An Enterprise-ontology based Conceptual-modeling Grammar for Representing Value Chain and Supply Chain Scripts

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Abstract: In business modeling the focus is shifting from the enterprise to the supply chain as the prime context. Contemporary business modeling grammars should allow each enterprise taking part in a supply chain to develop its own information system and at the same time support the creation of system interoperability and information sharing amongst business partners in the supply chain. This paper presents a conceptual modeling grammar for representing business scripts in a way that is observer-independent. That is, rather than presenting value chain information from the perspective of any partner in the supply chain (e.g., enterprise, supplier, customer, customer's customer, supplier's supplier) or from a completely neutral third party. This observer-independent conceptual-modeling grammar, which is given strength by grounding it in the mature Resource-Event-Agent model, is shown to represent information about business phenomena of diverse supply chain partners such that it can be integrated across enterprise boundaries.

1 INTRODUCTION

Conceptual modeling in information systems (i.e., the creation of an conceptual-modeling grammar for the purpose of designing information systems (Wand et al., 1995)) is a challenging task, especially because - in practice - enterprise information systems form a small part of a much larger information processing environment. Consequently, *conceptual-modeling grammars*, which provide sets of constructs and rules to model real-world domains (Wand and Weber, 2002), for the purpose of designing information systems cannot be considered standalone artifacts. Moody and Shanks (2003) show that significant benefits can be achieved through integration of information systems, and argue that considering individual systems in the context of an overall architecture is critical for developing quality information systems. Within conceptual modeling, the choice of an appropriate representation of data is one of the most crucial tasks in information systems development, as it is a major determinant of an information system's ability to integrate with other systems (Moody and Simsion, 1995).

Where the enterprise and its value adding processes could be considered the prime *conceptual modeling context*, which is the setting in which conceptual modeling occurs and conceptual-modeling scripts are used (Wand and Weber, 2002), in the past, the supply chain is becoming more and more important as a modeling context. A continuously faster globalizing world economy and increasing cooperation among supply chain partners increases the need to model the entire supply chain and not just individual players within it.

In some cases the conceptual-modeling context consists of both the supply chain and the enterprise (e.g., strategic alliances, joint ventures). As with all other forms of collaboration, a fair distribution of the added value among the collaborators is primordial. This issue receives a lot of attention with joint ventures, where each parent company expects to receive a fair part of the joint venture's added value, although this added value can be very diverse in nature (e.g., knowledge acquisition, financial returns, cost reduction) (Ariño and Ring, 2010), (Kumar, 2010). Fair distribution of added value between supply chain partners is also essential for closed-loop supply chains, where the reprocessing of end-of-life products needs to be profitable too (Kumar and Malegeant, 2006). To convince collaborators that added value is distributed

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correctly, collaborating supply chain partners and parent companies of a joint venture need to make data about their transactions with other supply chain partners or the joint venture available to their collaborators, cofounders or a trusted third party that certifies a fair distribution of added value between supply chain partners or parent companies. Such a certifying body would require an information system that takes the independent-observer view on the data that each trading partner generates about transactions, where the joint venture or the supply chain partner itself needs an information system that takes the trading-partner view on the transactions it participates in. The *independent-observer view* is a supply-chain-centric conceptual modeling context that looks at business from an independent observer perspective or 'helicopter' view (e.g., business seen as flows of goods, services and money between parties that are caused by business events initiated by these parties). The *trading partner view*, on the other hand, is an enterprise-centric conceptual modeling context that covers conceptual modeling scripts for enterprise information systems from the sole perspective of one particular party involved in business, called the 'trading partner' (e.g., an enterprise doing business in its role of customer, producer or supplier).

Although the concept of supply-chain-centric information systems is not new (Curran, 1991) and a lot of work has been attributed to the standardization and formalization of the information that is exchanged between trading partners for a transaction to take place (e.g., ebXML, UBL), supply chains and enterprises are still considered distinct conceptual modeling contexts when modeling information systems (ISO/IEC, 2007) and most enterprises rely on enterprise-centric information systems.

What is needed is a conceptual modeling grammar that allows each enterprise in a supply chain to develop its own private enterprise information system and at the same time support the creation of supply chain information systems (Tan et al., 2010).

This paper presents a conceptual modelling grammar that elaborates a reference model, which is based on the Resource-Event-Agent (REA) ontology (Geerts and McCarthy, 2002), and can be used for both the trading-partner and independent-observer view (Laurier et al., 2010) This conceptual modelling grammar for the business domain overarches the supply chain and enterprise domains of business information systems and provides a conceptual basis for both information systems development and integration.

Section 2 reviews the REA ontology, on which the conceptual-modeling grammar is based. Section 3 presents the conceptual-modeling grammar and shows how it is built from the primitives that occur in REA ontology (Geerts and McCarthy, 2002). Subsequently, section 4 presents archetypal conceptual-modeling scripts that demonstrate how this conceptual-modeling grammar can be used to integrate both conceptual modeling contexts (i.e., enterprise-centric and supply-chain centric) Next, section 5 compares the conceptual-modeling grammar to related conceptualizations used in enterprise modeling and supply chain modeling. Finally, section 6 concludes the paper and proposes ideas for future research.

2 INTRODUCTION TO REA

The original REA generalized accounting framework (McCarthy, 1982) was developed to create an environment in which accountants and non-accountants can share data about the same set of business phenomena. Based on ideas taken from Chen's Entity-Relationship model (Chen, 1976), an accounting conceptual modeling grammar was proposed in which concepts were given real-world business semantics (i.e., resources, events, agents) instead of the usual debit-credit-account semantics (e.g., accounts receivable, revenues deferred) which code operational information such that it is hard to decode for most non-accountants. The REA framework includes procedural mechanisms for taking different mutually compatible views on the same business reality. For instance, an REA *conceptual modeling script*, which is a product of a conceptual modeling process given a conceptual modeling grammar (Wand and Weber, 2002), would still contain a representation of all data required to restore the accounting view on business (e.g., calculate accounts receivable, revenues deferred, etc.), but would at the same time also support the data requirements of other kinds of operational and managerial business applications (e.g., stock control, policy setting, planning, management control, etc.).

Economic Resources (e.g., goods and services) represent objects that are scarce, have utility and are under the control of an economic agent (e.g., enterprise, household) (Ijiri, 1975), (McCarthy, 1982). The scarceness means that not every economic agent can control such resources at a certain point in time and indicates that for some economic agents trade is required to gain control over particular resources. The utility motivates why certain economic agents want to gain control over particular resources. *Economic Events* (e.g., produce, exchange, consume, distribute) result in changes (i.e., increases and decreases) of resource stocks (Yu, 1976), whereas *Economic Agents* represent legal or natural persons that participate in economic events (e.g., performing a task, enacting a process) or have custody over resources (i.e., having physical control over resource or controlling the access to resources)(ISO/IEC, 2007).

Later, the constructs from the data modeling grammar were augmented with axioms to create the actual REA ontology (Geerts and McCarthy, 2004). These axioms address the rules that govern business seen from the perspective of a single trading partner and describe the set of models intended by the ontology (Guarino, 1998).

The *first REA axiom* stipulates that at least one inflow event and one outflow event exist for each economic resource and that inflow and outflow events must affect identifiable resources (Geerts and McCarthy, 2004). Consequently, this axiom requires that every economic resource has its origin in an inflow event (i.e., increment) and a purpose (i.e., being used in an outflow/decrement event).

The *second REA axiom* addresses the economic rational by requiring that all events effecting an outflow must be eventually paired in duality relationships with events effecting an inflow and vice- versa (Geerts and McCarthy, 2004). Together, these two axioms define a healthy metabolism for an enterprise. The first axiom requires that all resources are useful and no resources will be stored perpetually. The second axiom requires that the enterprise is rewarded for its efforts, preventing that its resources drain away. The second REA axiom is also called the duality axiom. *Duality* balances changes in resources due to economic activity (Ijiri, 1975) and relates back to REA's accounting background. For instance, duality in market transactions dictates that when a company sells products to a customer (i.e., an economic event that decreases the value of the company's inventory of products), a requiting event like a payment or delivery of equally or higher valued goods (e.g., as in barter trade) by the customer must follow, meaning that there is a dual economic event that balances the decrease in value caused by the sale.

The *third REA axiom* then specifies that each exchange needs an instance of both the inside and outside subsets, requiring that each business transaction involves at least two trading partners (i.e., the enterprise that defines the viewpoint and an outside agent (e.g., supplier, customer)). Additionally, this axiom specifies that there is always an agent inside the enterprise (e.g., salesperson) that is accountable for the transaction.

Most recently, REA's trading-partner view on the economic reality was complemented with an independent-observer view. This independent-observer view was developed for the purpose of developing an ISO standard for open-edi (i.e., electronic data interchange) that is specific for business transactions (ISO/IEC, 2007).

3 THE REA CONCEPTUAL MODELING GRAMMAR

This section presents the conceptual-modeling grammar that is based on the REA ontology and is meant to be used for representing business transactions in a modeling context that requires both a trading-partner view and an independent-observer view. Committing a conceptual-modeling grammar to the conceptualization specified by a domain ontology (like REA is) ensures that relevant domain knowledge is captured (Guarino and Giaretta, 1995). This knowledge includes conditions that specify the configurations in the domain that are possible and those that are not (Evermann and Wand, 2005).

Fig. 1 shows the conceptual-modeling grammar that presents the trading-partner and independent-observer views as mutually compatible views on the same business reality. The model contains three REA primitives (i.e. economic resource, economic event, and economic agent) and a new concept (i.e. organizational unit) that allows us to integrate the mutually compatible views.

The *Organizational Unit* concept is used to model that certain economic agents (i.e., organizational units) have control over economic resources (i.e., ownership of the right to derive economic benefit from a resource), which entails the discretionary power to use or dispose of these resources via economic events in a legal way, where other (ordinary) economic agents can only have physical access (i.e., custody) to economic resources. Organizational units represent the entities that experience the effect of economic events, whereas agents represent the entities that engage in events (e.g., an employee performs an event that affects his employer's resources). So agents may have or control physical access to economic resources of which they are not the owner (i.e., having custody (ISO/IEC, 2007) but not economic control over the resources), which means that in that case the agents act on behalf of organizational units.

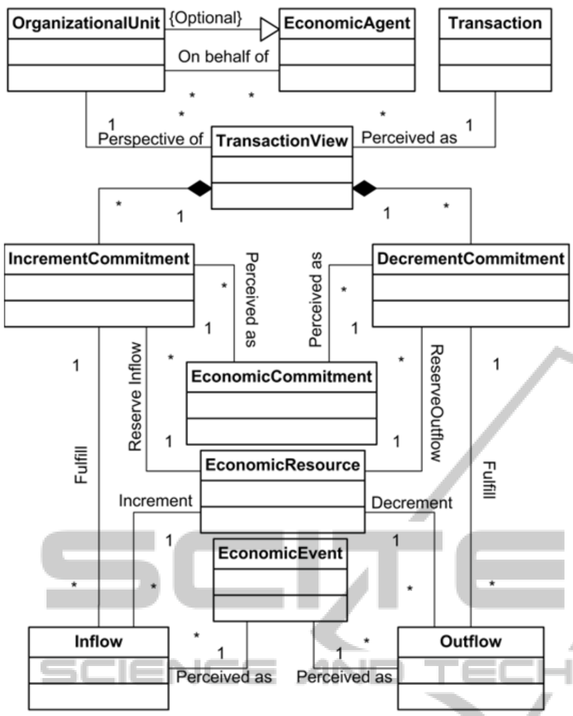

Figure 1: The REA Conceptual-Modeling Grammar.

For example, an employee is an agent for its employer (i.e., the employee performs tasks from which the employer reaps the full benefits). The effect of economic events that economic units experience is change of control (i.e., ownership). The ON_BEHALF_OF association (fig. 1) can also represent that an organizational unit, which is a kind of economic agent, acts on behalf of another organizational unit (e.g., a subsidiary on behalf of a parent company).

In fig. 1, the TRANSACTIONVIEW class models the duality principle embedded in the second REA axiom from the perspective of a single organizational unit (i.e. trading-partner view), which judges whether the increments and decrements it experiences in its perception of a transaction are well-balanced. The INFLOW and OUTFLOW classes were added to show the trading-partner view of organizational units that respectively gain or lose control (e.g., ownership) over resources and how the resource stocks they control respectively increase or decrease in value. The ECONOMICEVENT class was added to represent the independent-observer view on each economic event. The independent-observer and trading-partner view were made mutually compatible by linking the INFLOW and OUTFLOW classes to the ECONOMICEVENT class, which contains their perspective independent attributes (e.g. date). Subjective (i.e., related to the view of an organizational unit) attributes (e.g. value) need to be represented inside the INFLOW and OUTFLOW classes as they relate to the perspective of a single trading partner, which is represented by the TRANSACTIONVIEW class.

The first REA axiom requires that in conceptual modeling scripts every economic event relates to one or more economic resources through at least one inflow and one outflow, and that every economic resource relates to one economic event through and inflow and another economic event through an outflow.

The third REA axiom exclusively describes conceptual modeling scripts for exchanges, requiring that in these scripts the increment perception of an economic event is modeled by relating an organization unit to the economic event through an inflow and a transaction view and that the decrement perception of an economic event is modeled by relating another organization to the same economic event through an outflow and another transaction view. The third REA axiom also stipulates that there must always be an economic agent that participates in an economic event. The participation association between an economic agent and an economic event indicates that this economic agent engages in economic events for which it is accountable on behalf of this organizational unit.

REA also explicitly recognizes ECONOMIC_ COMMITMENTS, which are promises to perform economic events in the future as specified by a schedule or contract. As commitments represent planned events, the commitment side of the conceptual modeling grammar mirrors the event side of the model. Resembling events, commitments can be viewed as increment, decrement or both by an organizational unit. For instance, one clause in a contract may involve a future loss of resources (i.e., sale and delivery) for one organizational unit and a future gain of these resources (i.e., acquisition and receipt) for its opponent, whereas another clause in the same contract specifies the amount of money to be paid by the latter to the former. The RESERVE relationships then indicates which resources are reserved for the fulfillment of which commitments and what the result of this fulfillment will be, where the similar INCREMENT and DECREMENT relationships shows which resources are involved in an economic event and how the value of their stocks are affected.

Like events, commitments are dual in nature and such commitments are said to be reciprocal (Geerts and McCarthy, 2002). In fig. 1, reciprocities, like dualities, are represented by the TRANSACTIONVIEW class, which shows that the appreciation of balanced increment and decrement commitments is subjective since it is related to the viewpoint of exactly one organizational unit (e.g., the price paid or installment plan for a car is deemed fair by the buyer, the remuneration received for a car is deemed fair by the seller). In addition, increment (decrement) commitments can be fulfilled by one or more inflow (outflow) events.

To improve graph readability, the association primitives between the ECONOMICAGENT class and the ECONOMICRESOURCE (i.e. custody), ECONOMIC_ EVENT (i.e. participation), ECONOMICCOMMITMENT (i.e. specify) classes are not shown in fig. 1.

4 ARCHETYPAL CONCEPTUAL MODELING SCRIPTS

This section presents archetypal conceptual modeling scripts exemplifying a number of concept patterns (and variants) that apply when using the conceptual-modeling grammar introduced above. Additionally, this section demonstrates how the new grammar allows integrating the features of trading-partner and independent-observer view conceptual modeling scripts.

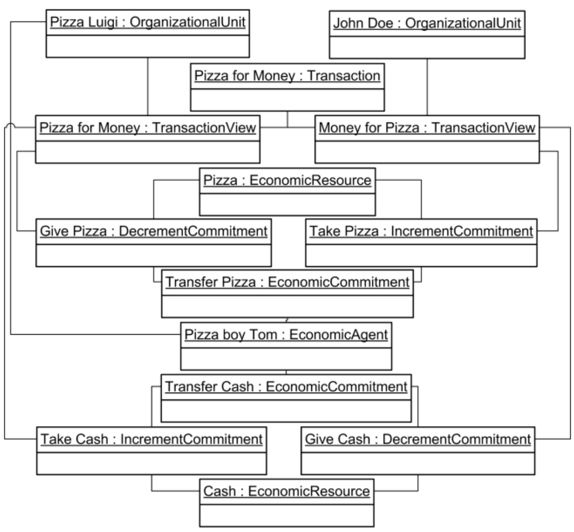

Figure 2: The Economic Agreement script.

The conceptual modeling script, which is represented as a UML object diagram, in fig. 2 exemplifies the use of the conceptual-modeling grammar to model an economic agreement, which is an arrangement of reciprocated economic commitments between two trading partners (ISO/IEC, 2007), representing the independent-observer view and both trading-partner views of the modeled transaction. To model the agreement, this economic agreement model applies the view integration principles introduced by (Laurier et al., 2010) at the level of economic commitments instead of economic events.

In the economic agreement script (fig. 2) models two opposing views of a transaction. The transaction will involve exchanging pizza for money from an independent-observer perspective. From Pizza Luigi's (i.e. seller) perspective, the exchange will involve giving pizza in return for cash. From John Doe's (i.e. buyer) perspective, the exchange will involve giving cash in return for pizza. From the independent-observer perspective, the opposing views can be distinguished easily as the pizza transfer commitment is perceived as a decrement commitment (i.e. future outflow) by the seller and an increment commitment (i.e. future inflow) by the buyer. On the other hand, the cash transfer is perceived as a future inflow by Pizza Luigi and a future outflow by John Doe. The agreement in fig. 2 also specifies that Pizza boy Tom will participate in both transfers on behalf of Pizza Luigi.

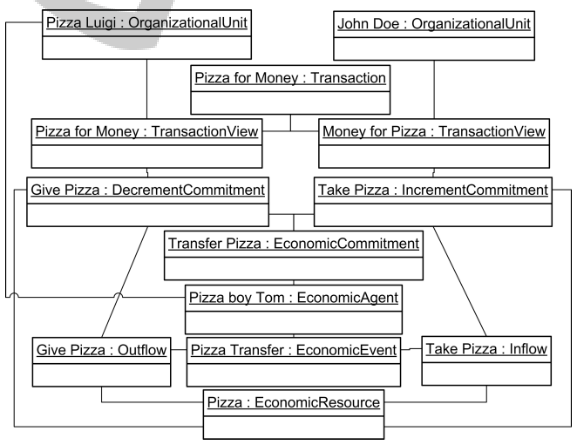

Figure 3: The Transfer Fulfillment script.

Fig. 3 shows from the independent-observer perspective and both trading-partner views how the TRANSFER PIZZA economic commitment is fulfilled by a PIZZA TRANSFER economic event. Consequently, the upper half of fig. 3 is identical to the upper half of fig. 2. The lower half of fig 2 was omitted because the fulfillment of the TRANSFER CASH economic commitment is almost identical to the fulfillment of the TRANSFER PIZZA economic commitment displayed in fig. 3. Therefore, it should be feasible for the reader to complete the model given the example in fig. 3.

As committed the PIZZA TRANSFER economic event, which fulfills the TRANSFER PIZZA economic commitment, is perceive as a resource outflow by Pizza Luigi and as a resource inflow by John Doe. As specified by the commitment, Pizza boy Tom participates in the event on behalf of Pizza Luigi and the reserved resource (i.e. the PIZZA) transferred from Pizza Luigi's to John Doe's.

Fig. 4 shows from John Doe's trading-partner view how an agreement or contract can be settled. Consequently, the left-hand side of fig. 4 is identical to the left-hand side of fig. 2. The right-hand side of fig. 2 was omitted as the settlement of John Doe's perspective on the agreement mirrors Pizza Luigi's perspective. Therefore, it should be feasible for the reader to complete the model given the example in fig. 4. As agreed, the TAKE PIZZA increment commitment, which is known as the TRANSFER PIZZA economic commitment in the independent-observer view, is fulfilled by the TAKE PIZZA inflow and the GIVE CASH decrement commitment, which is known as the TRANSFER CASH economic commitment in the independent-observer view, is fulfilled by the GIVE CASH outflow. In the independent-observer view, the TAKE PIZZA inflow is known as the TRANSFER PIZZA economic event and the GIVE CASH outflow is known as the TRANSFER CASH economic event. As specified by the commitments, Pizza boy Tom participates in the commitment fulfilling inflow and outflow.

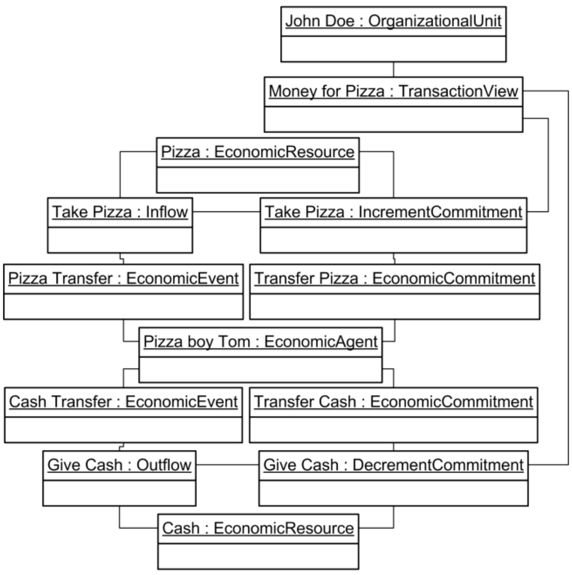

Figure 4: The Settlement script.

Claims can be modeled as incomplete settlement scripts. A positive claim is the expectation of a trading partner to receive a future inflow that fulfills an increment commitment that is enforceable due to a reciprocal decrement commitment that has been fulfilled by an outflow (.e.g. John Doe paid Pizza boy Tom and expects to receive his pizza). A negative claim is the obligation of a trading partner to deliver a future outflow that fulfills a decrement commitment that is enforceable due to a reciprocal increment commitment that has been fulfilled by an inflow (e.g. John Doe received his pizza and is obliged to pay).

Next to modeling the components of an exchange transaction between two trading-partners, as shown in fig. 2, 3 and 4, the conceptual-modeling grammar can be used to represent the components of a production process, including its planning and execution. In the REA terminology, such a model of a production process is called a conversion model, as it represents the conversion of one or more inputs into one or more outputs. For a more detailed analysis of conversion models, we refer to (Laurier and Poels, 2012).

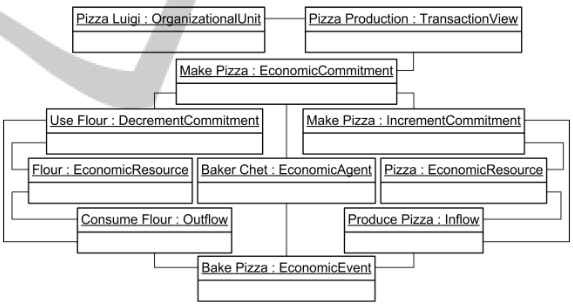

Figure 5: The Conversion Fulfillment script.

Fig. 5 shows the main components of a conversion script. First, it should be noted that a conversion script always refers the perspective of a single trading-partner (i.e. the organizational unit that has the conversion script as part of its business processes). Like the transfer fulfillment script (fig. 3), which is its exchange equivalent, the conversion fulfillment script consists of a planning layer and an execution layer. The planning layer consists of the economic commitment to make pizza; the execution layer consists of the economic event that actually produces the pizza. In fig. 5, the planned pizza production process involves using flour to make pizza. When additional planned in- and outputs need to be modeled, decrement and increment commitments can be added to the script. The script also reveals that the economic commitment specifies that "Baker Chet" will be responsible for the execution. The execution layer, shows that Baker Chet executed the actual pizza baking process exactly as planned, consuming the inputs that were reserved and producing the pizza's that were expected.

5 COMPARATIVE ANALYSIS

In this section, the REA conceptual-modeling grammar for representing business transactions in an integrated enterprise-centric and supply-chain-centric conceptual modeling context is compared with well-known related conceptualizations that are used for modeling business transactions. First, the merits of the new REA grammar vis-à-vis more traditional independent-observer and trading-partner view REA models are discussed.

In the new REA-based grammar, the 'from' and 'to' semantics that are typical for independent-observer view models can be derived from the inflow and outflow semantics. In the independent-observer perspective, an event as perceived by an independent observer makes resources flow from the organizational unit that perceives it as an outflow to the organizational unit that perceives it as an inflow. In the fulfill script (fig. 3), pizza is transferred from Pizza Luigi to John. Table 1 summarizes how the inflow and outflow semantics of the conceptual-modeling grammar can be translated to more traditional trading-partner and independent view model semantics.

Table 1: Inflow and Outflow Semantics Summary.

New grammar	Trading-partner view	Independent view
Inflow	Increment event	To
Outflow	Decrement event	From

Due to the exchange focus and the implicit trading-partner view it is possible to register one and the same transfer event as an increment event (i.e., receipt) in one system and a decrement event in another system. The REA conceptual-modeling grammar, on the other hand, makes it also possible to model business from both the trading-partner and independent-observer point of view, meaning that goods and money transfers are recognized only once in the independent-observer view but may be observed and registered twice or more (i.e., once in the view of each trading partner (e.g., as increment for one party and as decrement for the other party)).

Trading-partner models like the settlement script (fig. 4) mirror each other and conform to the semantics in the earlier REA trading-partner view models. For example, McCarthy (1982) identifies inside and outside parties, which are roles for economic agents. In McCarthy's models, the inside party is the person (i.e., economic agent) that is accountable for the transaction, the outside party the trading partner. In the example conceptual-modeling scripts presented above, the outside party can be recognized as the agent that does not act on behalf of the organizational unit that defines the transaction view. The settlement script (fig. 4) models John Doe's transaction perspective. John acts on behalf of himself, which means he also plays the inside party role. If another person would act on behalf of John, that other person would play the inside party role. In the settlement script, the outside party role is played by Pizza Luigi. Pizza boy Tom would be the inside party from the perspective of Pizza Luigi. A more detailed analysis of the inside and outside party roles can be found in (Laurier et al., 2010).

In the new grammar the trading partner that defines the view is explicitly modeled as the organizational unit that is related to the transaction view, where this view defining unit is implicit in McCarthy's, and also Hruby's (2006), trading-partner view models. In the example trading partner conceptual-modeling scripts, the Pizza transfer is perceived as an inflow by John and a outflow by Pizza Luigi, where the money transfer is perceived as an inflow by Pizza Luigi and an outflow by John. For John acquiring the pizza is dual to paying for it, where for Pizza Luigi delivering the pizza is dual to getting paid for it.

Next to models that document the current state and history of an organizational unit, the new REA conceptual modeling grammar can also be used to generate models that project planned future states. Of all potential future organizational unit states, such models include those that are desired and documented (e.g., contracts and agreements). Those contracts consist of increment and decrement commitments that are paired in reciprocity with each other and that mimic the economic agreement script exemplified in fig. 2.

6 CONCLUSIONS

This paper presented a new conceptual modeling grammar for the business domain that can be used for the modeling of business transactions from the perspective of trading partners as well as third parties. The conceptual basis for this model is the

REA ontology. The paper also presented archetypal conceptual-modeling scripts that instantiate the conceptual-modeling grammar. Via these scripts, exemplifying typical transaction patterns, it was demonstrated that the proposed model enables taking both an independent-observer view and a trading-partner view on business reality. This is undoubtedly the most distinctive feature of our proposal because it allows modelers to construct business models that provide a basis for developing information systems for each enterprise taking part in a supply chain and at the same time for facilitating system interoperability and information sharing amongst business partners.

The introduction of the organizational unit concept as business semantics viewpoint determining entity is a key feature of our model. Where previously, the perspective on business reality of each enterprise was represented in a separate script, the views of different enterprises that are part of a supply chain can now be jointly represented in a single script via the organizational unit concept and its relations with events and agents. This explicit representation of enterprise viewpoints allows for a central administration of independent-view transaction information and a federated administration of transaction information, which should help preserve their autonomy and isolation by sharing only information that is registered in their trading-partner view information systems that is relevant for the independent-observer view. Since both types of systems can now be based on the same conceptual modeling script, data interoperability is also expected to be facilitated when the integrated enterprises reach agreement about a minimal set of attributes (e.g., identifiers).

A limitation, though the result of a deliberate choice, is that the new REA-based grammar abstracts from application specific inferences like the sequencing of events or other process control flow aspects that are, for instance, key to workflow modeling. Another limitation is that only a descriptive evaluation of the presented conceptual modeling grammar was presented here. Another type of descriptive evaluation has been presented in (Laurier and Poels, 2012), where a conceptual modeling script for traceability is presented as a proof of concept for this conceptual modeling grammar.

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