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# Ontology-Driven Business Rule Specification

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**ABSTRACT:** Discovering business rules is a complex task for which many approaches have been proposed including analysis, extraction from code, and data mining. In this paper, a novel approach is presented in which business rules for an enterprise model are generated based on the semantics of a domain ontology. Starting from an enterprise model for which the business rules need to be defined, the approach consists of four steps: (1) classification of the enterprise model in terms of the domain ontology (semantic annotation), (2) matching of the enterprise model constructs with ontology-based Enterprise Model Configurations (EMCs), (3) determination of Business Rule Patterns (BRPs) associated with the EMCs, and (4) use of the semantic annotations to instantiate the business rule patterns; that is, to specify the actual business rules. The success of this approach depends on two factors: (1) the existence of a semantically rich domain ontology, and (2) the strength of the knowledge base consisting of EMC-BRP associations. The focus of this paper is on defining and illustrating the new business rule discovery approach: Ontology-Driven Business Rule Specification (ODBRS). The domain of interest is enterprise systems, and an extended version of the Resource-Event-Agent Enterprise Ontology (REA-EO) is used as the domain ontology. A small set of EMC-BRP associations—i.e., an example knowledge base—is developed for illustration purposes. The new approach is demonstrated with an example.

**Keywords:** business rule discovery and specification; enterprise ontologies; REA-EO.

## I. INTRODUCTION

Business rules are an integral part of enterprise systems and are defined by the Business Rules Group (2000, 4) as "statements that define or constrain some aspect of the business." Integrating business rules in enterprise systems encompasses a wide range of activities including discovery, specification, and implementation. The focus in this article is on discovery and specification, tasks that are typically executed by business professionals, not IT professionals. Several business rule discovery methods have been proposed throughout the years, including (1) discovery methods originate in requirements engineering (Von Halle 2002; Kardasis

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and Loucopoulos 2004), (2) extraction of business rules from existing code (Wang et al. 2004), (3) data mining (Rosca et al. 2002), and (4) model-driven discovery methods (Bajec and Krisper 2005; Xue and Feng 2006). None of these methods can discover all business rules, and their combined use is recommended (Xue and Feng 2006). In this paper, a novel approach for discovering and specifying business rules is presented: Ontology-Driven Business Rule Specification (ODBRS). This approach complements the existing methods, and its application should result in a more complete set of business rules. The domain orientation should also make it easy for business professionals to understand.

An ontology is an "explicit specification of a shared conceptualization" (Gruber 1993, 199). Common applications of ontologies include support of communication, software development, and systems integration (Gruninger and Lee 2002). The use of enterprise ontologies, a conceptual specification that shows the "essence of the operation of an enterprise" (Dietz 2006, 8), has been discussed at length in McCarthy (1982), Fox (1992), Uschold et al. (1998), Geerts and McCarthy (2000), Gordijn and Akkermans (2001), Dietz (2006), and Hruby et al. (2006). Although any enterprise ontology could have been considered for the approach presented in this paper, the Resource-Event-Agent Enterprise Ontology (REA-EO) (McCarthy 1982; Geerts and McCarthy 2000; Hruby et al. 2006) was chosen for the following three reasons: (1) the authors' familiarity with the REA-EO, (2) it is the dominant enterprise ontology in the Accounting Information Systems (AIS) literature, and (3) it has been formally defined, which facilitates semi-automatic discovery and specification of business rules (Gailly et al. 2008). Work by McCarthy (1982), Geerts and McCarthy (2000), Hruby et al. (2006), and Dunn (2012) is referred to for a more in-depth discussion of the REA-EO.

The research contribution of this paper can be summarized as follows. The REA-EO is a domain ontology that can be used to express a wide range of enterprise phenomena (Hruby et al. 2006). The novel idea is that REA-EO Enterprise Model Configurations (EMCs)—i.e., stereotypical patterns of economic phenomena defined in terms of the REA-EO—imply business rules. Identifying Business Rule Patterns (BRPs) and defining them in terms of EMCs represents the ODBRS discovery process and is a knowledge-creating activity. Once identified, BRPs can then be used for generating business rule specifications (BRs) as part of actual enterprise models. A unique characteristic of ontology-based BRPs is that they are applicable across business processes and business organizations.

The remainder of the paper is organized as follows. Section II describes the paper's contribution from a design science perspective. Section III presents the proposed business rule discovery and specification approach. Sections IV and V discuss the two supporting artifacts: the extended REA-EO vocabulary and the knowledge specifications. Section VI demonstrates ODBRS. A set of business rules (output) is generated starting from an example enterprise model (input). The paper ends with conclusions and further research directions.

## II. RESEARCH METHOD

Following the Design Science Research Methodology (DSRM) (Peffers et al. 2008; Geerts 2011), the research contribution of this paper is now defined more formally. The first step in the DSRM requests identification of the problem and motivation for the research. An in-depth literature review indicates that discovering and specifying business rules are challenging tasks (Von Halle 2002; Xue and Feng 2006), and different approaches have been proposed throughout the years including analysis, extraction from code, data mining, and model-driven discovery. Given the complexity of the task, these methods are complementary and current practice could benefit from improving existing approaches or from adding new ones.

The second step in the DSRM requests the definition of the objectives of a solution. The overall objective is to effectively determine relevant business rules. A unique objective for the approach presented in this paper is to discover, specify, and rely on BRPs that can be applied across business processes and business organizations. Further, the BRPs provide a vehicle that enables best practices to be applied to business rule specification.

The third step in the DSRM focuses on the actual design of the artifact. The main artifact presented in this paper is ODBRS as a novel approach to discovering and specifying business rules in which business rules are derived from ontological specifications. This is a method in terms of the framework presented by March and Smith (1995, 257): "a set of steps used to perform a task." Two supporting artifacts are an integral part of the operationalization of ODBRS. The first supporting artifact is an extended REA-EO vocabulary for defining semantic annotations, EMCs, and BRPs. Extensions required for ODBRS include association ends and role declarations. The second supporting artifact is the ODBRS knowledge base consisting of EMCs, BRPs, and the associations between them. Although an in-depth discussion of the design of such a knowledge base is beyond the scope of this paper, a small set of knowledge specifications will be created for illustration purposes.

The fourth step of the DSRM requests a demonstration of the novel artifact. ODBRS is demonstrated by applying its steps to an example enterprise model (input). The result is a set of fully integrated business rule specifications (output).

The fifth step of the DSRM focuses on evaluation: "Observe and measure how well the artifact supports a solution to the problem" (Peffers et al. 2008, 56). Important measures for the ODBRS include its efficacy and the relevance of the business rules generated. Moreover, whether the proposed method complements other approaches, i.e., whether it results in a more complete set of business rules, should be evaluated. As pointed out by Vaishnavi and Kuechler (2007) and Geerts (2011), evaluating an artifact requires a different skill set, and this part is left for future research.

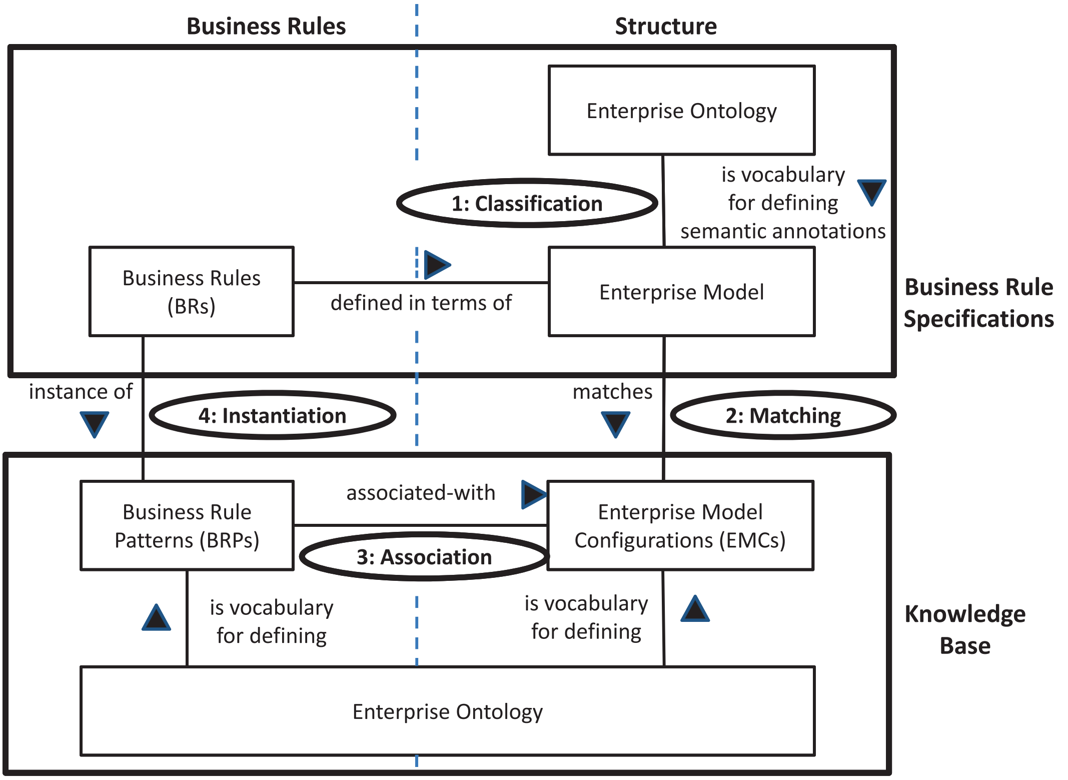
## III. ONTOLOGY-DRIVEN BUSINESS RULE SPECIFICATION

The focus of this paper is on ODBRS as an alternative approach for discovering and specifying business rules. Figure 1 portrays the four steps in ODBRS, and each one is briefly discussed.

(1) Classification: Semantic annotations are used to classify the economic phenomena in the enterprise model in terms of the REA-EO.
(2) Matching: Using the REA-EO semantic annotations, the constructs in the enterprise model are matched against the EMCs with the latter representing stereotypical, ontology-based definitions of economic phenomena.
(3) Association: The BRPs associated with the matching EMCs (Step 2) are identified.
(4) Instantiation: Business rule specifications are generated from the BRPs by replacing the ontological terms in the BRPs—which act as variables—with enterprise model elements.

Figure 1 not only portrays the four steps of ODBRS, but also illustrates the following. First, the business rule specifications depend on structural specifications (Ross 2003), and this dependency is illustrated in Figure 1 by the associations between "Business Rules" (left side) and "Structure" (right side). BRPs are defined in terms of EMCs while BRs are defined in terms of enterprise model constructs. Second, in Figure 1 the actual business rule specifications integrated with the enterprise model (upper part) are clearly separated from the knowledge base specifications that are used to generate the business rule specifications (lower part). The knowledge base consists of EMCs, BRPs, and the associations between them. Third, in Figure 1 the importance of the enterprise ontology is emphasized as a vocabulary for defining the semantic annotations, EMCs, and BRPs.

**FIGURE 1**
**The ODBRS Approach**




Although the focus of this paper is on ODBRS as an alternative business rule discovery and specification approach, the design of two supporting artifacts also needs to be discussed: (1) the extended REA-EO vocabulary that enables the knowledge specifications, and (2) the knowledge base itself, which is portrayed in the lower part of Figure 1.

## IV. REA-EO VOCABULARY FOR ODBRS

As shown in Figure 1, the enterprise ontology—i.e., the REA-EO—is used as a vocabulary for defining semantic annotations, EMCs, and BRPs. The definition of REA-EO based BRPs requires a vocabulary[1] that consists of the following four elements: (1) REA-EO object primitives, (2) REA-EO association primitives, (3) REA-EO association ends, and (4) REA-EO role declarations. Association ends and role declarations are typically not considered an integral part of the REA-EO vocabulary, and their role in ODBRS needs more explanation.

Association ends are instrumental for path navigation in the context of business rule specification. Therefore, association end definitions are considered for all REA-EO association primitives. Each association end is given a unique name. Role declarations assign a stereotypical, domain-specific role to attributes (Geerts and McCarthy 2006) and are important for generalizing

[1] All elements of the REA-EO vocabulary are presented in camel case notation.

business rule specifications that rely on attribute values. Role declarations can be part of a class or an association class (Geerts and McCarthy 2006).

Table 1 shows the REA-EO vocabulary used in this paper. The first column lists the ontological primitives (i.e., the vocabulary), the second column defines each one, and the third column provides the source of the definition. New ontological primitives created for ODBRS are indicated by "This paper" in the third column.

The vocabulary in Table 1 is a subset and an extension of the REA-EO vocabulary presented by McCarthy (1982), Geerts and McCarthy (2000), Hruby et al. (2006), and the International Organization for Standardization (ISO 2006). To keep things simple, the vocabulary is limited to the subset of the REA-EO vocabulary needed to illustrate ODBRS in this paper. For example, REA-EO primitives such as linkage, description, and grouping are not included. All extensions are association ends and role declarations with the exception of the Involvement and Return association primitives. The Specification association primitive defines the types of economic resources involved in a commitment (ISO 2006). To our knowledge, a similar association that defines the types of economic resources involved in an economic event is missing from the REA-EO. As shown in Table 1, the Involvement association primitive is added to the REA-EO vocabulary to address this issue. Return is a specific type of StockFlow association describing the reversing of a previous StockFlow and has its own behavior and constraints.

## V. ODBRS KNOWLEDGE BASE

As indicated in Figure 1, the ODBRS knowledge base consists of EMCs, BRPs, and the associations between them. To illustrate the role of the knowledge base as part of ODBRS in the "ODBRS Demonstration" section, a small set of knowledge specifications is developed in this section. The discussion starts from the BRPs, and the following are addressed for each one: (1) the constraint being supported, (2) the EMCs to which the BRP applies, and (3) a formal definition of the corresponding Business Rule Pattern Specifications (BRPSs).

The notation used for the representations of the EMCs is the Unified Modeling Language (UML) (Object Management Group 2007). More specifically, the following UML class diagram elements are used: class, association, association class, association end, attribute, and multiplicities. To keep things simple, other modeling constructs such as subtyping are ignored. UML was chosen because of its widespread use and the fact that UML provides mechanisms to graphically illustrate ODBRS such as stereotypes. Other conceptual modeling grammars such as Object Role Modeling (ORM) could have been used as well. BRPSs are defined as Object Constraint Language (OCL) invariants (Warmer and Kleppe 2003). OCL was chosen because of its widespread use, but other business rules representation languages such as Semantics of Business Vocabulary and Business Rules (SBVR) could have been used as well. The developed BRPSs must be interpreted at the instance level; that is, the actual business rules generated from the BRPSs are used to validate instances of an enterprise model.

### Business Rule Pattern 1 (BRP1)[2]

#### *Commitments Should Not Be Preceded by Their Fulfillment Economic Events*

An REA-EO fulfillment association is sequential and implies the following constraint: "when a commitment and an economic event are associated through a fulfillment association then the economic event should not precede the commitment." This is different from saying that a

[2] The relevance of the BRP, BRPS, and EMC numbers is limited to this paper.

**TABLE 1**

**REA-EO Vocabulary**

| Ontological Primitives | Definition | Source |
|---|---|---|
| Object Primitives | | |
| *Commitment* | Agreement to execute an economic event in a well-defined future that will result in an increase in resources or a decrease in resources. | Ijiri 1975; Geerts and McCarthy 2000 |
| *EconomicAgent* | Persons and agencies who participate in (outside) and are accountable for (inside) the economic events and commitments of the enterprise. | McCarthy 1982; Geerts and McCarthy 2000 |
| *EconomicEvent* | A class of phenomena that reflects changes in scarce means (economic resources) resulting from production, exchange, consumption, and distribution. | Yu 1976; McCarthy 1982 |
| *EconomicResource* | Objects that (1) are scarce and have utility, and (2) are under the control of an enterprise. | Ijiri 1975; McCarthy 1982 |
| *EconomicResourceType* | Describes types of economic resources. | Geerts and McCarthy 2006 |
| Association Primitives | | |
| *Duality* | An association between an economic event that results in an increase in the resource set of the enterprise and a corresponding economic event that results in a decrease. | Ijiri 1975; McCarthy 1982 |
| *Fulfillment* | An association between a commitment and an economic event describing how the economic event fulfills the commitment. | Geerts and McCarthy 2000 |
| *Involvement* | An association between an economic resource type and an economic event describing the increment[a] or decrement in the economic resource type. | This paper |
| *Participation* | An association between an economic event and the outside economic agent involved in the economic event. | McCarthy 1982; Geerts and McCarthy 2000 |
| *Reservation* | An association between an individually traced economic resource and a commitment describing the agreed-upon inflow or outflow of the economic resource. | Geerts and McCarthy 2000 |

*(continued on next page)*

**TABLE 1 (continued)**

| Ontological Primitives | Definition | Source |
|---|---|---|
| *Return* | An association between an individually traced economic resource and an economic event describing a reverse stockflow: an inflow reversing a previous outflow or an outflow reversing a previous inflow. | This paper |
| *Specification* | An association between an economic resource type and a commitment describing the agreed-upon increment or decrement in the economic resource type. | ISO 2006 |
| *StockFlow* | An association between an individually traced economic resource and an economic event describing the inflow or outflow of the economic resource as a result of the economic event. | McCarthy 1982 |
| *Typification* | An association linking instances of an object class (e.g., individually traced economic resources) to concepts (e.g., economic resource types) of which they are concrete realizations. | Geerts and McCarthy 2006 |
| Association Ends[b] | | |
| *DualityEconomicEventIn/Out*[c] | Refers to an inflow/outflow economic event that is the dual of an outflow/ inflow economic event as described by the duality association. | This paper |
| *FulfillmentCommitment* | Refers to a commitment being fulfilled by an economic event as described by the fulfillment association. | This paper |
| *FulfillmentEconomicEvent* | Refers to an economic event fulfilling a commitment as described by the fulfillment association. | This paper |
| *InvolvementInc/DecEconomicEvent* | Refers to an economic event that results in an increment/decrement of an economic resource type as described by the involvement association. | This paper |
| *ParticipationEconomicAgent* | Refers to the involvement of an (outside) economic agent in an economic event as described by the participation association. | This paper |
| *ReservationEconomicResource* | Refers to an economic resource committed to as described by the reservation association. | This paper |
| *ReturnIn/OutEconomicEvent* | Refers to an economic event that results in a reverse inflow/outflow of an economic resource as described by the return association. | This paper |

*(continued on next page)*

**TABLE 1 (continued)**

| Ontological Primitives | Definition | Source |
| --- | --- | --- |
| *SpecificationEconomicResourceType* | Refers to an economic resource type committed to as described by the specification association. | This paper |
| *StockFlowIn/OutEconomicEvent* | Refers to an economic event that results in an inflow/outflow of an economic resource as described by the stockflow association. | This paper |
| *StockFlowEconomicResource* | Refers to an economic resource affected by an economic event as described by the stockflow association. | This paper |
| *TypificationEconomicResourceType* | Refers to an economic resource type that applies to a specific economic resource as described by the typification association. | This paper |
| Role Declarations | | |
| *Price* | The amount of money given or set as consideration for the exchange of a resource. | This paper |
| *Quantity* | Number of resources in storage, committed to, or exchanged. | This paper |
| *Time* | The specific point in time at which either a commitment is being made or an economic event occurs. | This paper |

[a] We use inflow/outflow for individually traced resources and increment/decrement for resource types.
[b] Only the association ends needed for navigation in the BRP definitions discussed in the "ODBRS Knowledge Base" section are included.
[c] To save space, inflow(In)/increment(Inc) and outflow(Out)/decrement(Dec) association ends are described in one entry.

commitment can occur without an economic event or that an economic event can occur without a commitment; both are business rules that can be expressed with multiplicities.

The EMC for BRP1 is shown in Figure 2. An EMC represents a unique combination of domain-specific elements, in this particular case, a fulfillment association between a commitment and an economic event combined with two Time role declarations. A fulfillment association without the Time role declarations would be considered a different EMC.

**FIGURE 2**
**EMC1**

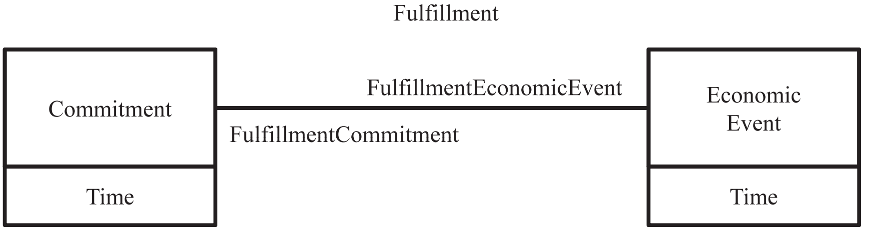


**TABLE 2**
**BPRS1**

| **BRPS1 (BRP1 – EMC1)** |
|---|
| **context** Commitment **inv** BRPS1: FulfillmentEconomicEvent.Time→forAll(x \| x >= Time) |

BRPS1—i.e., the formal specification of BRP1—is shown in Table 2. The syntax used is a combination of OCL and the REA-EO vocabulary. The latter represents the variables that need to be substituted by actual enterprise model elements when ontology-driven business rule specifications are generated. Commitment is an object primitive, FulfillmentEconomicEvent is an association end, and Time is a role declaration. Regarding economic events, Time refers to the time of occurrence; regarding commitments, Time refers to when the commitment is being made.

Multiplicities are not relevant for EMC1 since the BRPS assumes the more general case that a commitment can be fulfilled by multiple economic events.

### Business Rule Pattern 2 (BRP2)

#### *No Future Economic Events Are Recorded*

This rule implies that all economic events are recorded when they occur or after they have occurred. Similar to BRP1, an attribute with role declaration Time records the time of occurrence, for example, when the shipment of goods occurs. The EMC for BRP2 consists of the Economic Event class with a Time role declaration and is shown graphically in Figure 3. The formal specification of BRP2 (i.e., BRPS2) is represented in Table 3. This BRP shows how a constraint can be specified for a role declaration that applies across business processes and business organizations.

### Business Rule Pattern 3 (BRP3)

#### *Prices Have a Positive Numeric Value*

This rule states that all attributes with a Price role declaration should have a positive numeric value. This is similar to a sign check (Romney and Steinbart 2012) applied to a role declaration as opposed to a specific attribute. This BRP is different from the two previous ones since it applies

**FIGURE 3**
**EMC2**

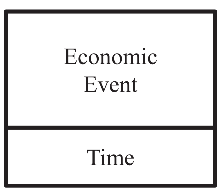


**TABLE 3**
**BRPS2**

| **BRPS2 (BRP2 – EMC2)** |
|---|
| **context** EconomicEvent **inv** BRPS2:<br><br>Time <= Date.now[a] |

[a] Syntax adapted from Warner and Kleppe (2003).

to many different REA-EO object and association primitives: EconomicResource (object), EconomicResourceType (object), Specification (association), and Involvement (association). Thus, this is a case in which a BRP applies to several EMCs (see Figure 4) and, therefore, there are several BRPSs for the same BRP. Formal specifications for all four BRPSs are shown in Table 4.

**FIGURE 4**
**EMC3, EMC4, EMC5, and EMC6**

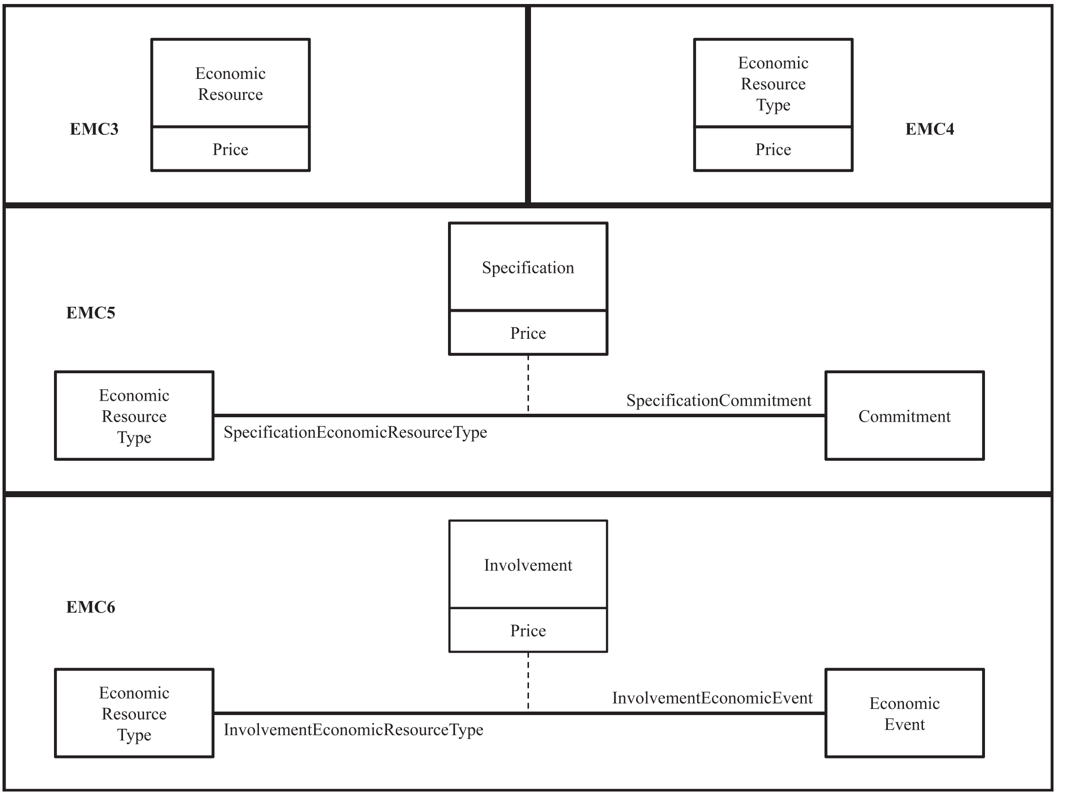


**TABLE 4**

**BRPS30, BRPS31, BRPS32, and BRPS33**

| |
|---|
| **BRPS30 (BRP3 – EMC3)** |
| **context** EconomicResource **inv** BRPS30:<br><br>Price > 0 |
| **BRPS31 (BRP3 – EMC4)** |
| **context** EconomicResourceType **inv** BRPS31:<br><br>Price > 0 |
| **BRPS32 (BRP3 – EMC5)** |
| **context** Specification **inv** BRPS32:<br><br>Price > 0 |
| **BRPS33: (BRP3 – EMC6)** |
| **context** Involvement **inv** BRPS33:<br><br>Price > 0 |

### Business Rule Pattern 4 (BRP4)

***Only Existing Resources Can Participate in an Outflow/Decrement Economic Event***

There is a sequential relationship between REA-EO inflow/increment economic events and outflow/decrement economic events. Although resources can be considered at any time, they can be given up (outflow/decrement) only if they are available. Figure 5 shows that BRP4 applies to two different EMCs. EMC7, portrayed in the upper panel of Figure 5, reflects the situation in which the resources are individually traced. Following McCarthy (1982), the Economic Resource–Economic Event associations are labeled as being of REA-EO type StockFlow. Association ends are used to differentiate between inflows and outflows: StockFlowInEconomicEvent and StockFlowOutEconomicEvent.

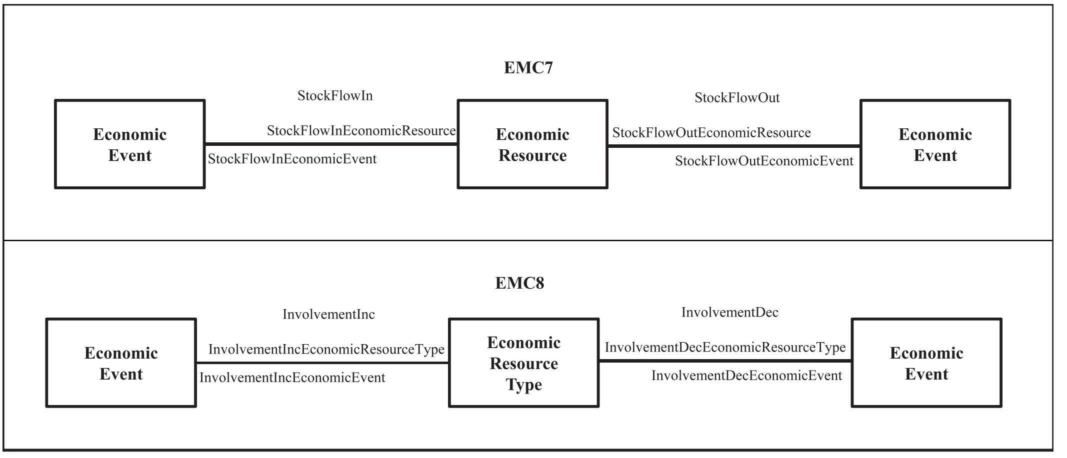
EMC8, portrayed in the lower panel of Figure 5, reflects the situation in which information is recorded for resource types only; that is, information regarding the physical transfer of the resources is summarized. Following the definitions in Table 1, the EMC8 associations are labeled as being of REA-EO type Involvement and are further differentiated as either increments (inc) or decrements (dec). BRPS40 and BRPS41 are specified in Table 5.

### Business Rule Pattern 5 (BRP5)

***Economic Resources Transferred Match the Economic Resources Committed To***

Again, there are two different EMCs to which BRP5 applies, and they are presented in Figure 6. EMC9 represents the situation in which a specific, uniquely identified item is committed to. As

**FIGURE 5**
**EMC7 and EMC8**



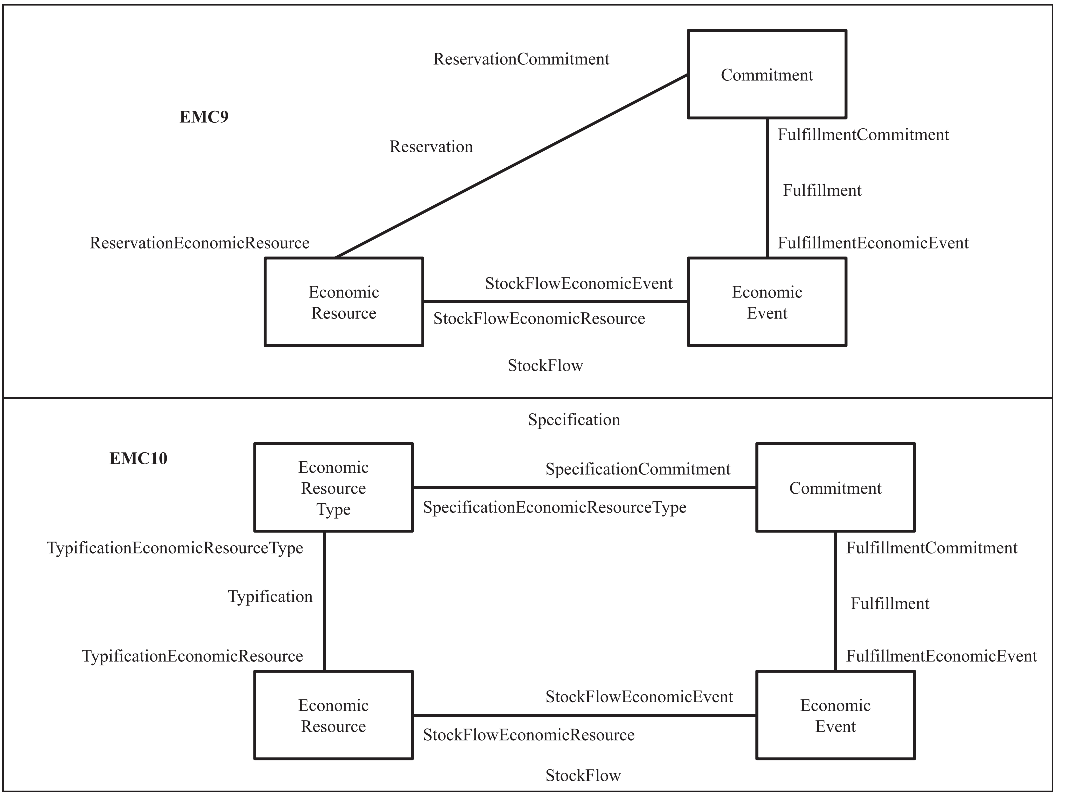

shown in the upper panel of Figure 6, this situation is expressed in REA-EO with a reservation association. An important validation rule for the scenario defined by EMC9 is whether the resource being transferred is the resource committed to. Given that BRP5 holds for inflows and outflows, the ReservationEconomicResource and StockFlowEconomicResource association ends are used without further differentiation.

EMC10 represents the situation in which a type is committed to. As shown in the lower panel of Figure 6, this situation is expressed in REA-EO with a specification association. An important validation rule for the scenario defined by EMC10 is whether the resource being transferred is of the type committed to. The two BRPSs are specified in Table 6.

**TABLE 5**
**BRPS40 and BRPS41**

| **BRPS40 (BRP4 – EMC7)** |
|---|
| **context** EconomicResource **inv** BRPS40:<br>StockFlowOutEconomicEvent →notEmpty() implies<br>StockFlowInEconomicEvent → notEmpty() |
| **BRPS41 (BRP4 – EMC8)** |
| **context** EconomicResourceType **inv** BRPS41:<br>InvolvementDecEconomicEvent →notEmpty() implies<br>InvolvementIncEconomicEvent → notEmpty() |

**FIGURE 6**
**EMC9 and EMC10**




## Business Rule Pattern 6 (BRP6)

### *The Number of Items Transferred Should Not Exceed the Number of Items Committed To*

An important characteristic of BRP6 is that multiplicities determine the specifications. Among others, this increases the number of different EMCs to deal with. Two of the possible EMCs are discussed. The first one, EMC11, is represented in the upper panel of Figure 7 and is similar to EMC9 but with specific multiplicity patterns added. The second one, EMC12, is represented in the lower panel of Figure 7 and is similar to EMC10 but, again, with specific multiplicity patterns added.

EMC11 portrays a scenario in which (1) a commitment is fulfilled by one economic event and an economic event fulfills one commitment only, and (2) economic resources are individually traced. An underscore indicates that the value of the multiplicity is irrelevant for the business rule specification. Given that there is only one economic event for a commitment, in this scenario, the number of items transferred should be equal to the number of items committed to. Table 7 shows how this constraint (BRPS60) can be formally defined using OCL.

EMC12 portrays a more complex scenario that deals with (1) commitments defined in terms of resource types—indicated by the REA-EO Specification association, (2) a role declaration—Quantity—specified as part of the Specification association class, and (3) partial fulfillments as defined by the multiplicities for the Fulfillment association. An important business rule to be supported for this scenario is that the total number of resources of a specific type transferred cannot

**TABLE 6**
**BRPS50 and BRPS51**

| **BRPS50 (BRP5 – EMC9)** |
|---|
| **context** EconomicEvent **inv** BRPS50: FulfillmentCommitment.ReservationEconomicResource → includesAll(StockFlowEconomicResource) |
| **BRPS51 (BRP5 – EMC10)** |
| **context** EconomicEvent **inv** BRPS51: FulfillmentCommitment.SpecificationEconomicResourceType → includesAll(StockFlowEconomicResource.TypificationEconomicResourceType) |

exceed the number of committed resources for that type. The formal definition for this constraint is specified as BRPS61 in Table 7.

### Business Rule Pattern 7 (BRP7)

#### *Only Resources That Have Been Transferred Can Be Returned*

EMC13 in Figure 8 represents the stereotypical pattern for incoming returns for individually traced economic resources: a duality association connects a Return-inflow and a StockFlow-outflow in which the same economic resource is involved. Although the return nature of the inflow association in EMC13 is implied, the semantics are made more explicit by creating a Return association primitive. The additional semantics also improve the understanding of the formal specification of BRP7, which is shown in Table 8.

### Business Rule Pattern 8 (BRP8)

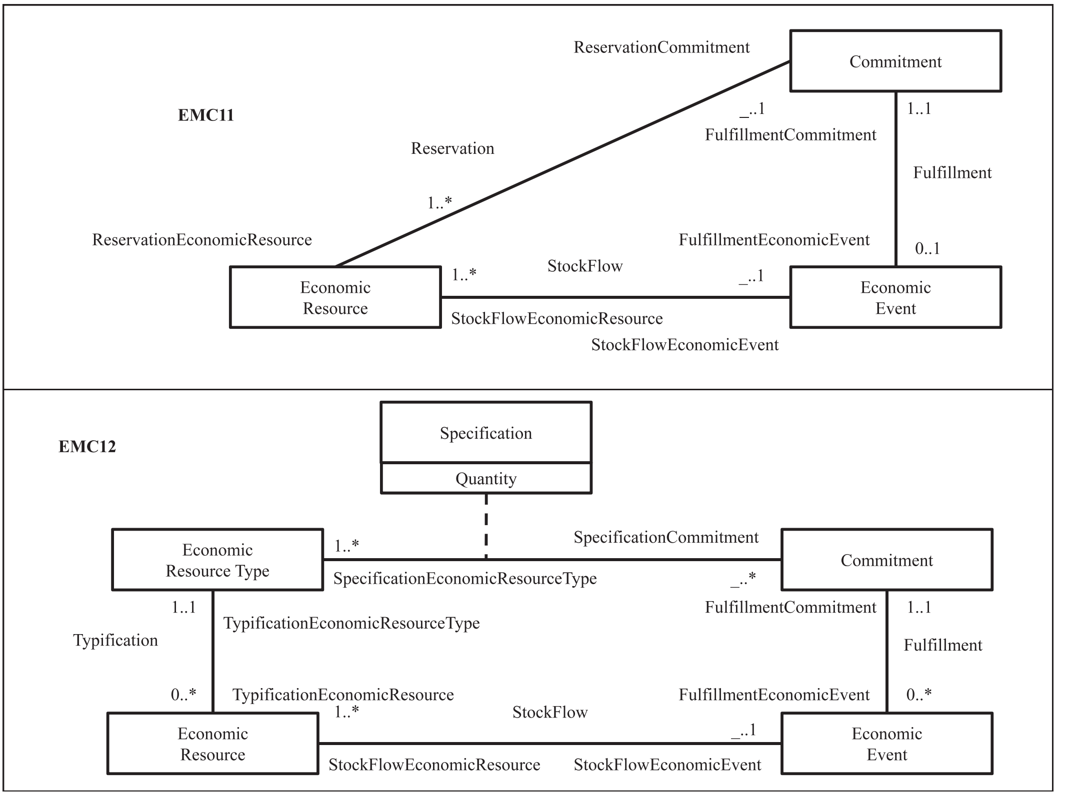
#### *A Resource Can Be Returned (Inflow) Only by the Agent to Whom the Resource Was Transferred (Outflow)*

EMC14 in Figure 9 extends EMC13 with the economic agents involved in the returns. Now the constraint specifies that an economic resource should be returned by the agent to whom the resource was transferred. Although multiplicities are not modeled in Figure 9, a more general case is assumed in which more than one (outside) economic agent can be involved in the same economic event. The rule then becomes that the agents returning the economic resource should be a subset of the agents to whom the resource was transferred. Table 9 formally defines this constraint using OCL.

## VI. ODBRS DEMONSTRATION

In this section, ODBRS is demonstrated as an alternative business rule discovery method by applying the BRPSs defined to an actual enterprise model. In terms of design science research, the

**FIGURE 7**
**EMC11 and EMC12**




discussion weaves design and demonstration. First, the role of enterprise models in ODBRS is explained. Following, each of the four steps indicated in Figure 1 are discussed in more detail: classification, matching, association, and instantiation.

## Enterprise Models

An enterprise model is a conceptual specification that describes how a specific business entity operates and creates value. Business rules and enterprise models are strongly intertwined: "rules always build on facts and facts always build on terms" (Ross 2003, 270). ODBRS assumes that business rules are generated starting from an enterprise model that has already been defined. Figure 10 shows the enterprise model used as input for the example.[3,4] This model represents part of a revenue cycle, but the Delivery economic event is included to illustrate BRP4.

Figure 11 visually portrays the ODBRS process step-by-step starting from a specific Enterprise Model Fragment (EMF). An EMF is any possible instantiation of a modeling grammar ranging

[3] To save space, the REA-EO semantic annotations are already included. They should be ignored at this point.
[4] In Figure 10, all inflows, outflows, increments, and decrements are explicitly defined, even when the applicable rules, defined in the "ODBRS Knowledge Base" section, do not require such differentiation (e.g., BRPS51).

**TABLE 7**

**BRPS60 and BRPS61**

| |
|---|
| **BRPS60 (BRP6 – EMC11)** |
| **context** EconomicEvent **inv** BRPS60:<br>FulfillmentCommitment.ReservationEconomicResource → size() =<br>StockFlowEconomicResource→ size() |
| **BRPS61 (BRP6 – EMC12)** |
| **context** EconomicEvent **inv** BRPS61:<br>FulfillmentCommitment.Specification→forAll(x \| x.Quantity >=<br>StockFlowEconomicResource<br>→ select(y\|y.TypificationEconomicResourceType<br>= x.SpecificationEconomicResourceType)→size()) |

from a single construct—e.g., an entity such as Shipment—to the complete enterprise model. Obviously, the number of EMFs, even for a simple enterprise model such as the one in Figure 10, is high. More specifically, Figure 11 demonstrates how the business rule in Panel E (BR1) is generated from the EMF in Panel A by the application of ODBRS. A visual approach was chosen since it fully exposes the details of the ODBRS process.

**FIGURE 8**
**EMC13**

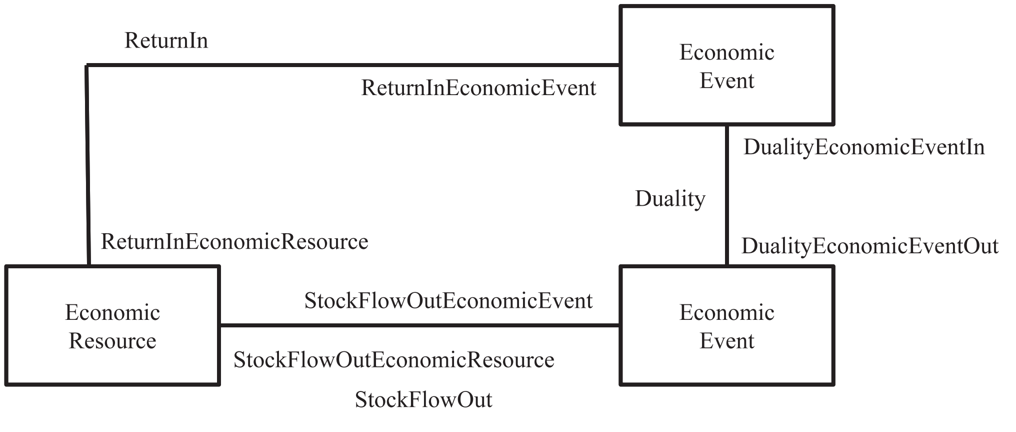


**TABLE 8**
**BRPS7**

| **BRPS7 (BRP7 – EMC13)** |
|---|
| **context** EconomicResource **inv** BRPS7:<br>StockFlowOutEconomicEvent.DualityEconomicEventIn→<br>includesAll(ReturnInEconomicEvent) |

### Classification

Semantic annotations have become increasingly popular with the emergence of the "Semantic Web" (Berners-Lee et al. 2001). They give meaning to data and have been used in a wide variety of applications, including interchange (Park and Ram 2004; Vujasinovic et al. 2010; Cardoso and Bussler 2011) and reasoning (Sedbrook and Newmark 2008). In the AIS area, the use of semantic annotations is widespread. The prototypical example of semantically enriched accounting data is the eXtensible Business Reporting Language (XBRL), which has been used for a wide range of applications (Bovee et al. 2005; Debreceny et al. 2009). In addition, numerous studies illustrate how to employ REA-EO semantic annotations for validation and information retrieval applications (Geerts 1993; Rockwell and McCarthy 1999; Geerts and McCarthy 2000). This is known as augmented intentional reasoning: "active use of conceptual structures augmented with the domain-specific REA structures imposed on top of the enterprise schema" (Geerts and McCarthy 2000, 128). This technique is also used in this paper.

For ODBRS, the semantic annotations give domain-specific meaning to an enterprise model. As shown in Panel B in Figure 11, UML stereotypes are used for adding semantic annotations: For example, Shipment is classified as an Economic Event, Order is classified as a Commitment, the association between the two is classified as an instantiation of the REA-EO Fulfillment primitive,

**FIGURE 9**
**EMC14**

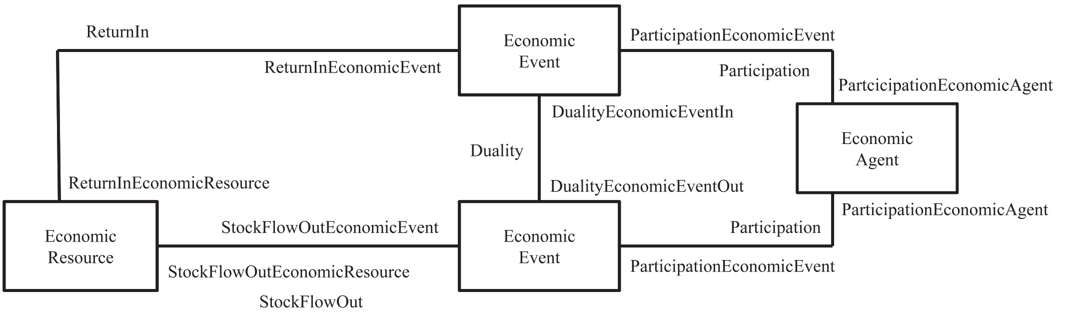


**TABLE 9**
**BRPS8**

| **BRPS8 (BRP8-EMC14)** |
| --- |
| **context** EconomicResource **inv** BRPS8:<br>StockFlowOutEconomicEvent.ParticipationEconomicAgent→<br>includesAll(ReturnInEconomicEvent.ParticipationEconomicAgent) |

the shipment association end is classified as an instance of FulfillmentEconomicEvent, and a Time role declaration is assigned to both date attributes.

Figure 10 shows all semantic annotations for the example enterprise model, and they should be considered the result of the first step of ODBRS: classification. Obviously, the classification process should be subject to validation. For example, a duality association should always be between

**FIGURE 10**
**Enterprise Model**

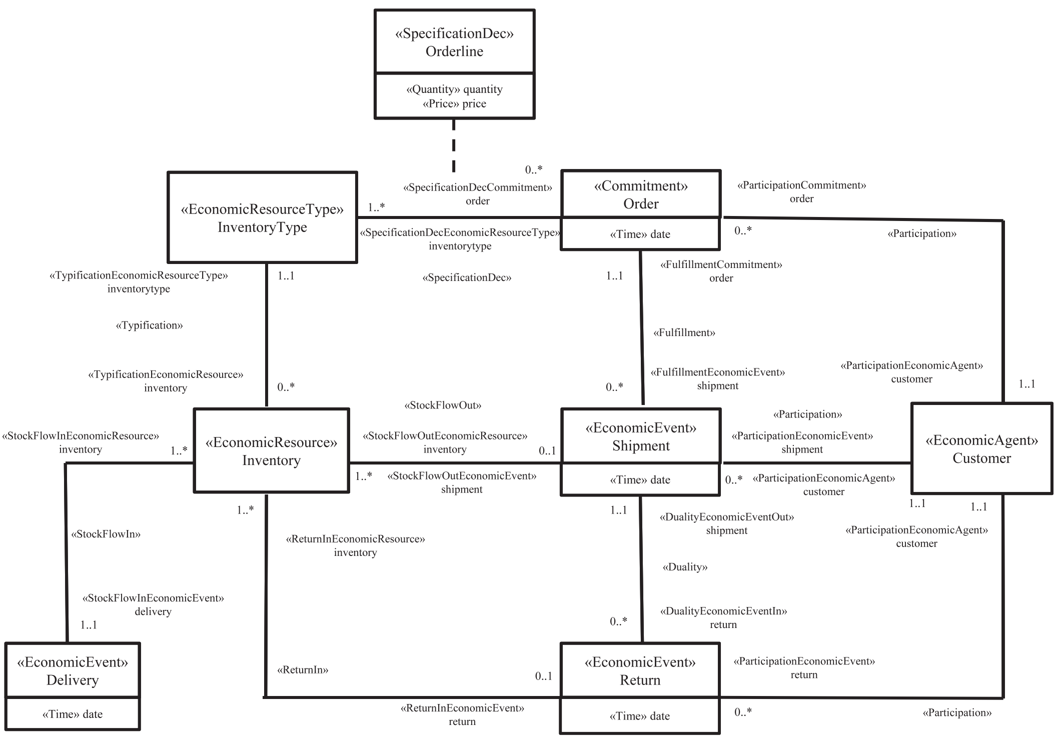
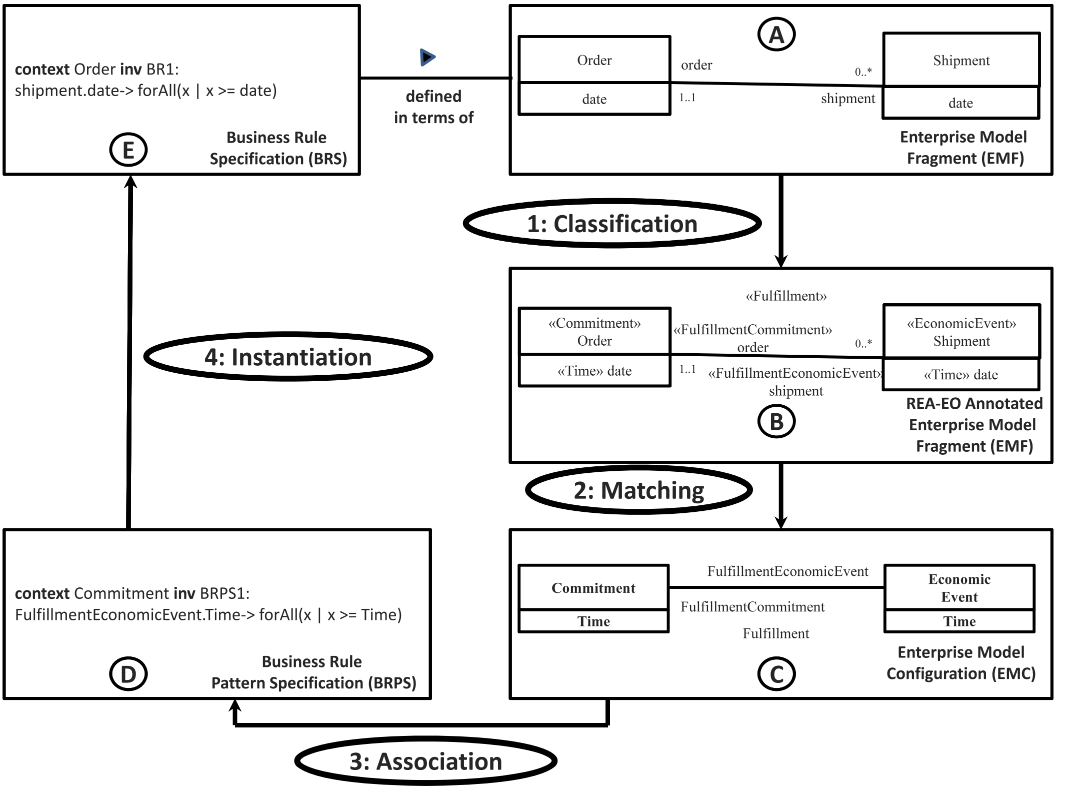


**FIGURE 11**
**Visual Illustration of ODBRS**




economic events with opposite flows. Many studies have explored automated validation based on the explicit representation of REA-EO semantics, including work by Geerts (1993), Geerts et al. (1996), and Rockwell and McCarthy (1999).

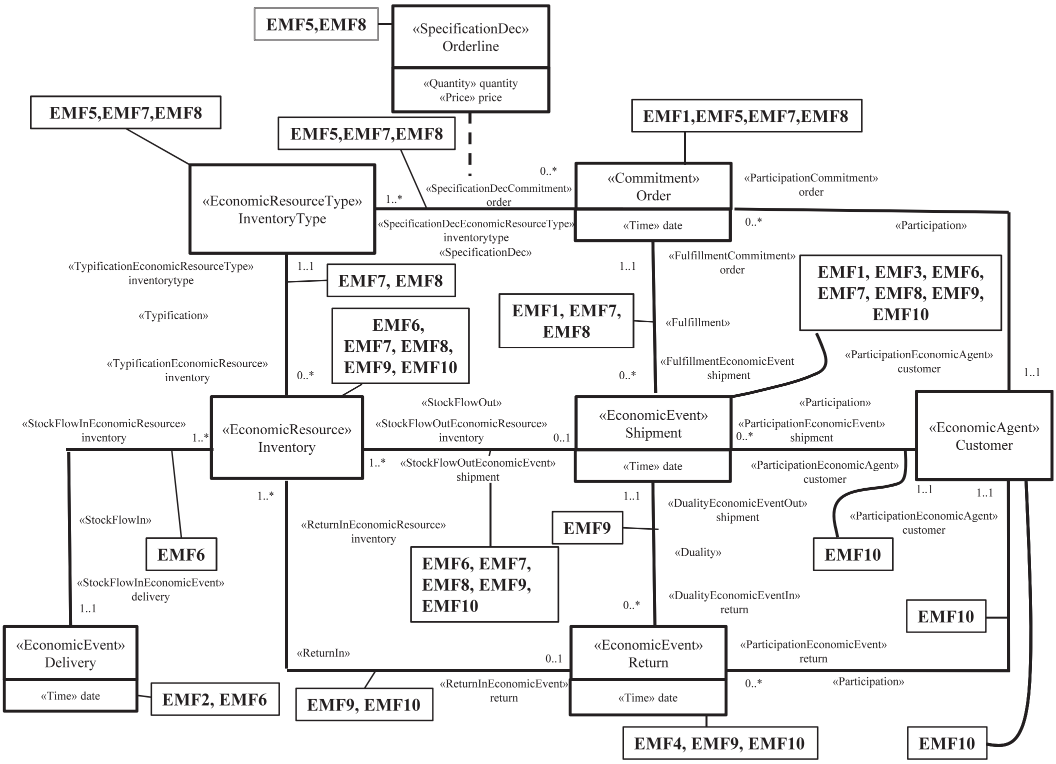
## Matching

During this step, EMFs are matched against EMCs. In Figure 11, the REA-EO annotated EMF in Panel B matches with—and thus is an instance of—the EMC represented in Panel C. In Figure 12, ten EMFs are identified for the example enterprise model, and each one is linked to the matching EMC in Table 10.

Next, two characteristics of the matching process are discussed in more detail. First, not all EMCs discussed occur in the third column of Table 10. Among others, this is because different practices and, thus, EMCs can be associated with the same situation, e.g., EMC7 (individually traced) versus EMC8 (recording of type-level resources).

Second, Figure 13 defines a meta-model for the different ODBRS concepts: EMF, EMC, BRP, BRPS, and BR. Table 10 illustrates the "matches" association in the meta-model. There can be more than one EMF for an EMC. For example, EMC2 applies to all three Economic Events in the enterprise model in Figure 12 and, thus, to three EMFs: EMF2, EMF3, and EMF4. However, at most one EMC can apply to an EMF.

**FIGURE 12**
**Enterprise Model with EMF Definitions**




Although visual matching helps with illustrating the ODBRS matching process, visual matching is feasible for very small examples only. Real-world matching would require help from automated tools. A prerequisite for automated support is the explicit representation of the semantic annotations and the semantics of the EMCs. The use of Prolog for such explicit representation and reasoning is discussed in Geerts (1993) and Geerts and McCarthy (2000). More recently, the introduction of semantic web technologies has further improved the possibilities of representing and reasoning with such annotations.

## Association

Several associations between EMCs and BRPs were discussed in the "ODBRS Knowledge Base" section, and their use as part of ODBRS is elaborated here. Panel D of Figure 11 shows that BRPS1 (and thus BRP1) is associated with EMC1 and defined in terms of its vocabulary: Commitment, FulfillmentEconomicEvent, and Time.

The association step represents a process that links BRPs with EMCs. The meta-model in Figure 13 more formally defines this link—i.e., the "associated-with" association. For ODBRS, only EMCs for which at least one BRP exists are relevant. Obviously, there can be more than one BRP for the same EMC. For example, several date-related constraints could be defined for EMC2. Further, there can be more than one EMC for the same BRP as illustrated by BRP4, which applies to EMC7 and EMC8. A BRPS—shown as an association class in Figure 13—formally defines the

**TABLE 10**
**EMF-EMC Matching**

| Enterprise Model Fragment (EMF) | instance of | Enterprise Model Configuration (EMC) |
|---|---|---|
| EMF1 | → | EMC1 |
| EMF2; EMF3; EMF4 | → | EMC2 |
| EMF5 | → | EMC5 |
| EMF6 | → | EMC7 |
| EMF7 | → | EMC10 |
| EMF8 | → | EMC12 |
| EMF9 | → | EMC13 |
| EMF10 | → | EMC14 |

application of a BRP to a specific EMC. Table 11 summarizes all BRPSs that were developed as part of the example knowledge base in the "ODBRS Knowledge Base" section and illustrates the "associated-with" association. The BRPSs that apply to the enterprise model in Figure 10 are italicized.

## Instantiation

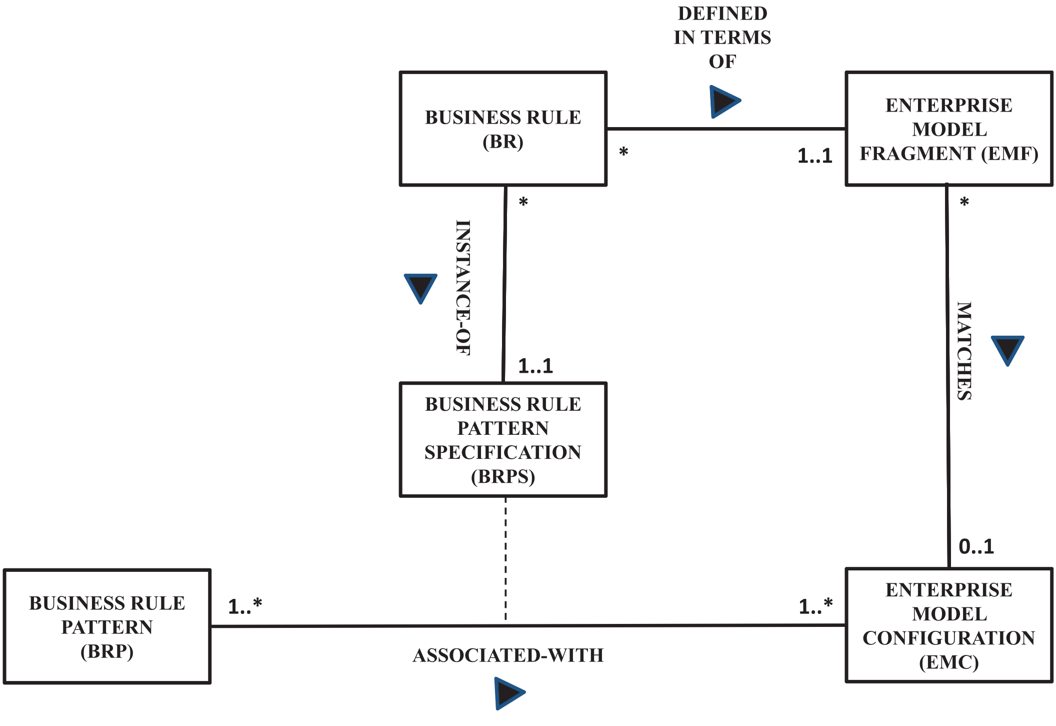
During the ODBRS instantiation process, the actual business rules associated with the enterprise model are generated. Here, the REA-EO primitives that function as variables in the BRPSs are substituted by actual elements from the enterprise model. The following substitutions were made to generate the business rule specification in Panel E of Figure 11: Commitment →Order; FulfillmentEconomicEvent.Time →shipment.date; Time →date. The "defined in terms of" association in Figure 11 further indicates that the specified business rule is fully integrated with the enterprise model used as input for the example (Panel A).

As shown by the meta-model in Figure 13, a BRPS can generate many business rules, but each business rule is an instantiation of exactly one BRPS. Table 12 lists all OCL business rule specifications resulting from applying ODBRS to the enterprise model in Figure 10. Stated differently, this is the output generated by ODBRS when using the enterprise model in Figure 10 as input. The first column in Table 12 is used to indicate of which BRPS the business rule is an instantiation.

## VII. CONCLUSIONS AND FURTHER RESEARCH DIRECTIONS

This paper presents ODBRS as an alternative approach to discovering and specifying business rules. Strengths of this approach include the following: (1) the ability to develop business rule specifications based on formally defined patterns that have been refactored and evaluated using test

**FIGURE 13**
**ODBRS Meta-Model**




cases (Correa and Werner 2007), and (2) the reuse of the business rule patterns across business processes and business organizations. ODBRS complements other business rule discovery approaches such as analysis, extraction from code, and data mining. Having discussed the characteristics and mechanics of ODBRS, it is important to differentiate it from other research projects in the same area.

First, a clear distinction needs to be made between ontology-driven design rules and ontology-driven business rules. The first category represents rules that provide guidance in building enterprise models. An example of such a rule in the context of the REA-EO is that for each economic resource in an enterprise model, there must be at least one inflow association and at least one outflow association. Business rules apply to instances of REA-EO primitives and are part of the actual software system.

Second, the ideas presented in this paper somewhat overlap with a series of papers that aim at facilitating the development of OCL constraints (Costal et al. 2006; Ackermann and Turowski 2006), which is time consuming and error prone (Cabot et al. 2010; Wahler et al. 2010). For instance, Ackermann and Turowski (2006) develop OCL specification patterns that are used to automatically generate OCL constraints that specify behavioral aspects of software components. The most important differentiating characteristic of ODBRS is its strong reliance on domain-specific knowledge.

The focus of this paper is on ODBRS as a method, and many issues that need further exploration, including the following four, remain. First, a visual approach to ODBRS was chosen in this paper. Although this approach helps with understanding the underlying process,

**TABLE 11**

**EMC-BRP Associations**

| EMC | BRP | BRPS |
|---|---|---|
| EMC1 | BRP1 | *BRPS1* |
| EMC2 | BRP2 | *BRPS2* |
| EMC3 | BRP3 | BRPS30 |
| EMC4 | BRP3 | BRPS31 |
| EMC5 | BRP3 | *BRPS32* |
| EMC6 | BRP3 | BRPS33 |
| EMC7 | BRP4 | *BRPS40* |
| EMC8 | BRP4 | BRPS41 |
| EMC9 | BRP5 | BRPS50 |
| EMC10 | BRP5 | *BRPS51* |
| EMC11 | BRP6 | BRPS60 |
| EMC12 | BRP6 | *BRPS61* |
| EMC13 | BRP7 | *BRPS7* |
| EMC14 | BRP8 | *BRPS8* |

operationalization of ODBRS requires advanced automated support, including tool support for defining semantic annotations and reasoning capabilities during matching and instantiation.

Second, the strength of ODBRS depends on the expressivity of the domain-specific vocabulary being used, and the depth and relevance of the knowledge base. In this paper, a limited number of examples were presented for illustration purposes, and more in-depth research is required for both: a more advanced study of REA-EO's vocabulary and the development of more advanced BRPs and BRPSs.

Third, as pointed out earlier in the paper, none of the methods can discover all rules, and this is true for ODBRS as well. Thus, more research is needed that evaluates the complementarity of ODBRS to other methods: How many new, relevant rules can be generated by this method? More research is also needed to fully understand other criteria that determine the success of ODBRS such as complexity and cost. The development of a full-fledged knowledge base would be a helpful tool for evaluation purposes.

Fourth, the visual approach presented here might be helpful in an educational setting. Among others, this approach requires students to classify an enterprise model in terms of the REA-EO, to fully understand different EMCs and thus different business practices, to identify and analyze

**TABLE 12**

**Business Rule Specifications**

<table>
<tr><th>BRPS</th><th>BUSINESS RULE SPECIFICATION</th></tr>
<tr><td>1</td><td>context Order inv BR1:<br>shipment.date →forAll(x|x >= date)</td></tr>
<tr><td>2</td><td>context Delivery inv BR2:<br>date <= Date.now</td></tr>
<tr><td>2</td><td>context Shipment inv BR3:<br>date <= Date.now</td></tr>
<tr><td>2</td><td>context Return inv BR4:<br>date <= Date.now</td></tr>
<tr><td>32</td><td>context Orderline inv BR5:<br>price > 0</td></tr>
<tr><td>40</td><td>context Inventory inv BR6:<br>shipment->notEmpty() implies delivery->notEmpty()</td></tr>
<tr><td>51</td><td>context Shipment inv BR7:<br>order.inventorytype → includesAll(inventory.inventorytype)</td></tr>
<tr><td>61</td><td>context Shipment inv BR8:<br>order.orderline→forAll(x|x.quantity >=<br>inventory→select(y|y.inventorytype =<br>x.inventorytype) →size())</td></tr>
<tr><td>7</td><td>context Inventory inv BR9:<br>shipment.return→includesAll(return)</td></tr>
<tr><td>8</td><td>context Inventory inv BR10:<br>shipment.customer → includesAll(return.customer)</td></tr>
</table>

business rule patterns that apply across business processes and business organizations, and to define actual business rule specifications based on best practices.

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