

An Enterprise Ontology Based Conceptual Modeling Grammar

For Representing Value Chain and Supply Chain Scripts

Abstract

In business modeling the focus is shifting from individual enterprises to the supply chains in which they collaborate. 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 both observer-dependent and independent. That is, value chain information should be represented in a format that is suitable for the perspective of any partner in the supply chain (e.g., enterprise, supplier, customer, customer's customer, supplier's supplier) and for the perspective of a completely neutral third party (e.g., government). The proposed 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

Keywords

Enterprise Ontology, Business Modeling, Information System Integration, Conceptual-modeling Grammar

Introduction

Conceptual modeling in information systems (i.e., the creation of a conceptual-modeling grammar for the purpose of designing information systems (Wand, Monarchi, Parsons, & Woo, 1995)) is a challenging task, especially because - in practice - enterprise (information) systems, which are a subset of information systems (Davenport, 2000), 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 & 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 a crucial task in information systems development, as it is a major determinant of an information system's ability to integrate with other systems (Daniel. L. Moody & Simsion, 1995).

Where the enterprise and its value adding processes have been considered the prime *conceptual modeling context*, which is the setting in which conceptual modeling occurs and conceptual-modeling scripts are used (Wand & Weber, 2002), in the past, the

supply chain is becoming more and more important as a modeling context (Min & Zhou, 2002). 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 partners within it (Cong, Zhang, Liu, & Huang, 2010; Huang, 2012).

In some cases the conceptual-modeling context consists of both the supply chain and the enterprise (e.g., virtual enterprises, 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 & Ring, 2010; M. V. S. 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 (S. Kumar & Malegeant, 2006). To convince collaborators that added value is distributed 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, RosettaNet), 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 (Koh, Gunasekaran, & Goodman, 2011).

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, Niels, Klein, & Rukanova, 2010).

This paper presents a conceptual modeling grammar that elaborates a reference model, which is based on the Resource-Event-Agent (REA) ontology (Guido L. Geerts & McCarthy, 2002), and can be used for both the trading-partner and independent-observer view (Laurier, Bernaert, & Poels, 2010). This conceptual modeling 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. The modeling grammar was committed¹ to the REA ontology because of REA's structuring orientation, which facilitates knowledge representation and interpretation by structuring knowledge in easily recognizable recurrent patterns (Dunn & McCarthy, 1997; Poels, Maes, Gailly, & Paemeleire, 2007; Polovina, 2013). The structuring orientation is one of the features of REA that has made it popular in several domains, including education, knowledge management and supply chain management (Gailly, Laurier, & Poels, 2008; Guido L. Geerts, 2011). An *ontology* is an intentional semantic structure that assembles the terms that are presumed to exist in some area of interest, which is often called the *universe of discourse* or *semantic domain*, the relationships that hold among them and the implicit rules constraining the structure of this (piece of) reality. (Genesereth & Nilsson, 1987; Guarino & Giaretta, 1995) In this definition, the work *intentional* refers to a structure describing various possible states of affairs, as opposed to *extensional*, which would refer to a structure describing a particular state of affairs. The word *semantic* indicates that the structure has meaning, which is defined as the relationship between (a structure of) symbols and a mental model of the intentional structure in the mind of the observer. This mental model is also called a *conceptualization* (Gruber, 1993).

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 (Guido L. Geerts & 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

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 & 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.).

¹ A modeling grammar's ontological commitment is an intentional structure that assigns grammar symbols to ontology constructs, such that all grammatically valid models are intended models according to the underlying ontology (Guizzardi, 2013)

Later, the constructs from the data modeling grammar were augmented with axioms to create the actual REA ontology (Guido L. Geerts & 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).

More 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).

Most recently, the REA axioms have been rephrased to distinguish their implications for conceptual modeling scripts for *supply chains* (i.e. the level at which individual enterprises communicate and trade), *value chains* (i.e. the level at which individual enterprises or organizations balance logistic flows with mirroring money flows) and *business processes* (i.e. the individual processes that use information to orchestrate logistic, operational and financial flows and produce information while orchestrating) (Laurier & Poels, 2013b). Supply chain scripts correspond to the independent-observer view, value chain and business process scripts correspond to the trading-partner view of the original REA ontology. Value chain scripts interface value chain and business process scripts, representing the entrepreneur script, which describes how trading partners engage in value-added exchanges (G. L. Geerts & McCarthy, 1999). This entrepreneur script contains three major parts (i.e., acquisition, revenue and conversion cycle) and an auxiliary part (i.e., financing cycle). The *acquisition cycle* represents how the individual trading partner purchases materials and labor from its suppliers (e.g., material vendors, employees) usually in return for money. The acquisition cycle is similar to the SCOR (Council, 2006) source process, which also relates the operational processes that acquire products with the payments that remunerate them. The *revenue cycle*, on the other hand, represents how the individual trading partner sells finished goods to its customers, usually in return for money (McCarthy, 2003). The revenue cycle intersects with the SCOR deliver process, which makes sure delivered products generate return. The acquisition and revenue cycle represent the opposing views of trading partners involved in the same exchange. The *conversion cycle* shows how labor and raw materials are converted into finished goods inside the trading partner's organization. The conversion cycle incorporates the entire SCOR make process. The auxiliary financing cycle then supplies the acquisition cycle with money by acquiring money through the revenue cycle or from creditors (e.g., banks, shareholders). This financing cycle is a main difference between the SCOR reference model for supply chains and the REA ontology because the financing cycle is not explicitly addressed in SCOR due to its operational focus.

The REA primitive that represent business concepts with real-world business semantics are discusses in the first subsection, the REA axioms in the second.

REA primitives

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, p. 51; 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, p. 256), whereas *Economic Agents* represent legal or natural persons that participate in economic events (e.g., performing a task, enacting a process) or control resources (i.e., having physical control over resource or controlling the access to resources)(ISO/IEC, 2007). The minimal diagram in fig.1, visualizes the REA primitives described above. The affect and duality relationship are discussed below.

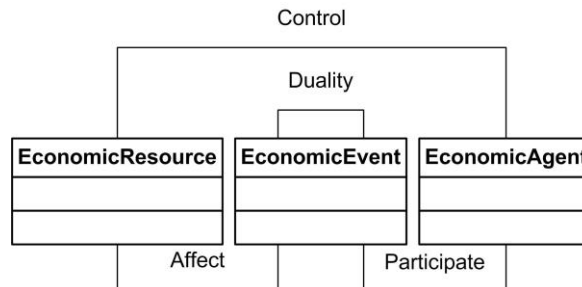


Figure1. A minimal diagram of the REA primitives.

REA axioms

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 (Guido L. Geerts & McCarthy, 2004). Consequently, this axiom requires that in modeling scripts every economic resource has an inflow event (i.e., increment) as source and an outflow event (i.e., decrement event) as sink.

In supply chain scripts, the source is the outflow event for the organization that provides the resource, and the sink is the inflow event for the organization that receives the resource that was provided by its trading partner. In business process scripts, the first REA axiom imposes that resources cannot be stocked eternally inside organizations, and that economic events must produce resources (i.e. inflow) or consume resources (i.e. outflow). In value chain scripts, the first REA axiom has to be satisfied by ensuring that every resource in- and outflow that affects the organization at the supply chain level, relates to a resource that is known at the level of the organization's business processes. Consequently, this axiom defines the integration points between the supply chain and the business process level at the level of value chains

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 (Guido L. Geerts & McCarthy, 2004). Together, the first and second axiom 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 requiring 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 second REA axiom has no implications for supply chain scripts. In acquisition cycle scripts, which are a kind of value chain scripts that model the viewpoint of the buying trading partner, the second REA axiom requires that a resource inflow (typically

a product or service acquisition) has to be eventually paired in duality with a resource outflow (typically a payment), to settle a purchase. In revenue cycle scripts, which model the opposing view of the selling trading partner on acquisition cycle scripts, a resource outflow (typically a product or service delivery) has to be paired in duality with a resource inflow (typically getting paid), to settle a sale. As the REA ontology abstracts from process aspects (e.g., temporal order) acquisition and revenue cycle scripts in which advance payments that are settled with a delivery (or a refund) are equally valid. Both the conversion cycle and financing cycle scripts are subject to the business process model interpretation of the second REA axiom, which imposes that an organization’s resource outflows find their origin in its resource inflows.

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)) in supply chain scripts. Additionally, this axiom specifies that there is always an agent inside the enterprise (e.g., salesperson) that is accountable for the transaction in business process scripts. Table 1 summarizes the script modeling guidelines as incorporated in the REA axioms.

Table 1. Script modeling guidelines as incorporated in the REA ontology axioms (Laurier & Poels, 2013b)

	1st REA Axiom	2nd REA Axiom	3rd REA Axiom
Supply Chain	<i>Resources have to flow from one organization to another</i>		<i>each exchange requires at least two organizations</i>
Value Chain	<i>Inflow and outflow events must affect identifiable resources.</i>	<i>each organization involved in an exchange has to provide resources to receive other resources</i>	
Business Process	<i>at least one inflow event and outflow event exist for each economic resource and that inflow and outflow events must affect identifiable resources</i>	<i>all events consuming a resource must eventually produce a resource and vice versa</i>	<i>at least one member of the organization should be responsible for each economic event</i>

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. In order to facilitate communication between trading partners, which typically use trading-partner models with opposing views (e.g., acquisition and revenue cycle script) to model the same transaction, and with neutral parties, which usually require independent-observer models, this modeling grammar contains a set² of REA primitive that force all

² We do not claim that this would be the only set of REA primitives that allows for view-independent modeling.

trading-partners and neutral observers to make the exact same model of a transaction regardless of their viewpoint.

Committing a conceptual-modeling grammar to the conceptualization specified by a domain ontology (like REA is) ensures that relevant domain knowledge is captured (Guarino & Giarretta, 1995). This knowledge includes conditions that specify the configurations in the domain that are possible and those that are not (Evermann & Wand, 2005).

Fig.2 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.

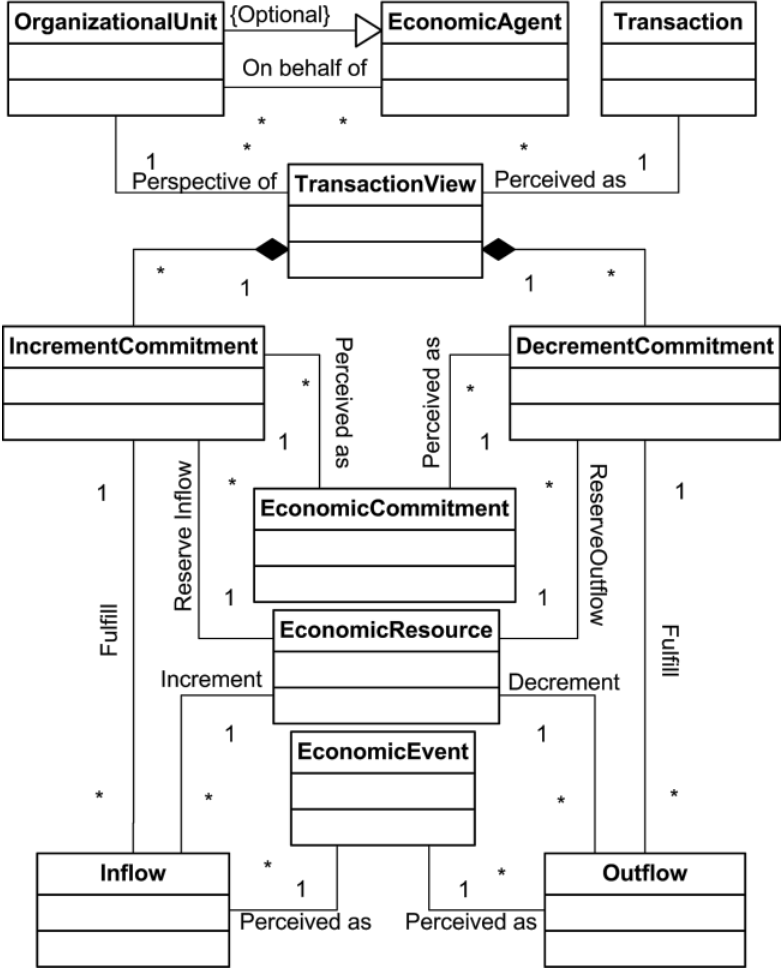


Figure2: The REA Conceptual-Modeling Grammar.

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. 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.2) 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). The optional specialization between ECONOMICAGENT and ORGANIZATIONALUNIT models that each organizational unit is an economic agents, but that not all economic agents are organizational units.

In fig.2, 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 an 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 (Guido L. Geerts & McCarthy, 2002). In fig.2, 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.2.

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 both trading-partner and independent-observer view conceptual modeling scripts. The scripts represent parts of a scenario, which is a descriptive design evaluation method accepted in design science (Hevner, March, Jinsoo, & Ram, 2004). The scenario was inspired by Hruby's pizza scenario (Hruby, 2006), but has been adapted to highlight the characteristics of the modeling grammar presented above.

The conceptual modeling script, which is represented as a UML object diagram, in fig. 3 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. The agreement script applies the view integration principles introduced by Laurier et al. (2010 ; 2013a) to model all perspectives (i.e., trading-partner and observer-independent).

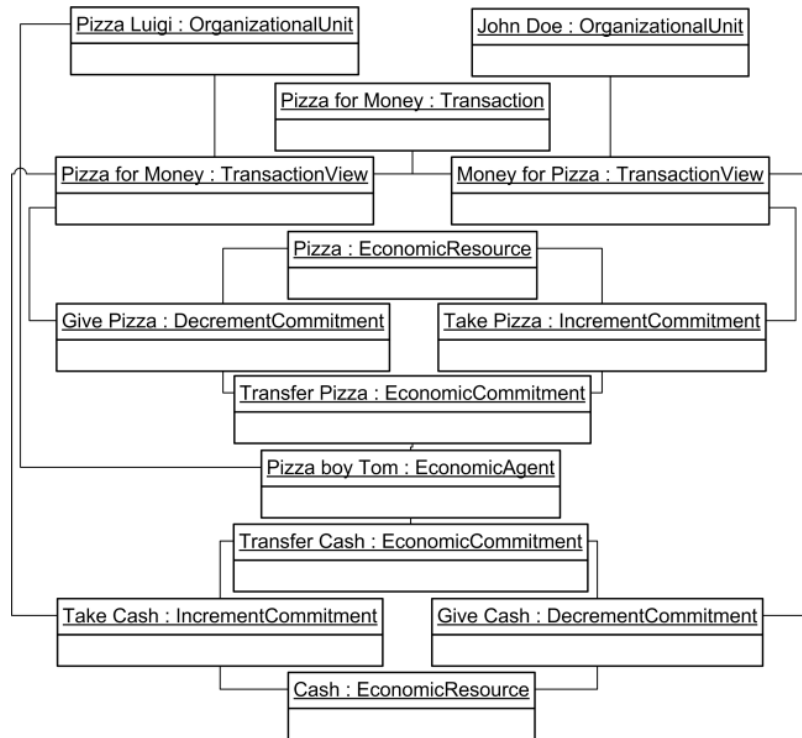


Figure3: The Economic Agreement script.

The economic agreement script (fig.3) models two opposing views of a transaction. The transaction will involve exchanging pizza for money from an independent-observer perspective. In Pizza Luigi's (i.e. seller) revenue cycle script, the exchange will involve giving pizza in return for cash. In John Doe's (i.e. buyer) acquisition cycle script, the exchange will involve giving cash in return for pizza. In the observer independent supply chains script, 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.3 also specifies that Pizza boy Tom will participate in both transfers on behalf of Pizza Luigi. Since Pizza Luigi and Tom know that their trading partner has an opposing view, they should be able draw the entire agreement script.

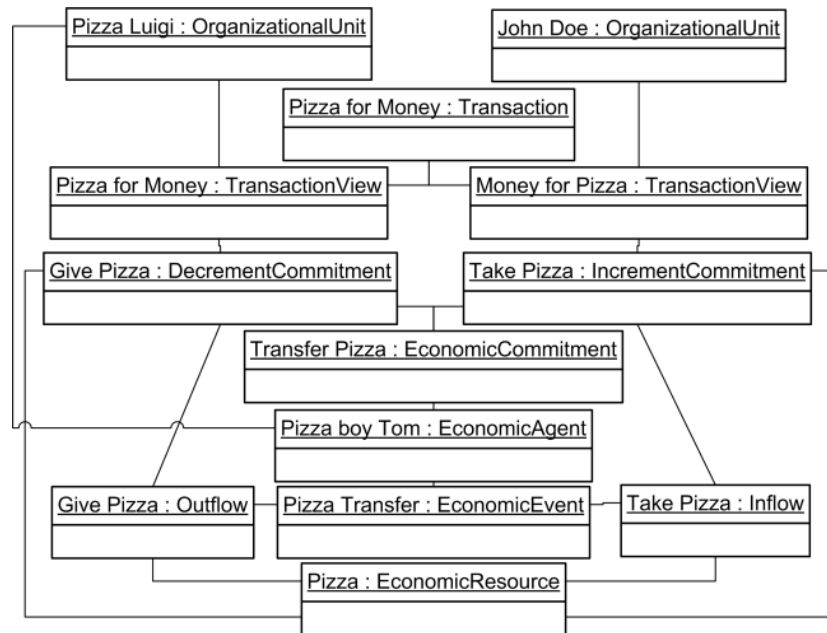


Figure4: The Transfer Fulfillment script.

Fig.4 shows the observer independent supply chain script and both trading-partner value chain scripts for the fulfillment of the TRANSFER PIZZA economic commitment by a PIZZA TRANSFER economic event. Consequently, the upper half of fig.4 is identical to the upper half of fig.3. The lower half of fig.3 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.4. Therefore, it should be feasible for the reader to complete the script given the example in fig.4.

As committed the PIZZA TRANSFER economic event, which fulfills the TRANSFER PIZZA economic commitment, is perceived 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.5 shows John Doe's value chain script of an agreement or contract being settled. Consequently, the left-hand side of fig.5 is identical to the left-hand side of fig.3. The right-hand side of fig.3 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 script given the example in fig.5. As agreed, the TAKE PIZZA increment commitment, which is known as the TRANSFER PIZZA economic commitment in the observer independent supply chain script, is fulfilled by the TAKE PIZZA inflow and the GIVE CASH decrement commitment, which is known as the TRANSFER CASH economic commitment in the observer independent supply chain script, 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.

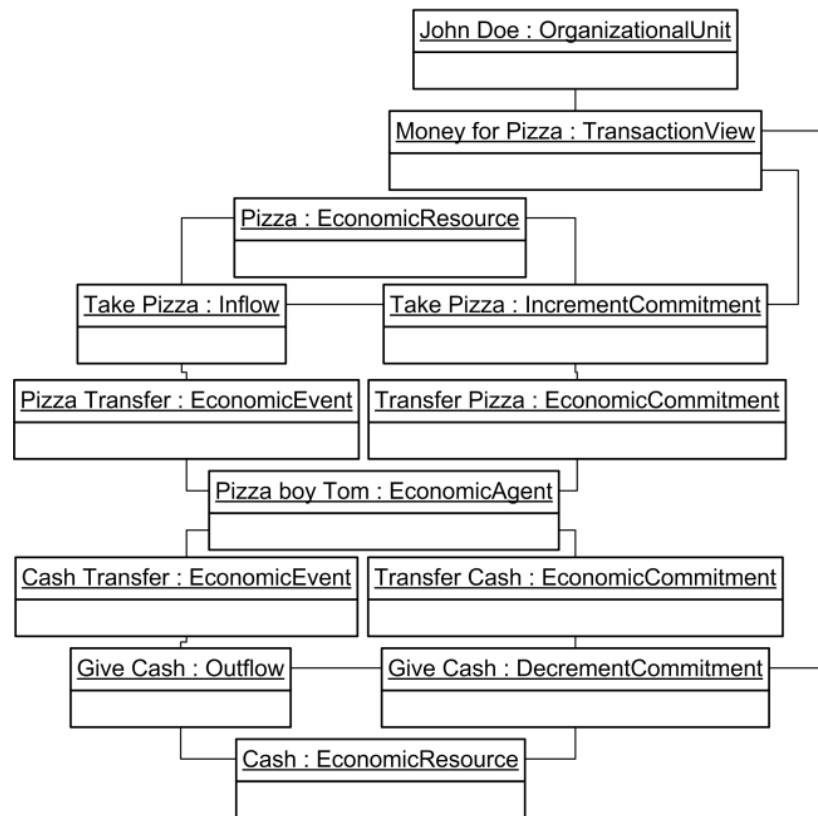


Figure5: The Settlement script.

Next to modeling the components of an exchange transaction between two trading-partners, as shown in fig.3,4 and5, 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 script of a production process is called a conversion script, 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 & Poels, 2012).

Fig.6 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.4), 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.6, 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.

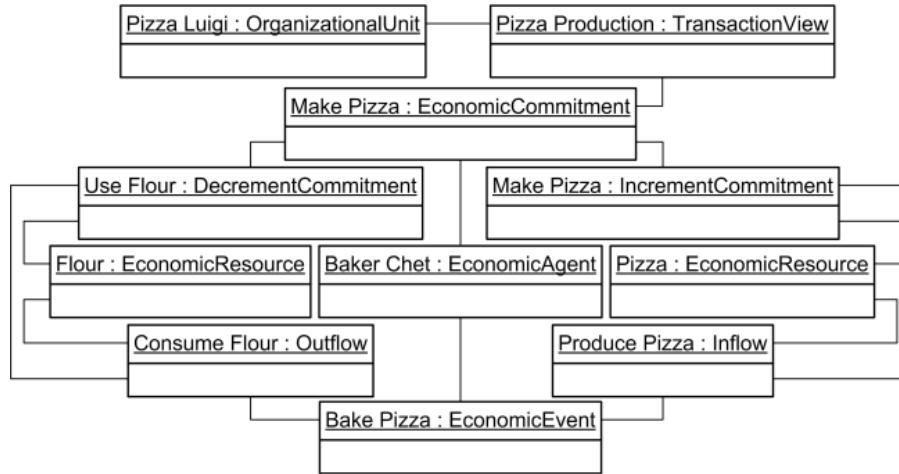


Figure6: The Conversion Fulfillment script.

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. The merits of the new REA grammar vis-à-vis include a unification of the inflow-outflow semantics of and the identification of the integration points between the more traditional independent-observer and trading-partner view REA modeling scripts. The unified semantics are discussed in the first subsection, the integration points are discussed in the second subsection.

Increment and Decrement Event, From and To

In the new REA-based grammar, the ‘from’ and ‘to’ semantics that are typical for independent-observer view scripts (i.e. supply chain scripts) 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.4), pizza is transferred from Pizza Luigi to John. Table 2 summarizes how the inflow and outflow semantics of the conceptual-modeling grammar can be translated to more traditional trading-partner (i.e. value chain and business process) and observer-independent (i.e. supply chain) script semantics.

Table 2: 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 perspective 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)).

Inside and Outside Agent

Trading-partner models like the settlement script (fig.5) mirror each other and conform to the semantics in the earlier REA trading-partner view models, which take the perspective of a single enterprise. 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 on behalf of this single perspective-defining enterprise. The *outside party* is the trading partner of this perspective-defining enterprise. In the initial model (McCarthy, 1982), the inside and outside agents were modeled as separate classes (i.e. economic unit for outside agents and economic agent for inside agents), in ISO's business transaction scenario standard (ISO/IEC, 2007) both were modeled as roles of economic agents.

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.5) 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.

Hruby's modeling scripts assign *provider* and *recipient* roles to economic agents. Both increment and decrement events are associated with providers and recipients. *Providers* are agents associated with decrement events, which have been called outflows in our scripts, and act on behalf of the organizational unit that defines the viewpoint of the script and hence experiences the stock decrease. In McCarthy's model this provider would be the inside party associated with a decrement event. *Recipients* are economic agents associated with increments events, which have been called inflows in our scripts, and act on behalf of the organizational unit that defines the viewpoint of the script and hence experiences the stock increase. In McCarthy's model this recipient would be the inside agent associated with an increment event.

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 an 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.3. Table 3 summarizes these view relations between agents, commitments and events, and the conceptual differences for the participation relation (i.e. agent-event) in McCarthy's and Hruby's reference models.

Table 3: Provider and Recipient as Inside and Outside Agent.

Agent Role	Event	
	Inflow	Outflow
Provider	Outside Party	Inside Party
Recipient	Inside Party	Outside Party
	Increment	Decrement
	Commitment	

Related Research

The observer-independent version of the REA ontology (Haugen, 2007; Haugen & McCarthy, 2000; ISO/IEC, 2007) is not the only supply chain ontology that has been developed over the years. However, like SAP's data-model (O'Leary, 2004) many of them are REA compliant. The e3value ontology also shares many concepts with the REA ontology (Andersson et al., 2006). As it was developed for analyzing the profitability of value networks (e.g., virtual enterprises), e3value often incorporates the concepts at a higher level of abstraction (e.g., type, kind) or aggregation (e.g., group, set) than REA, which was developed for more operational purposes (e.g., accounting), does. Like e3value, many other supply chain ontologies (e.g., TOVE, IDEON) focus on strategic (instead of operation) aspects (Grubic & Fan, 2010).

Several more operational supply chain ontologies have been developed as well (e.g., FTTO, BVCO). The Food Track & Trace Ontology (FTTO) is an ontology developed for food traceability control, which contains the primitives Agent, Food Product, Process, Query and Service Product. Except for Query each of them can be mapped REA primitives (i.e., Agent to Economic Agent, Food and Service Product to Economic Resource, and Process to Economic Event) (Pizzuti, Mirabelli, Sanz-Bobi, & Gómez-González, 2014). Hence this food traceability can be seen as a specialization of the REA ontology as it has been applied for food traceability (Laurier & Poels, 2012). The Basic Value Chain Ontology (BVCO) (Arthofer, Engelhardt-Nowitzki, Feichtenschlager, & Girardi, 2012) is another ontology that is similar to the observer-independent version of REA. Although BVCO seems to account for an independent-observer (i.e., Unit) and a trading-partner (i.e., Inventory) perspective on economic resources and explicitly models the organizational unit, which is called Party, to which the inventory belongs, it does not provide a mechanism to switch views or derive one view from another. Chandra (Chandra & Kamrani, 2003; Chandra & Tumanyan, 2007) proposes an observer-independent ontology that focusses on the logistic aspects of supply chains.

Leukel and Kirn (2008) propose a SCOR-based process taxonomy, where Lu et al. (2010) combine a SCOR-based process ontology with a product ontology to build a supply chain ontology for observer independent models. Zdravkovic et al. present a similar ontology, adding metrics and best practices (Zdravkovic, Panetto, Trajanovic, & Aubry, 2011). SCOntology is similar to BVCO, is based on SCOR and contains a concept called Organizational Unit, which seems to match the definition above (Vegetti, Gonnet, Henning, & Leone, 2005). As part of their ontology for agent-based monitoring of fulfillment processes, Zimmermann et al. (2005) present discuss the relations between actors, which resemble economic agents, orders, which are a kind of economic commitment, and activities, which are related to economic events.

Finally, the EAGLET ontology is extension of the observer-independent version of the REA ontology developed for highly visible supply chains (Guido L. Geerts & O'Leary, 2014). Except for the EAGLET and e3value ontology, all ontologies in this section focus on the logistic aspects of supply chains, abstracting from the economic rationale. In REA

this rationale is represented by duality and the second axiom, in e3value by the value interface concept (Guido L. Geerts & McCarthy, 2004; Gordijn, 2002).

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, which is embedded in the trading-partner view models, as well as third parties, which is typical for the independent-observer view models. 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 supply chain 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), and communication protocols (e.g. Dietz' Enterprise Ontology (Dietz, 2003)).

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 & 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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