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The Game of Trust: Using Behavioral Experiment as a Tool to Assess and Collect Trust-Related Data

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Abstract. Trust is one of the most important dimensions in developing and maintaining business relationships. However, due to the difficult to collect trust-related data from industry, given its concerns surrounding privacy and trade secret protection, it still very problematic to investigate it. Motivated by the growing interest in behavioral research in the field of operations and supply chain management, and by the lack of supply chain trust-related datasets, the authors of this paper proposed and designed a novel trust behavioral experiment. Utilizing concepts of gamification and serious games, the experiment is capable of gathering information regarding individuals' behavior during procurement, information exchange, and ordering decisions considering trust relations in the context of supply chains.

Keywords: Trust, Behavioral Experiment, Supply Chains, Gamification

1 Introduction

It is the overall aim of this ongoing research project to create a novel behavioral experiment (i.e. The Game of Trust) to assess the influence of trust relationships in B2B supply chains. While this specific approach is unprecedented, serious games already have quite a history in the area of supply chain research and management. Some notable examples include the *Beer Game* [1], the *Mango Game* [2] and the *Trust and Trace Game* [3].

The goal of the experiment is to expose the participants to situations where they do not only have to trust another participant and take risks in order to achieve profit but they can also distrust a certain player and diminish their interactions to that specific participant. The game creates a negotiation environment where players interact with all players of neighboring tiers in the supply chain with the objective of distributing the products along the supply chain in order to achieve profit.

2 The Game of Trust: Initial Concept

Considering all the existing material and research in this area the decision has been made to set up the GAME OF TRUST based on these known and established concepts. The promise of this approach is twofold: First, it avoids redoing work already done by others. Second, making use of known concepts will ensure a flatter learning curve for users.

As the baseline model for the proposed game the *Beer Game* has been selected. Since it has been developed at the MIT in the 1960s, it has been improved [1] and become one of the most known serious games in the SC domain. However, since the *Beer Game* is typically used to visualize the Bullwhip effect (BWE), it lacks mechanisms to enforce or observe the trusting behavior. These concepts were thus extracted from respectively inspired by the lesser known *Trust and Trace Game* [3] and *Mango Game* [2]. In these games e.g. delivering parties can deliver low-quality items as high-quality ones with the receiving parties being enabled to check the actual quality or to 'trust'.

One component of interest in the initial phase was the supply chain. The *Beer Game* uses a four tier supply chain, where each tier is assigned exactly one player. Considering the intention to include and measure the trusting behavior of participants, such a simple supply chain construction has been identified as a severe limitation. The underlying reason is that the player at each tier is forced to interact with his/her direct neighbors. While this is sufficient for interaction, the degree of risk and uncertainty - which are required properties for trust [4] - can assumed to be low or non-existent. To sanitize this issue and in order to create a market place closer to the real world [5], the decision was made to change the original *Beer Game* supply chain structure. Accordingly, the GAME OF TRUST will allow multiple players at each supply chain tier (see Fig. 1). Furthermore, the *Distributor* tier has been removed. While this tier helps to



Fig. 1. Game of Trust Supply Chain

increase the BWE within the *Beer Game*, the interactions (which are analyzed for trusting behavior) were found to be very similar to the *Distributor* tier so that keeping one of the two tiers simplifies the game without restricting its research potentials.

A sample scenario and design were created to conduct an offline test execution. In the course of the conducted test run the participants had to deal with a very simple and abstract supply chain scenario (*buying and selling products*). It

was conducted with members of the development team and several Ph.D. students working at the Department of Information Systems in Münster. Selecting participants working in Information Systems research being familiar with the concept of the supply chain was a purposeful decision: First, it allowed to conduct the trial without time-consuming introductions into the topic. Second, it enabled the participants to focus on the game mechanics instead of struggling to understand new supply chain concepts. Finally, people with a background in scientific research were supposed to be more capable of providing critical advice regarding methodological or conceptual issues the game version at test might still exhibit.

The subsequent analysis of the trial revealed that the initial GAME OF TRUST had some severe design misconceptions. One of them was the fact that the participants were required to record every action and transaction manually on a set of sheets. Some of the recordings required simple calculations (e.g. *computation of sales volume*), which further intensified the time issues. Aside from the duration issue, the experiment further revealed that the number of interactions was too high. Based on the learnings, the initial analysis step has been reopened to achieve a more desirable solution.

2.1 Game dynamics

This section focuses on explaining the current game dynamics, player roles, and rules in a thorough manner while avoiding adjustable features such as the specific price for a product at the top of the supply chain.

The game is based on rounds with four phases being executed at each round: Negotiation, Delivery, Financial Closure and Questionnaire. The negotiation phase is based on the Double Auction Mechanism proposed by [6], where a match of the offer and the demand of two negotiation partners is performed in order to allocate the availability of the supplying partner. The matching is performed in three steps, with the upper-tier partner first expressing the expected availability of products. Secondly, the lower-tier partner will make an order based on this availability and the demand of that it has to fulfill. Lastly, the initiator either accepts or rejects the order. A special case where the order matches the initial availability of products causes the order to be accepted automatically. The adaptation of the mechanism in the Trust Game assigns the role of the intermediary deciding the possible allocation of products to the supplying partner.

The delivery phase consists of a two-step sequence. All roles will receive products at the beginning of the phase, with Manufacturers receiving the production of the round and the Suppliers and Retailers receiving the order of the previous round. On the second step, the players will be able to send out the products that have been ordered out of their current updated inventory. For the Retailers, this second step is the delivery of products to the final consumer for demand fulfillment. After the first step is performed, Suppliers and Retailers have the option to execute the previously mentioned Quality Revelation. It will incur a cost for them but will avoid negative consequences when handing a product down the

supply chain. If a lie is revealed, a penalty must be paid by the player who delivered the mislabeled product. If a player Alice receives a product and decides to trust the labeling without revealing the quality and sell the product, and this product is then checked for quality and revealed to be a mislabeling, then Alice is held accountable and must pay the penalty instead of the player providing the product to Alice originally. This setup adds a new layer of risk to the trusting behavior.

The financial closure phase involves the calculation of all costs and incomes for each player. The income of each player is based on the products successfully delivered. Expenses are the sum of all costs. The game considers inventory cost and backordering cost for all roles, quality revelation cost for Suppliers and Retailers, and production costs for Manufacturers.

Finally, a subjective assessment of trust in the form of questionnaires is performed. This evaluation intends to reflect the perception of the players regarding their interaction with other participants with regards to promised quality, successful or unsuccessful negotiations, timely delivery, etc.

2.2 Trust Assessment

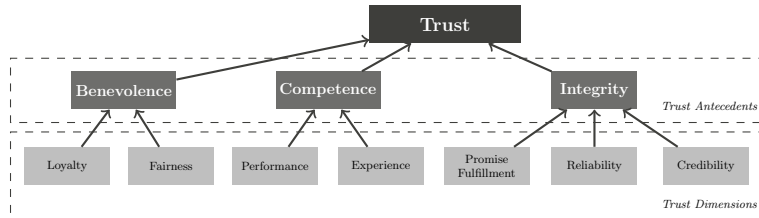


Fig. 2. Trust - Dimensions and Trust-Antecedents

To assess trust within the created game a comprehensive literature review had to be conducted, to identify common trust dimensions and measures. The identified dimension and measurement/antecedent structure is visualized in Fig. 2. While literature proposes dozens of different trust antecedents, *Benevolence*, *Competence* (both see e.g. [7, 8]) and *Integrity* (see e.g. [9]) were found to be the most dominant ones. As each of these antecedents is rather abstract and as such hard to compute, sets of sub-dimensions were selected to enable a formalization similar to the one conducted by [10].

The overall goal is to profile users when performing a specific game relevant decision. Optimally these set of values should correspond to the subjective perception of another participant. In how far this is actually the case a questionnaire within the game is conducted to examine the subjective perception and look for conformity. To enable their usage they had to be adapted to the data that can actually be gathered throughout the execution of the game.

The negotiation is defined between two participants $from_i$ and to_i . The $offer_i$, which has the same structure as the $order_i$, defines quantity and price for each product type. The $delivery_i$ contains in total the same amount of products as the $order$ but additionally, each of those products has two quality levels: one is referring to the actual quality and another one the quality as described by the participant $from$. Receiving the $order_i$, $from_i$ can still decide to not accept it due to too high prices demanded by to_i . This boolean information is defined as a_i . One special feature of the online game is the opportunity to reveal the quality and thereby get the real quality of each product of the delivery. If the participant to_i actually revealed the quality of a received $delivery_i$, q_i is **true**, otherwise it is **false**. Lastly, a negotiation always has a promised delivery date d_{pi} which can either be assumed to have a predefined value of e.g. zero, as it is done in the online game, or it has to be defined in the negotiation phase. Accordingly, an actual delivery date d_{ai} describes the date of the delivery. rnd_i refers to the round of n_i .

This data is utilized in the formulas for each sub-dimension as shown below. Each one is used to assess and measure one negotiation i .

Integrity: *Promise Fulfillment* I_P is defined as the likelihood of a trustee keeping a promise to its trustor. Since the definition is based on the discrepancy between promised and actual delivery date in a number of rounds, it only makes sense to calculate this measure from a Supplier to a Manufacturer or from a Retailer to a Supplier. I_P simply takes the difference of the actual to the promised delivery date divided by the latter one. This way late delivery results in a higher actual delivery date and therefore the ratio increases. To assign late deliveries a lower score, the derived ratio is subtracted from the ideal value of one. To retain interpretability in terms mapping I_P to $\{0, 1\}$, it is set to zero if the actual delivery took longer than two times the promised delivery date (as otherwise, it would be smaller than zero).

$$I_P = \begin{cases} \left(1 - \frac{d_{ai} - d_{pi}}{d_{pi}}\right), & d_{ai} \leq 2 \cdot d_{pi} \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

The definition of *Reliability* is straightforward defined as either being one, and therefore accepted, or zero, if the negotiation has not been accepted. One decisive action that directly affects the trustworthiness is the quality revelation. Similar to *Reliability* the revelation can directly be inferred. If the quality is revealed, the *credibility* of that negotiation is zero and one vice versa.

Competence: The *Performance* measure C_P is assessing differences in total quality of delivery. It is used to calculate the performance of each negotiation. The best performance is achieved if the actual quality qty_i^{actual} of n_i is at least as high as the promised quality $qty_i^{promised}$. This means that the participant was able to deliver as he promised and is therefore not lying. The other case occurs if the actual quality of a delivery is worse than promised. As an additional weighting factor the price p_i is used, so that the *Performance* degrades faster if

products are not only sold with a wrong but also for a very high price.

$$C_P = \begin{cases} 1, & \text{if } val_i \geq 0 \\ \frac{1}{|val_i|}, & \text{otherwise} \end{cases} \quad (2)$$

$$val_i = \sum_{qty_j \in qty} (p_{qty_j} \cdot qty_j^{actual}) - (p_{qty_j} \cdot qty_j^{promised})$$

Experience in this context describes the inclination to a specific product type. A participant is considered to be experienced with one type of product if the number of products of that type sold in negotiation n_i is high in comparison to the number of products of all other types in n_i . The equation is one if the number of delivered elements of a quality level qty_j e_{qty_j} ($qty_j \in qty$) is zero for all levels except one.

$$C_E = \frac{\max(e_{qty_j})}{\sum_{qty_k \in qty} e_{qty_k}}, \quad qty_j \in qty \quad (3)$$

Benevolence: *Loyalty* defines whether the two participants in a negotiation n_i were loyal to each other. A loyal participant in the GAME OF TRUST is defined as someone only interacting with one potential client (L_{\rightarrow}^i) or source (L_{\leftarrow}^i). So for a *Manufacturer* M_i *Loyalty* would mean to trade with only one *Wholesaler* W_i . Similarly the *Wholesaler* would only be fully loyal if he traded with exactly one M_i . The *Loyalty* in the negotiation n_i is defined as the average of the *Loyaltys* of the two participants $from_i$ and to_i .

$$N_{\rightarrow}^j = \{n_i \in N \mid from_i = from_j \wedge rnd_j = rnd_i \wedge a_i = 1\} \quad (4)$$

$$N_{\leftarrow}^j = \{n_i \in N \mid to_i = to_j \wedge rnd_j = rnd_i \wedge a_i = 1\} \quad (5)$$

$$L_{\rightarrow}^i = \begin{cases} 2, & \text{if } |N_{\rightarrow}^i| = 1 \\ 1, & \text{if } |N_{\rightarrow}^i| > 1 \\ 0, & \text{otherwise} \end{cases} \quad (6)$$

$$L_{\leftarrow}^i = \begin{cases} 2, & \text{if } |N_{\leftarrow}^i| = 1 \\ 1, & \text{if } |N_{\leftarrow}^i| > 1 \\ 0, & \text{otherwise} \end{cases} \quad (7)$$

$$L_i = \frac{1}{2} * (L_{\rightarrow}^i + L_{\leftarrow}^i) \quad (8)$$

The *Fairness* of a negotiation n_i is calculated based on the price $p_{qty}(n_i)$ for each product quality qty sold in n_i in comparison to the prices demanded by participants with the same role r .

$$N_r = \{n_i \in N \mid role(from_i) = r\} \quad (9)$$

$$b_{fi} = \frac{1}{|qty|} \cdot \sum_{qty_j \in qty} \left(1 - \frac{p_{qty_j}(n_i)}{\max(p_{qty_j}(N_r))} \right), \quad r = role(from_i) \quad (10)$$

Comparing the prices to those of other negotiations n_i from the same supply chain tier is necessary to obtain meaningful *Fairness* measures. This is grounded on the assumption that the price should rise over the tiers.

3 Future Work: Digital Game

Based on the experiences with the offline based test run, the decision was made to create a digital version of the GAME OF TRUST. The digital version ensures that each player of the game will always be presented with the right forms and that he/she can not forget to enter necessary data. A second major factor for the decision to go digital was the ability to scale. The conducted offline test already revealed the need for a significant amount of moderation work. As the game is intended to help with the collection of profilable data, a lot of moderation overhead was deemed problematic since it would limit the ability to gather a large data set. Providing an electronic online version solves this issues even in two ways: It takes over the moderation part and furthermore enables the game to be played by a larger set of people.

Given the focus on data collection, a difficult trade-off had to be made for the game. On the one hand, the game had to be sufficiently appealing to attract players (and thus data), while on the contrary, it had to be created with minimal effort. Since the GAME OF TRUST is a game experiment hybrid, it was possible to make use of already existing frameworks for online studies. After evaluating the existing alternatives, JATOS [11] was selected as the framework of choice. It already represents a complete service to deliver the experiment/game to the users.

The game design for the virtual GAME OF TRUST will closely follow the design of the offline experiment. For each supply chain role, an interface tailored to the needs of the role will be offered. The data collection is organized in line with the actual implementation of the user interface. It aims at capturing as many as possible details about player interactions in a separate database. Going for more data than might be minimally needed aids to enable future more-sophisticated profiling projects without being forced to create a new dataset.

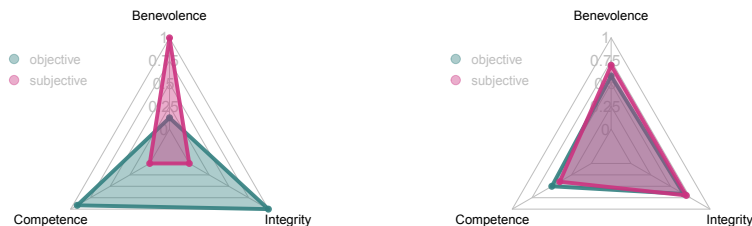


Fig. 3. Mapping Between Subjective and Objective Trust Measures

First experiments with the software prototype were already able to showcase its promise. One potential use of the collected objective and subjective trust data is e.g. the validation of the used trust measures. For example Fig. 3 shows that for some transactions the user-perceived trust nearly maps the computed objective trust (right image), whereas on other occasions the gaps are still large. Given a larger experimental dataset, the GAME OF TRUST will help to identify

accurate trust measures which can then subsequently be used to generate valid, trust-based user profiles for supply chain interactions.

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