and/or the broken parts sent back. Afterward, the supplier sends the defective parts again and the customer tracks the complaint until all replacement parts are received. If the supplier handles the complaint satisfactorily, the customer will buy again. If this is not the case and the customer is dissatisfied with the process management, then the exit strategy might be chosen. In the latter case, the supplier has no chance to contact the dissatisfied customer if a defective shipment is delivered and the customer decides not to complain. This can be the case if the complaint process is more costly then the value of the defective products. Dissatisfied with the delivered quality, it is likely that such a customer will discontinue the business relationship.

As Figure 1 reveals, dissatisfying scenarios can emerge for suppliers, even when the shipment was faultless. A solution to the dissatisfying results for customers and suppliers might be offered by an automated reputation-based system where customers do not have to prove that parts of a shipment are damaged or missing. Instead, the supplier simply believes the customer based on the reputation the customer has

Figure 1. Customer action alternatives



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acquired in past transactions and trusts him or her in the case of complaints.

Designing an RTMS-based Automated Customer Complaint-Handling Solution

In this section, a simplified customer complaint process is described to reduce the handling costs for suppliers and customers. It will be shown that from a game-theoretical point of view, the simplified customer complaint-handling process dominates the conventional process if customers are always truthful. If truthful customers cannot be assumed, a reputation mechanism is introduced to inhibit cheating. Before digging deeper into the conventional and the simplified complaint-handling process from a game-theoretic perspective, the assumptions our model is based on are delimited:

- Neither supplier nor customer knows the exact value of the defective ratio *d*.
- The exact quality of the products en route is not known (e.g., due to unknown conditions during the shipment).
- There is a long-term recurring business relationship between supplier and customer. Products are exchanged frequently between both of them.
- The value of a single order is relatively low, as can be observed for raw materials or office supplies.
- The customer complaint-handling costs of the new simplified process are ignored. In the simplified process, the customer only has to send an electronic notification to the supplier without shipping the defective items; the supplier does not have to perform a manual check of the incoming goods and thus is assumed to cause no relevant costs compared to the conventional scenario, where the customer has to process the defective shipment for physically returning it to the supplier.
- There are no limitations referring to legal issues.

We use a game-theoretical design approach to analyze the trade situation for the conventional and the simplified complaint-handling process. In a conventional complaint-handling process, the customer checks the shipment, and if there are defects, the defective parts of the shipment are sent back freight forward to the supplier. The supplier checks whether the complaint is justified. Both partners have expenses due to the manual processing and shipment of products. Table 1 depicts the cost matrix in a game with a conventional customer complaint process.

If the shipment is indeed defective and the customer decides to reclaim (see the upper left cell in Table 1), both customer and supplier pay for manual handling of the customer complaints c_C^C and c_S^C, respectively. Additionally, the supplier will not be paid for its defective products, and the value v (ranging from 0 to the total value of the shipment if all parts are defective) of these parts

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Table 1. Conventional customer complaint process cost matrix

		Customer complains?	
		Yes	No
Shipment defect?	Yes (d)	Customer: complaint costs (c_C^C) Supplier: {0; fraction of defective shipment (v)+} complaint costs (c_S^C)	Customer: {0; fraction of defective shipment (v)} Supplier: 0
	No (1-d)	Customer: complaint costs (c_C^C) Supplier: complaint costs (c_S^C)	Customer: 0 Supplier: 0

is lost. When the customer decides not to reclaim the defective products (see the upper right cell in Table 1), his or her loss equals the value of the defective shipped products v. If the shipped products have only minor defects, the consumer may be able to use the products partially, thereby reducing his or her loss to a fraction of v, indicating the shipment's remaining utility. Nevertheless, compared to flawless products, the consumer encounters loss ranging from a cost of 0 for minor defects to the value of the shipment v for major defects. If the shipment is not defective and the customer decides to issue a complaint (see the lower left cell in Table 1), both partners will have to pay complaint costs c_C^C and c_S^C. After the order is sent back, the supplier checks the products and finds them nondefective and may reship them or sell them to another customer. Thus, there are no further costs, despite the complaint processing costs. In cases where the shipment is not defective and the customer does not decide to reclaim (see the lower right cell in Table 1), the transaction is completed as originally intended with no additional cost outside the regular transaction process.

Now an RTMS-supported, simplified customer complaint-handling process is implemented, reducing complaint costs for both partners. In cases when the customer decides to complain about a shipment, the supplier trusts the customer, assuming the products are indeed defective without the need for validation. The customer subtracts the invoice accordingly or a new shipment is immediately scheduled and the supplier does not audit the complaint further. This new setting is described in Table 2.

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Table 2. Simplified customer complaint process cost matrix

Shipment defect?	Customer complains? Yes	Customer complains? No
Yes (d)	Customer: 0 Supplier: fraction of defective shipment (*v*)	Customer: {0; fraction of defective shipment (*v*)} Supplier: 0
No (1-d)	Customer: - fraction of defective shipment (-*v*) Supplier: fraction of defective shipment (*v*)	Customer: 0 Supplier: 0

If the shipment is not defective and the customer decides not to reclaim (see the lower right cell in Table 2), the situation is unchanged. In cases where the products are defective and the customer does not complain (see the upper right cell in Table 2), the situation is unchanged, despite the lack of complaint costs. The critical case is a cheating customer who lodges a complaint for a shipment that is not defective at all (see the lower left cell in Table 2). In this case, the customer does not pay for the faultless products. She/he immediately *earns* the value of the products ("negative loss costs (-*v*)"). On the other hand, the supplier loses the value of the products shipped.

Comparing both situations reveals that for defective product shipments, the second scenario with a simplified customer complaint process is advantageous. If supplier-side complaint costs are less than the value of the shipment, only the lower left quadrant of the cost-matrix is disadvantageous. This outcome, which implies a cheating customer, should be avoided.

As we have seen, the costs of shipping and handling complaints in a specific market are important for the viability of the simplified customer complaint process. In the case of low or negligible shipping and complaint-handling costs, it might be rational to always return defective shipments, depending on the relationship of total complaint costs to the individual value of a shipment. However, if total complaint costs are high in relation to the shipment's value, the simplified complaint process can realize substantial cost savings.

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The Reputation and Trust Management System to Inhibit Fraudulent Behavior

In the case of accurate shipments, there is a significant difference between the conventional and simplified scenario. If the customer decides to complain for faultless shipment, then she/he will not have to pay for the faultless products and immediately gains the value *v*. Concurrently, the supplier loses the equivalent value because it trusts the customer and does not perform a quality check on the reclaimed products that would expose a cheating customer. If there is no additional monitoring or control structure, the customer will always reclaim the delivered shipments, regardless of the actual status (whether it is indeed defective or not) in the scenario with the new system. It is a weakly dominant strategy for the customer always to complain. Thus, the supplier always loses the equivalent value of the shipment if no mechanism is applied to counter cheating behavior.

In an idealized world, customers would always tell the truth to reduce transaction costs. Both partners could improve their respective position in all cases, because only the upper left and lower right sections in Table 2 would be relevant. Assuming a customer who is always telling the truth reveals that the conventional complaint-handling mechanism is dominated by the simplified automated complaint handling. Both parties benefit from the reduction of transaction costs when processing complaints. Nevertheless, the world is not ideal, and the customer might be tempted to complain about defective products even if it is not justified. The pivotal question here is how to assure that the customer has no interest in cheating. One solution is to apply an inexpensive incentive mechanism enforced by a RTMS.

Reputation in this context is based on business transactions with a certain customer in the past. The more orders successfully processed in the past, the higher the reputation account (and the higher the level of trust). Otherwise, the customer withdraws from hid or her reputation account on the supplier side if transactions failed in the past. In the simplest case, the supplier could estimate the defection rate *d* of its products *r* and adjust the customer's reputation account if his or her complaint rate significantly differs from the estimated quality (e.g., by applying a χ^2 test).

The supplier's credible threat is to switch back to the conventional customer complaint-handling mechanism, imposing complaint-processing costs on future transactions. This threat only works for infinitely repeated games, as are assumed in this model. This assumption seems appropriate for our setting, since B2B relationships are often characterized as long-term relationships with frequently recurring transactions. The supplier can implement several strategies to ensure that the customer is truthful. The following strategies can be applied, if the supplier knows the defection rate *d* with reasonably high accuracy:

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- The supplier can randomly select reclaimed shipments and request the customer to return the products for an intensive test. If the products are faultless, the customer cannot be trusted and is removed from the simplified customer complaint-handling process. The process is immediately switched back to the traditional handling process. This *grim trigger* strategy is potentially suboptimal if the customer accidentally complains about products that are not defective.
- The supplier can switch back to the conventional complaint-handling process if the ratio of complained products significantly exceeds the defectiveness ratio *d*. This mechanism only works if the supplier knows the defectiveness ratio *d* with high accuracy.
- Each customer receives a reputation account for a given period, calculated as the product of the mean ordered value and the quality parameter *d*. If a customer reclaims a shipment, the shipment's value is subtracted from this account and if the account is exhausted, the customer has to justify his or her behavior. This mechanism also relies strongly on the accuracy of the parameter *d*.

The threshold for identifying cheating behavior on the part of a customer should be chosen according to the accuracy with which *d* is known. If *d* is not known and is subject to change, this threshold should be increased and vice versa.

If the supplier does not know the defectiveness ratio *d,* it can improve the reputation mechanism by taking into account the responses of all other customers for each product. Each customer has individual reputation values for each product. If a customer reclaims a shipment, the value of this shipment is subtracted from his or her reputation account for the product in question. Afterward, the reputation values of all customers receive a bonus. This bonus for product *r* and customer *i* is calculated as an adjusted ratio of the mean quantity ordered by the customer. This value can be regularly recalculated for all orders of a given period (e.g., monthly). The following equation calculates the reputation bonus for each customer *i* and product *r*.

$$bonus_r^i = \frac{q_r^i}{\sum_{j-1}^{n} q_r^j} * p_r q_r^d$$

p_r: price of product *r*

q_r^i: aggregated quantity of product r ordered by customer *i* in a given period

q_r^j: aggregated quantity of product *r* ordered by customer *j* in a given period

n: number of customers with reputation accounts

q_r^d: quantity of defective product *r* that is reclaimed

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The RTMS works as follows: If all customers are acting truthfully, the individual reputation accounts for every product will be zero on average. A simple example should illustrate the mechanism: A defectiveness ratio *d* of 10%, a price of 1 for a given product *r* and three customers are assumed. The first customer regularly orders 1,000 units, customer 2 orders 50 units and customer 3 orders 200 units. Each customer reclaims truthfully 10% of the shipments. When the first customer reclaims 100 units, his or her reputation account is immediately reduced by 100, equivalent to the total value of the complaint. Afterwards, all customers' reputation accounts are given a bonus (including the customer initiating the claim), resulting in 80 bonus points for customer 1, 4 bonus points for customer 2, and 16 bonus points for customer 3. This process is also applied for the complaints of the other customers, leading to neutral reputation accounts at the end of the selected period.

If one of the customers decides to cheat and complains with a higher ratio (e.g., 15%), then his or her reputation account will be negative while the accounts of the other customers will be positive. If the first customer complains 15% of his or her shipments and the other customers complain 10%, their respective reputation accounts for the illustrative example will be -10, +2, and +7.2. Customers with a higher complaint ratio than other customers can be identified by their negative reputation accounts. The first cheating customer will put him- or herself into an inferior position compared to truthful customers. This system can only be cheated if all customers collude to produce a consistent and artificially inflated complaint ratio. Furthermore, the mechanism does not work with a small number of customers. If there were only one customer, then the reputation value would never deviate.

EXPERIMENTAL EVALUATION OF THE PROPOSED REPUTATION AND TRUST MANAGEMENT SYSTEM

To evaluate the developed solution as suggested in Hevner's third guideline regarding design science, we constructed a simulation to conduct sensitivity analyses for different transaction frequencies and fractions of potential cheaters in the market. For simplification and computational reasons, we assume that the structure of relationships remains unchanged within each simulation run—customers are always able to correctly assess the quality of the delivered products (faultless or defective), and that the production capacities of the suppliers' facilities are not limited. Further, we assume that there are no shortages and arbitrary amounts of products ordered may be delivered. The following section describes the dynamic behavior of the simulation and explains the core processes performed by the simulated agents. In the subsequent section, specific simulation settings are described and the results are discussed.

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Model Evaluation and Simulation Setting

The simulation implements the proposed IS-based reputation model and assesses environmental conditions where suppliers using the proposed solution would outperform comparable suppliers without it. For the simulation, an idealized trading situation between suppliers and customers is assumed. An arbitrary number of suppliers and customers can be simulated, including truthful acting, as well as cheating customers. The transaction starts with the customer who generates an order. The receiving supplier executes and ships the ordered goods to the customer who is checking the incoming delivery. A random percentage of products in the suppliers' shipments is defective. The customers check the shipments and decide whether to complain or not. All suppliers receive identical orders in order to compare different parameterizations of the reputation mechanism.

If the specified supplier implements the reputation system, a new shipment will be scheduled immediately after a customer complaint is lodged—if the customer's reputation value is high enough (in accordance with the reputation mechanism outlined in section 0). Furthermore, the system will also update reputation values of all customers. If a customer exceeds a prespecified reputation threshold on the lower bound, the supplier will switch back to conventional mode and check all complained products. Although we assume every supplier is deploying a quality management program to ensure high standards in production, a small but unavoidable ratio d of defective products leaves every company unnoticed. For our study, this defective ratio follows a normal distribution but can be freely configured in the model. The performance of each supplier is assessed by the operating profit resulting from the difference between revenues and costs. Revenues are calculated for faultless shipped and paid products that do not result in a customer complaint. Occurring costs are (1) variable costs for each product shipped (independent of faultless or defective) and (2) costs imposed by processing customer complaints if no RTMS is in place. Customers in our simulation approach randomly issue identical orders to all suppliers. They also check all shipments arriving from the suppliers. If they are truthful customers, they will only complain if the shipment is indeed defective. Cheating customers, in contrast, may also reject a fraction of shipments that are not defective. Simulation time is discrete and a fixed number of processes are executed for all agents in every simulated period (see Figure 2).

As an initial condition, all suppliers will designate all customers as *trusted.* If a customer exceeds his or her reputation threshold, she/he will be removed from *trusted* status, requiring him or her to resend the shipment, thus generating complaint handling costs.

At the beginning of a period, each customer randomly decides with a prespecified probability whether she/he

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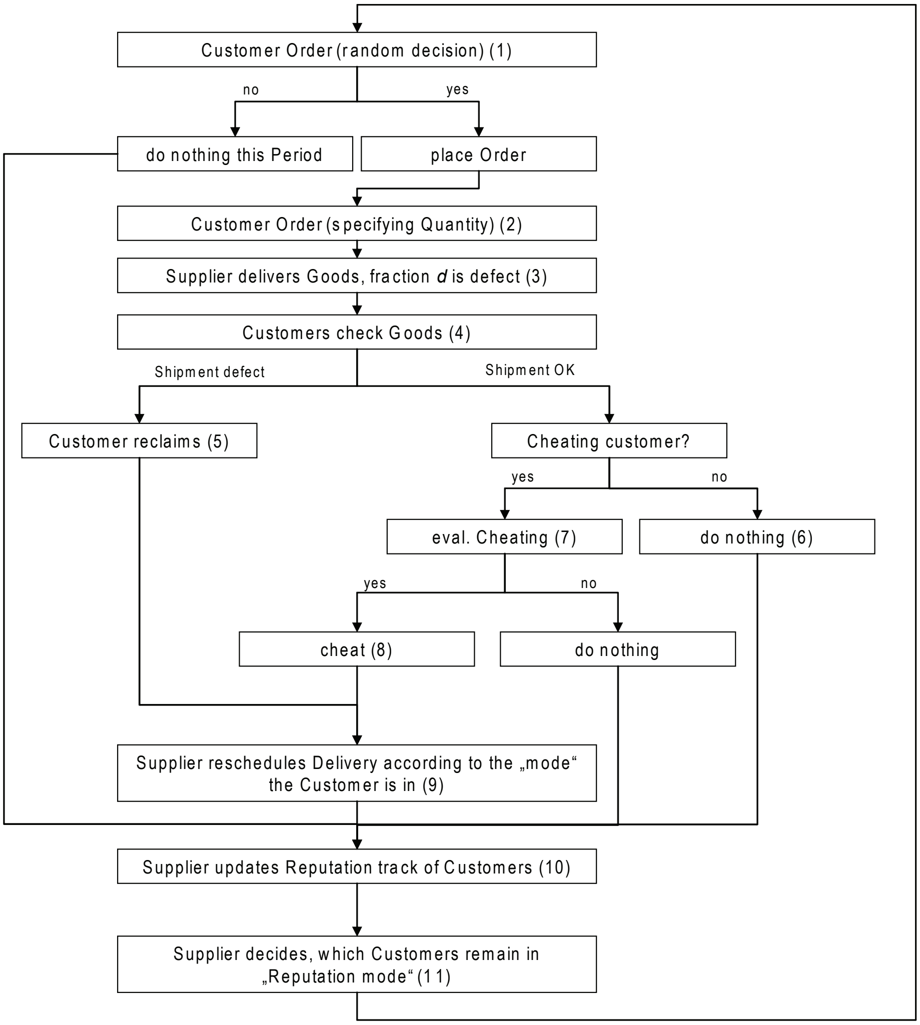
Figure 2. Course of action of a simulated period



issues an order in this period or not (1). By varying the order likelihood of a customer, the transaction frequency between supplier and customer can be adjusted. If the customer decides to order in this period, she/he calculates an order quantity drawn randomly from a normal distribution and issues identical orders to all suppliers (2). Mean and standard deviation are prespecified in the simulation setting. After receiving orders from all customers, suppliers process orders and ship goods according to the quantities requested. A randomly drawn fraction of products shipped is defective. The defective ratio is normally distributed; the mean defective ratio and the standard deviation are input parameters of the simulation (3). After all goods have been shipped, customers

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check the received shipments to determine whether they have received defective products (4). If defective products are included in the shipment, the customer immediately issues a complaint message to the supplier specifying the amount of defective products (5). If the shipment is faultless and the customer is configured to act truthfully, nothing happens (6). If the shipment is faultless but the customer is configured as a potential cheater, she/he decides whether to cheat or not (7). If she/he decides to cheat, a complaint message is issued (8). In the next step, suppliers process all complaints received and act according to the trust status of the customer. If the customer is in trusted mode, the shipment is rescheduled without further checks and the reputation value of the customer is adjusted. If the customer is not in trusted mode, the shipment must be sent back by the customer to allow the supplier to verify the claim. If there are indeed defective products in the shipment, a new shipment is scheduled containing faultless products; otherwise nothing happens (9). Finally, all suppliers update the reputation values of all customers who are in trusted mode (10) and decide which customers to keep in trusted mode for the next period (11). Step 11 marks the conclusion of the simulation period after which a new period begins with customers deciding whether to order.

To compare the different simulation runs, some settings are kept constant throughout all simulation runs. Each market simulation consists of 1,000 consumers and four suppliers each, trading for 1,000 periods. Each simulation run is repeated 50 times. Furthermore, all suppliers produce with an equal ratio of defective products (mean 0.02, standard deviation 0.05) in all simulations. The four simulated suppliers differ in terms of (1) reputation account thresholds and (2) usage of the reputation account mechanism:

- Suppliers 1, 2, and 3 differ in their threshold for determining whether a consumer regularly cheats or not.
- Supplier 1 applies a very high threshold, which means that she/he will apply the reputation account all the time (all customers will always be in trusted mode).
- Supplier 2 applies a medium threshold.
- Supplier 3 applies a low threshold.
- Supplier 4 does not apply the reputation account at all and marks the "bottom line" of a supplier without the proposed mechanism.
- Therefore, Suppliers 1 and 4 will mark the two extremes of the scale, with 1 always trusting all consumers and 4 never using reputation accounts (and therefore literally distrusting all consumers).

The 1,000 consumers share consistent overall parameters, differing only in their attitude toward "cheating". A fraction of the 1,000 consumers will never cheat, while others will consider cheating, the proportion of whom will

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be varied in the simulation runs. When placing an order, all consumers share the same normal distribution of order quantity (mean = 100, *SD* = 75). They also will always complain if there is at least one defective item in a given shipment. If a consumer belongs to the group of cheating consumers, she/he will try to cheat with a likelihood of 15%. If she/he decides to cheat, she/he will always try to complain 20% of the original (faultless) shipment.

To assess in which market settings the RTMS will be advantageous, different idealized markets are simulated. In the following, the impact of transaction frequency and the impact of different fractions of cheating consumers on the reputation system will be investigated (cf. Table 3).

Sensitivity Analysis of the RTMS

To analyze the results, the average number of cheated products per 1,000 items shipped was calculated. Figure 3 provides the results for the four simulated market scenarios. The headers depict the type of market scenario (e.g., HFHC stands for *high frequency of transactions, and high fraction of cheating consumers*; see also Table 3).

As expected, Supplier 4, who always distrusts all customers and does not apply the reputation mechanism, does not experience loss through cheating customers since, even if there is complaint, it will always check whether the claim was valid. On the other hand, Supplier 1, who always trusts everyone and employs the new system, has a ratio of approximately 12 cheated items per

Table 3. Parameterization of different market scenarios

Market scenarios	Low transaction frequency, low fraction of cheating consumers (LFLC)	Low transaction frequency, high fraction of cheating consumers (LFHC)	High transaction frequency, low fraction of cheating consumers (HFLC)	High transaction frequency, high fraction of cheating consumers (HFHC)
Parameterization				
Transaction frequency (order probability)	5%	5%	30%	30%
Fraction of cheating consumers	5%	25%	5%	25%

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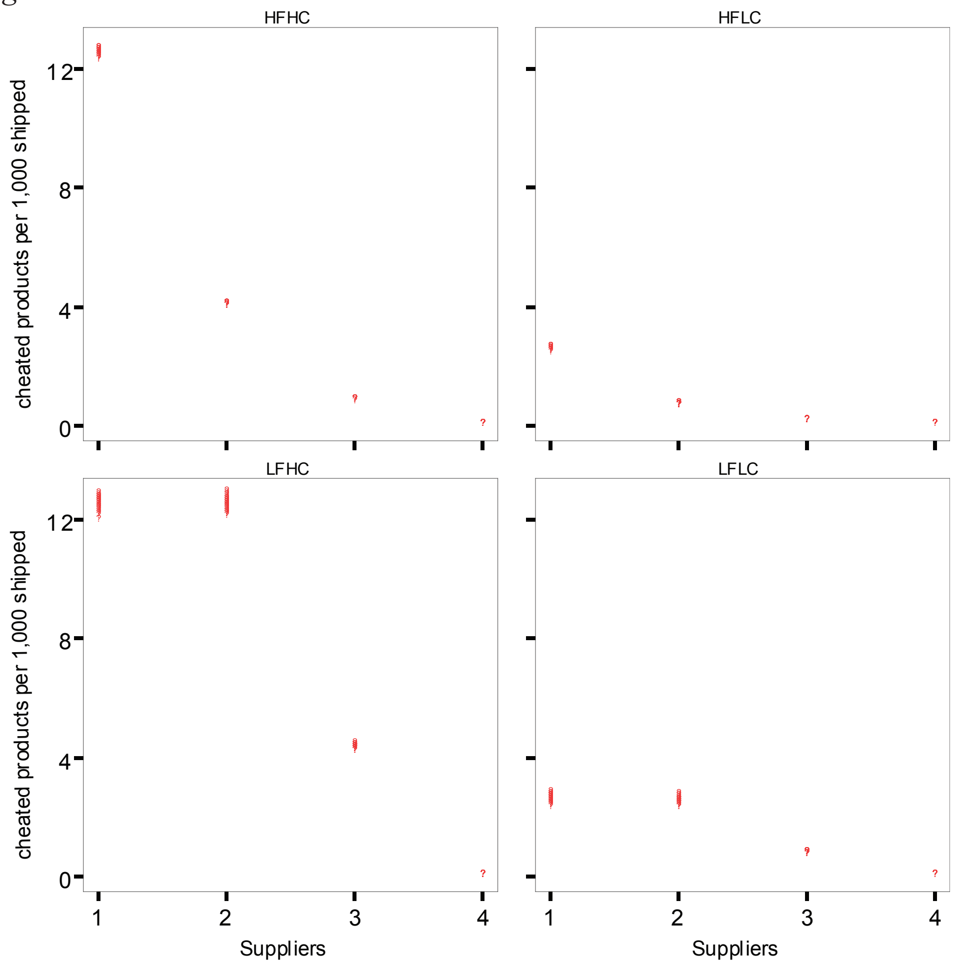
Figure 3. Simulation results



1,000 shipped in the scenarios with a high fraction of cheating consumers, and 3 cheated items per 1,000 shipped in the low cheating scenario. For the other suppliers, the fraction of cheated products not detected ranges between those extremes. Therefore, it can be stated that for the given settings, the reputation account system is able to identify cheating customers and to eliminate them from the trusted mode system (cp. Suppliers 2 and 3). In the case of markets with low transaction frequency, Supplier 2 is unable to achieve a better result than Supplier 1. In these cases, the reputation account system takes more time to identify the cheating customers. The system works best in markets with a high transaction frequency. In markets with low transaction frequency, the system will fail. In low-transaction-frequency scenarios, the threshold ratios must

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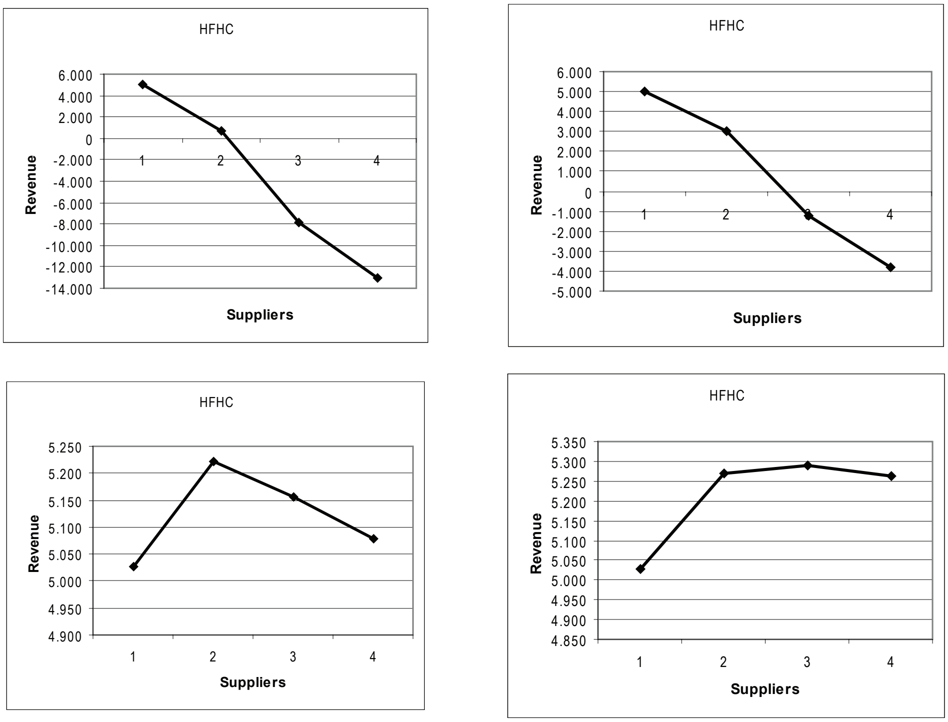
be set lower to ensure that cheating consumers are identified. In scenarios with a low transaction frequency and a low fraction of cheating customers (cp. LFLC), the effect of the reputation account system is small.

Profitability Analysis of the RTMS

We now look at the profits of suppliers depending on the customer complaint-handling costs. The absolute number of complaints is independent of the costs associated with the complaint. Based on the mean values of the simulation runs, it is feasible to calculate the financial flows in each market scenario. For the HFHC market scenario, the results for different complaint-handlings costs levels are depicted in Figure 4. The main tendency can also be found in the other scenarios, but it is most clearly visible in this scenario. If customer complaint-handling costs are high compared to variable production costs, the reputation account solution is always advantageous (cp. Supplier 4 without deploying a reputation account solution has the highest losses of all suppliers in the upper two diagrams of Figure 4). Not until customer complaint handling costs nearly equal product revenues (see Fig-

Figure 4. Profits (complaint-handling costs: upper left = 100, upper right = 50, lower left = 2, lower right = 1)



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ure 4, lower left diagram) or are below product revenues (see Figure 4, lower right diagram), does the supplier without the reputation account mechanism become profitable. In these scenarios depicted in the lower two diagrams, the reputation account mechanism is not always the best solution, especially the "always trust" strategy of Supplier 1 should not be applied.

In summary, the proposed reputation account mechanism is especially advantageous in settings where (a) the transaction frequency is high, (b) the individual complaint-handling costs are high compared to product revenues, and (c) the market has a high fraction of potentially cheating consumers. In markets where complaint-handling costs are low compared to the individual production costs, the reputation account mechanism should not be deployed.

SUMMARY AND CONCLUSIONS

The combination of information systems and game-theory inspired reputation and trust accounts in a RTMS establishes new solutions to automate business transactions where human decisions were formerly necessary. Through the reduction of manual handling and shipping costs, quality of the complaint-handling process may be increased both for customers and suppliers, resulting in higher customer retention. A game-theoretic analysis of the order and customer complaint process has yielded insights into undesired outcomes of the interaction of suppliers and customers. While faulty deliveries will always remain a problem, costs associated with customer complaint-handling can be reduced significantly if substituting human decision competence with an automated information system. Thus, we believe that an economic interpretation of existing information systems may help to uncover as-yet unrealized potential for computer-mediated applications and offer the RTMS as an example for this claim. The RTMS allows firms to deploy a simplified customer complaint-handling process while preventing customers from acting opportunistically. The RTMS has been developed according to the guidelines put forward for design science approaches and has been tested in an agent-based artificial setting, indicating its strength in specific market environments. In more detail, the RTMS has been found applicable in market environments where (a) the transaction frequency is high, (b) the individual complaint-handling costs are high compared to product revenues, and (c) the market has a high fraction of potentially cheating consumers.

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