

# Ontological grounding of accounting frameworks

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## Abstract

The International Financial Reporting Standards Conceptual Framework (IFRS CF) serves as the foundation for developing Standards, which are used in 168 jurisdictions. However, despite its continuous evolution over the past half-century, the primary concepts, and the application of the Framework in formulating Standards demand foster ontological and computational progress. Furthermore, the misalignment of the IFRS CF with other accounting frameworks, particularly the one used in the United States, hinders the development of converged standards and information systems and complicates the understanding of the core concepts.

We propose an ontology of the Conceptual Framework for Accounting and Financial Reporting, grounded in the Unified Foundational Ontology (UFO) and the Core Ontology for Financial Reporting Information Systems (COFRIS), constructed as an enterprise value cycle. It is developed, presented, and verified using OntoUML tools. The ontological analysis includes suggestions for improvement and convergence of accounting frameworks. The ontology is aimed as a basis for standard setting and accounting model development. An example of a value cycle model for audit is provided.

## Keywords

UFO, OntoUML, Value Cycle Model, Financial Reporting, COFRIS, Shared Information Systems

## 1. Introduction


The Conceptual Framework for Financial Reporting developed over five decades, is intended to be a robust decision-making matrix aiding in the formulation of high-quality international accounting and financial reporting standards (IFRS) [1,2,3]. Regrettably, considerable discrepancies exist in the core concepts and their definitions within and across international and local, financial and sustainability, enterprise and public sector accounting frameworks. In a study of 100 companies, it was found that 63 companies that reported operating profit in the financial statements used at least nine different definitions [3]. While the conceptual frameworks have a “Basis for Conclusions”, the foundational concepts and theories have been forgotten to some extent. Also, the advancements in technologies have yet to find representation within these frameworks. To address these challenges, the proposal of engineering a Framework Ontology emerges as a viable solution. The Unified Foundational Ontology (UFO) [4] and its accompanying OntoUML tool ecosystem [5] have a successful track record in supporting ontological analysis of complex related notions and standards, improving the quality of domain representations, and facilitating domain comprehension and interoperability. Within the realm of grounding on UFO and its subontologies, we also include COFRIS—the core ontology of financial reporting information systems [9].


The problem of engineering ontology for economics and accounting has been regarded before, e.g. [7], although as far as our knowledge extends, [8] is the sole documented effort exclusively focused on the (previous iteration of the) framework itself. Other efforts were devoted to the ontology of Economic Exchange and its use in accounting. Several ontologies for economic exchange were proposed grounded in UFO, and in a recent work, they have been consolidated for the purpose of standard setting [9]. One of the main contributions of these exchange ontologies and other literature e.g. [10] is the shared ledger or shared information system perspective of exchange parties on transactions, promising cost and assurance benefits for accounting, especially in a blockchain and

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ER2023: Companion Proceedings of the 42nd International Conference on Conceptual Modeling: ER Forum, 7th SCME, Project Exhibitions, Posters and Demos, and Doctoral Consortium, November 06-09, 2023, Lisbon, Portugal

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 CEUR Workshop Proceedings (CEUR-WS.org)

platform environment. Treating transactions predominantly as shared processes rather than outcomes unique to individual enterprises represents a pertinent extension of the existing frameworks. However, accounting and financial reporting in addition to capturing transactions need to recognize, measure, and present information about the enterprise's disposition to produce financial results. For example, it is impossible to infer from the shared view the particular contracting costs and whether they will be capitalized or expensed.

The research goal of this study is to provide an ontological analysis of the Conceptual Framework, using UFO and COFRIS, for the improvement and convergence of the accounting frameworks. The overall research frame is Design Science Research where COFRIS, as it has been developed along several cycles so far is the core artifact. The current paper represents a new design cycle; the primary research goal is to validate the usefulness of COFRIS by applying it to a practical purpose and to extend COFRIS if needed. We start with a concise overview of the IFRS Conceptual Framework, its counterpart within the United States, and definitions of the used social concepts from UFO-C and COFRIS, in Section 2. In Section 3, we introduce the CF Ontology in OntoUML and propose suggestions for convergence and sharing. In Section 4 the CF Ontology is used to construct a value cycle model for production- and distribution-oriented enterprises. The results of the CF ontological analysis is illustrated by an example of a value cycle model for audit in Section 5. Section 6 concludes and outlines further validation work.

## 2. Background

The International Accounting Standards Board Conceptual Framework (IFRS CF) sets out the fundamental concepts that guide the standard-setters in developing international accounting and financial reporting standards. The Framework is summarized here in the short reviews of its chapters [1]:

1. *The Objective of Financial Reporting* is to provide financial information about the reporting entity (aka *Enterprise*) that is useful to existing and potential *investors* and *creditors* in making decisions relating to providing resources to the entity. Financial reports provide information about (a) the nature and amounts of the entity's Economic Resources and the Claims against the entity; (b) the effects of transactions and other events that change an entity's Economic Resources and Claims; (c) the efficiency and effectiveness with which the entity's management discharged their stewardship [and custody] responsibilities.
2. *The Qualitative Characteristics of Useful Financial Information*. The information must be *relevant* and *faithfully* represent what it purports to represent. The usefulness of information is enhanced if it is *comparable* across entities and over time, *verifiable*, *timely*, and *understandable*. Information is *material* if omitting it or misstating it could influence decisions made on the basis of the report. *Cost* is a pervasive constraint on the information that can be provided by reporting.
3. *The Reporting Entity* is an entity that is required (or chooses) to prepare financial statements, it can be a legal entity or a portion of an entity or can comprise more than one entity. Reporting entity is (in a *phase* of) a going concern, i.e., is creating value. Decision-useful information is provided in the following *Financial Reports*: (a) in the statement of financial position, by recognizing assets, liabilities, and equity; (b) in the statement(s) of financial performance, by recognizing income and expenses; (c) in other statements and notes, by presenting and disclosing information about, e.g., cash flows, and contributions from owners and distributions to them.
4. *Definitions of Elements of Financial Statements*. See Table 2 [1].
5. *Criteria for Recognition, Guidance on Derecognition*. Recognition is the process of capturing for inclusion in the financial statements an item that meets the definition of one of the elements—either alone or in aggregation with other items—in words and by a monetary amount. Derecognition is the removal of all or part of a recognized asset or liability. The amount at which an asset, a liability, or equity is recognized is referred to as its *Carrying Amount*. If it is uncertain

whether an asset or liability exists, or the probability of an inflow or outflow of economic benefits is low, the asset or liability is not recognized.

6. *Measurement Bases and Guidance on When to Use them.* Elements recognized in financial statements are quantified in monetary terms applying a measurement basis - *Historical cost* and *Current value*. The latter includes (a) fair value; (b) value in use for assets and fulfillment value for liabilities; and (c) current cost. Conceptually, an item bears all these values.

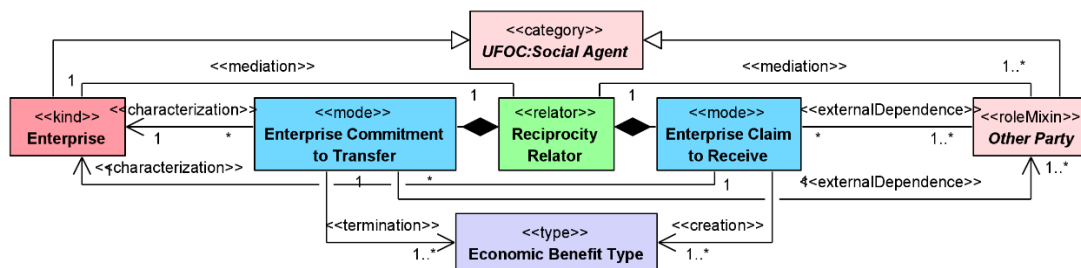
7. *Concepts and Guidance on Presentation and Disclosure.* Classification of elements based on shared characteristics for presentation and disclosure include the *Economic Nature* of the item, its *Role* (or *Function*) in the entity's *Activities*, and how it is measured.

Numerous other accounting and financial reporting frameworks exist, each tailored to different activities and jurisdictions. A significant counterpart to the IFRS CF is the United States GAAP Conceptual Framework for Financial Reporting (US GAAP CF) [2]. While there is a declared intention to minimize differences across these frameworks and standards, considering variations in legal, regulatory, or social norms [2], there are substantial specificities. Generally, the US GAAP CF contains a broader array of core concepts than in IFRS CF, such as Transactions and Other Events, Economic Exchange, Transfer of Obligations, and Service Provision [2]. The US GAAP Framework defines ten core elements in contrast with IFRS CF's five elements [1]. The US GAAP CF has dismissed the asset control and custody concepts present in IFRS CF and exhibits differences in core element sets and definitions.

## 2.1. Unified Foundational Ontology (UFO)

Unified Foundational Ontology (UFO) is an axiomatic domain-independent formal Theory. UFO is divided into three layered compliance sets: UFO-A, an ontology of concrete *endurants* – of *substantials* and *aspects* [4], UFO-B, an ontology of *events* [12], and UFO-C, an ontology of *intentional* and *social* entities [6]. OntoUML is a language whose meta-model has been designed to comply with the ontological distinctions and axiomatization put forth by UFO [5]. OntoUML diagrams (e.g., Figure 1) represent types. The stereotypes of concepts and relations (in addition to those of UML) used are described in Table 1.

In UFO-C, *agents* and (non-agentive) *objects* specialize *substantials* [6]. *Objects* can be *physical* and *social* (e.g., economic resources, money). *Agents* can be *physical* (e.g., a person) or *institutional* (e.g., an enterprise) and have *intentional aspects* that can be *mental* or *social*. *Mental aspects* include *intentions*, *beliefs* (that can be justified by *situations*), and *desires* (which express the will of an *agent* toward a *situation*). The notion of *intention* refers to a *situation* that the *agent commits* to bring about by pursuing *goals* and executing *actions*. A *closed intention* specializes *commitment* to pursue a *goal* in a specific way, i.e., constrained by a particular type of *action type* termed a *plan* [6] or a *schedule*.



**Figure 1:** OntoUML diagram of Reciprocity Relator. Adapted from [13]. Enterprise view. In all diagrams, types are represented in purple, objects in pink, modes in blue, events in yellow, and relators in green.

*Social commitments* and *claims* specialize *social aspects* [6]. A *social commitment* is the commitment of an agent (a *committer*) towards another agent (a *claimer*). As an externally dependent mode, a social commitment is a *characterization* of the *committer*, has *externalDependence* on the *claimer*, and causes the creation of an *internal commitment* in the

*committer* [6]. Also, *correlative* to this *internal commitment*, a (*comparative*) *social claim* of the *claimer* towards the *committer* is created.

Commitments and claims always form a pair that refers to unique propositional content. A *social relator, mediated by agents*, is an example of a *relator* composed of *correlative* commitments/claims. *Actions* are intentional events, i.e., events that are performed by agents to satisfy their goals. *Actions* are *manifestations* of agent modes and action *types* are specified in commitment *schedules* or by committed resource *types* [6].

*Reciprocity relators* [13, 9] combine commitments (or *correlative* claims) of *each* of the two agents, e.g., the enterprise and the other market participant(s), as in contracts. The services ontology UFO-S [13] regards reciprocity relator as an agreement to exchange service actions.

**Table 1**  
OntoUML Stereotypes of entities and *primitive* relations used [5]

Stereotype	Description	Example from this paper <sup>1</sup>
«type»	High-order type whose instances are themselves types.	Service Type, Resource Type
«instantiation»	Relation between an entity type and its higher order type	Asset → Asset Type
«category»	Necessary properties that are shared by entities of multiple kinds.	Underlying Object, Social Agent
«kind»	Type of objects that exist according to a particular conceptualization of the given domain. These fundamental types describe what the objects in that domain essentially are.	Enterprise, Person
«subkind»	Subdivision of a kind.	Bank, Investment Contract
«phase»	Anti-rigid sortal type that captures a cluster of change conditions in intrinsic properties	Economic Resource, Economic Claim
«phaseMixin»	Anti-rigid non-sortal type that captures a cluster of change conditions in intrinsic properties, for instances of multiple kinds	Creditor, Debtor
«role»	Relationally dependent universal, capturing relational properties shared by instances of a given kind	Asset, Liability, Equity Claim. Principal
«roleMixin»	Role for types that represent properties shared by entities of multiple kinds	Other Party, Hired Provider, Seller, Buyer
«quality»	Aspect that can be directly associated with structured value spaces.	Transaction Price, Historical Cost
«mode»	Aspect that cannot be directly associated with structured value spaces.	Right to Inflow, Obligation to Outflow
«characterization»	Relation between a bearer type and its «quality» or «mode».	Enterprise ← Right to Inflow, Input Asset ← Cost
«externalDependence»	Identifies an endurant type on which the mode depends	Other Party ← Right to Inflow
«relator»	Truth-maker of relational propositions. Relations (classes of n-tuples) can be completely derived from relators.	Reciprocity Relator, Unit of Account, Contract
«mediation»	Relation between a «relator» and the entities it connects	Enterprise – Contract– Seller
«event» and relations:	Class whose instances are events.	Economic Event, Transfer
«historicalRole»	Role played by sortal objects in an event.	Resource Transferred
«historicalRoleMixin»	Role played by non-sortal objects in an event.	Service Provider
«participation»	Relation between an endurant type and the event type.	Enterprise ← Transfer
«bringsAbout»	Relation between a situation type and the event type.	Contract Asset ← Realization
«creation»	Relation between an endurant type and the event type [or mode] of creation of the endurants.	Asset Increase ← Receipt, (aka recognition)
«termination»	Relation between an endurant type and the event type [or mode] of making the endurant nature “historical”.	Asset Decrease ← Transfer, (aka derecognition)
«manifestation»	Relation between a mode and event type in which the mode is manifested and [partially] terminated	Right to Receive → Receipt, (aka fulfillment)

## 2.2. Core Ontology for Financial Reporting Information Systems (COFRIS)

<sup>1</sup> We use the same stereotypes for relations between endurant types and modes as for relations between endurant types and event types.

COFRIS adds economic resource flow and affected resource stock concepts to the commitments/obligations and their (incremental) fulfillment [9]. Furthermore, economic resources are considered a set of institutional rights that have the potential to produce economic benefits. Adjective *economic* means the monetary valuation of the concept and is sometimes omitted.

An *Economic Exchange* is defined as a transaction whereby two economic agents (A and B) conclude and execute contracted reciprocal performance obligations to transfer economic resources and to provide services, affecting both parties' resources and activities, with the goal of producing economic benefits for either party [9].

Transactions are regarded primarily as institutional actions of *Resource Transfer* (see Figure 2) of rights (and incurrence of claims) that may involve simultaneous or postponed service provision, object custody, delivery, or production. The resource flow affects economic resources (and claims) held and controlled by transactors, termed assets (and liabilities), valued by their holders or the market [1]. The market is a network of market participants – enterprises and persons serving to facilitate exchanges and economic resource rights.

As illustrated in Figure 2, a *Market Participant* (aka economic agent) acting in the *role* of an *Obligor* (denoted as *x*) bears a *Performance Obligation to Transfer*. This obligation is *fulfilled* by an *event* termed *Resource Transfer* and is directed towards other parties in the *role* of *Obligee* (denoted as *y*). The obligation entails the *creation* of a *Transferred Resource* flow of a specified type typically through the *termination* of the *Obligor's* existing *Assets* (*creation* of incurred *Liabilities*) but possibly as part of the *Obligor's* *Activities* (suppose it receives a service from a provider and immediately transfers it to the customer). Upon its *termination*, the *Transferred Resource* flow contributes to the *creation* of the *Obligee's* *Assets* (*termination* of *Liabilities*) or is directly expensed within the *Obligee's* *Activities*.

For instance, in a basic sales contract, an enterprise employs designated quantities of grain assets *and* a hired workforce to transfer and deliver these resources to the other party. In return, the enterprise's cash assets are affected by the receipt of cash, but the accompanying bank's services are expensed.

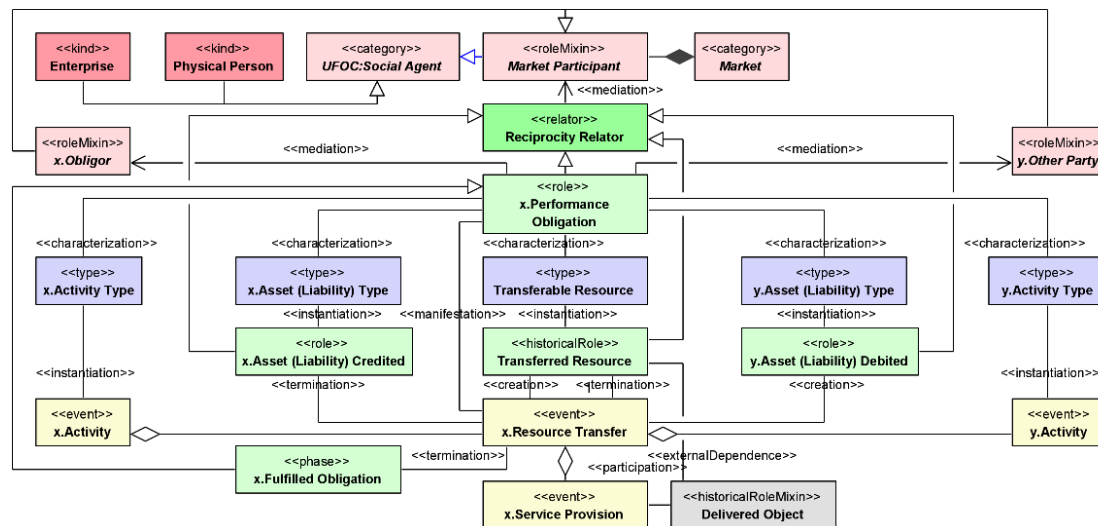


Figure 2: OntoUML diagram. COFRIS. Fragment of Performance Pattern.

### 3. Ontology of conceptual frameworks for financial reporting

This Section presents the CF Ontology by (1) presenting core concepts used in both frameworks (IFRS and US GAAP), and (2) conducting ontological analysis by visually representing and describing the nature of these concepts through OntoUML diagrams. The questions to be answered are (1) What are the core economic events and their participants; (2) What are the core economic resources and claims and their roles and phases affected by these events? In addition to (computational) grounding, the key requirements for CF Ontology include the need to accommodate the convergence of distinct frameworks and the availability of shared information systems. Beyond harmonizing core concept-

based common standard-setting and improving comparability, convergence should generalize different concepts that were introduced for solving particular problems in different frameworks. The shared information systems requirement calls for correlative standard-setting, alleviating cost constraints, and improving verifiability and comparability.

Building upon the foundation laid by COFRIS, CF Ontology takes a broader perspective by encompassing not only economic exchanges, but also owner transactions, service provision, and other events, roles, and phases of resources and claims additionally required for the frameworks. The concepts and terminology have been refined to align closely with those used in established frameworks, with particular attention given to cross-lingual validation using GPT-4 for term testing, including the nuanced selection of terminologies, such as differentiating between *Received Resources* and *Resources Received*. We have tried to minimize the introduction of new concepts beyond those found in existing frameworks. However, it is assumed that for most concepts, corresponding *high-order types* and *correlative* counterparts of concepts exist.

The UFO foundational concepts will be denoted in camelCase italics, such as *roleMixin* but CF Ontology concepts in italics, starting in uppercase – *Input Asset*.

### 3.1. Transaction pattern

Figure 3, the part of CF Ontology, shows the core model of transactions between an enterprise and other parties. This represents a generalization of the economic exchange model of COFRIS. The existing frameworks have the reporting entity perspective. We assume that an *Enterprise* is a *Market Participant* in some *Environment* and holds economic resources and claims that are affected by *Economic Events* - transactions and other events with enterprise *participation*. Within its *Business Activities*, the enterprise enters into transactions with other market participants with the goal of maximizing equity for its owners. We generalize the institutional actions of transfer (and receipt) and their participants to those of outflow (and inflow) of economic benefits. Initially, we refer to Table 2 for IFRS framework-based definitions of economic resources and claims, units of account, and executory contracts.

**Table 2**

Definitions of the core elements of financial statements [1]. Our comments are in square brackets.

Resources and claims	Element	Definition or description
<b>Economic resource</b>	–	A right that has the potential to produce economic benefits.
	Asset	A present economic resource controlled by the entity as a result of past events.
<b>Claim [against the entity]</b>	Liability	A present obligation of the entity to transfer an economic resource as a result of past events.
	Equity	The residual interest in the assets of the entity after deducting all its liabilities.
<b>Unit of account</b>	–	The right [to inflow] or the group of rights, the obligation [to outflow] or the group of obligations, or the group of rights and obligations, to which recognition criteria and measurement concepts are applied [1:4.48].
<b>Executory contract</b>	–	A combined right and obligation to exchange economic resources. [1:4.57]
<b>Changes in economic resources and claims, reflecting financial performance</b>	Income	Increases in assets, or decreases in liabilities, that result in increases in equity, other than those relating to contributions from holders of equity claims.
	Expenses	Decreases in assets, or increases in liabilities, that result in decreases in equity, other than those relating to distributions to holders of equity claims.
<b>Other changes in economic resources and claims</b>	–	Contributions from holders of equity claims [owners], and distributions to them.
	–	Exchanges of assets or liabilities that do not result in increases or decreases in equity.

In Section 2, we refer to *reciprocity relators* as relators of enterprise claims and commitments. Similarly, we define *Units of Account* as *relators* of enterprise *Obligations to Outflow* of economic benefits and related *Rights to Inflow* of economic benefits. The rights to inflow may either arise from ownership of a particular physical or social *Underlying object* or be based on the *correlative* obligations imposed on other parties.

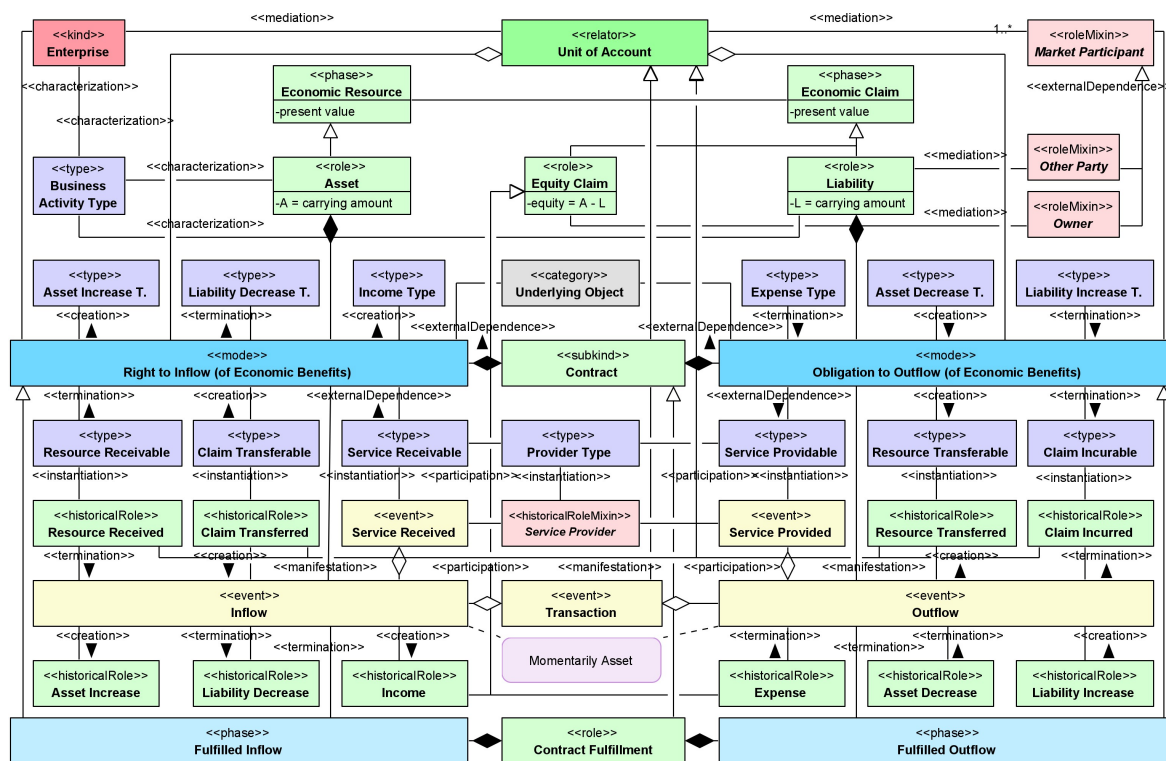
When these rights are predisposed to yield economic benefits—specifically, eventual cash inflows that are either greater than cash outflows of the related obligations for outflows or no such obligations exist, the units of account are categorized as *Economic Resources*.

Conversely, if the outflows are greater, or no rights exist, accounts are considered *Economic Claims* against the enterprise (aka economic obligations).

*Contracts* are *subkinds* of units of account having inseparable rights and obligations mutually agreed between two parties. *Executory Contract* is a *phase* of an unfulfilled contract with the net cash flow value typically equal to zero. Contracts, resources, and claims are not static; they are subject to fulfillment and fluctuating valuations. Therefore, we conceptualize them as distinct but interconnected *phases* within the lifecycle of a unit of account.

Economic resources and claims represent the rights and obligations between generic market participants and are characterized by market or transaction price, they represent stock held by a participant as well as a flow in a transaction, and changes in stock resulting from transactions and other events.

*Assets specialize* economic resources held and controlled by an enterprise, possibly adding enterprise-specific restrictions and additions on their recognition, purpose, and measurement. *Control* means the ability of the enterprise to realize the potential of the resource within some *Business Activity type*. Conversely, *Liabilities specialize Claims* that the enterprise has no practical ability to avoid. Control is not included in US GAAP CF.



**Figure 3:** CF Ontology. OntoUML diagram of Transaction Pattern. Enterprise View. Asset and Liability Increase and Decrease relationship with Assets and Liabilities is omitted to simplify the figure.

Given the specialization of relationships within the enterprise - assets, liabilities, and equity claims specialize resources and claims as *roles*. *Right to Inflow* and *Obligation to Outflow* manifestation progresses their fulfillment from *Executory* to *(Partially) Fulfilled* phases. Fulfilled rights and obligations of a contract result in *Contract Fulfillment Assets* or *Liabilities*.

The transactions and other events of an enterprise lead to changes in assets and liabilities. Related changes in equity - income, and expenses are accumulations of owners' claims per reporting period and depict the component of the equity resulting from the particular type of economic event. This component should explain also *why* and *how* [2:18] these changes happen, creating some *construct overload* [4:30], because the changes in *Equity Claims per Period* need to be also categorized either

by affected *Activities* or by the *Economic Nature* of the change. *Activities* (aka *Function* or *Role*), involve production, realization, or administration. The *Economic Nature* of the income or expenses involves the type of goods or services used or produced, transferred, or received. The need for more detailed information is also proved by the recent acceptance of financial statement user requirements to report expenses both by function *and* nature [3].

In accordance with COFRIS and our analysis, we find that the information about *Rights* and *Obligations*, *Inflow* and *Outflow Events*, *Resource* and *Claim Flows*, *Service Provision*, and *Service Providers* is shared between parties and is essential for revealing the economic nature of the change. Conceptually, events, their participants, and resource flow should be recognized as such and independently, as also proposed in ISO/IEC FDIS 15944-4: 2015 Standard REA Ontology [7].

The *Resource* and *Claim Flow* is different from the *Asset and Liability Change* in Table 2 (called ‘transferred component’ in [1:5.28] which can be regarded as *concept redundancy* [4:33]). It is different because service provision within the transfer generally *Consumes* assets and liabilities to *Produce* resource and claim flows. Consequently, there is a *concept deficit* in the CF.

The *Claim* incurrence and *Service Provision* as outflows of economic benefits are included in the liability definitions in US GAAP CF [2:10], but there is an explicit concept deficit in [1]. *Service Provision* requires a *Service Provider* which may be different from transaction parties and needs resources or claims authorized for providing services.

A *construct excess* [4:32] emerges in frameworks, which stipulate that “services provided by other entities can be assets of an entity only momentarily as they are received and used, and they commonly are recognized as *Expenses* when received” [2]. Our claim is that the services or any other resources whereby their consumption appears simultaneously with production are events (or processes) but not assets if we assume the historical mode of description [12] and should be treated as *Outflow event* parts of *Inflow events*. The momentary asset concept of the frameworks leads to the double overload because such an asset is not recognized but the characteristics of two (inflow and outflow) actions are mingled into one expense item.

All participants of the outflow and inflow events – changes in assets, liabilities, and equity claims, as well as resource and claim flows, play the *historicalRoles* and have *Historical Cost* valuation (conceptually a separate event is required to establish *Current Value*). The service provider plays the *historicalRoleMixin*. In detail, *Outflows* specialize economic events and are *manifestations of Obligations to Outflow*, and involve:

1. *termination of Asset Decreases<sup>2</sup>/creation of Liability Increases, termination of Expenses,*
2. *Consumption of Inflows or Services Provided for Production* resulting in
3. *creation of Resources Transferred/termination of Claims Incurred.*

*Inflows* specialize economic events and are *manifestations of Rights to Inflow*, and involve:

1. *termination of the Resources Received/creation of the Claims Transferred,* and
2. *Consumption of Services Received for Production* resulting in *Outflows*, or
3. *creation of Asset Increases/termination of Liability Decreases, creation of Income.*

The transactions as processes in a shared IS can be observed more independently than changes in participant-specific assets and claims. In addition, the information about the affected resources and claims of *all* parties [10] of a transaction can be used for reporting and process mining. If we assume shared information systems, then the information about resource stocks (such as a ‘building in process’) and activities of the other party (such as administration) affected by the enterprise services is available and can be used in the reporting.

### 3.2. Core categories of transactions and other events

According to the needs of accounting and as in more detail described in [2], we will specialize the transaction pattern and other events that are the base of financial reporting into owner, exchange, and service provision transactions and environment and market impact adjustment events, see Figure 4. We will show only specialized concepts of the diagram in Figure 3 in this diagram.

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<sup>2</sup> In IFRS parlance: the derecognition of an asset, or a decrease in the carrying amount of an asset [1:5.4]



Investment Contracts specialize Contracts by Owners specializing Other Parties. Owner Transactions fulfill Investment Contracts and comprise Contributions and Distributions. Contributions specialize Inflows by creation of Investments by Owners that redefine Income. Distributions specialize Outflows by termination of Distributions to Owners that redefine Expenses. The state and value of the investment contract are tracked by Equity Claim which includes the fulfilled parts of contribution and distribution.

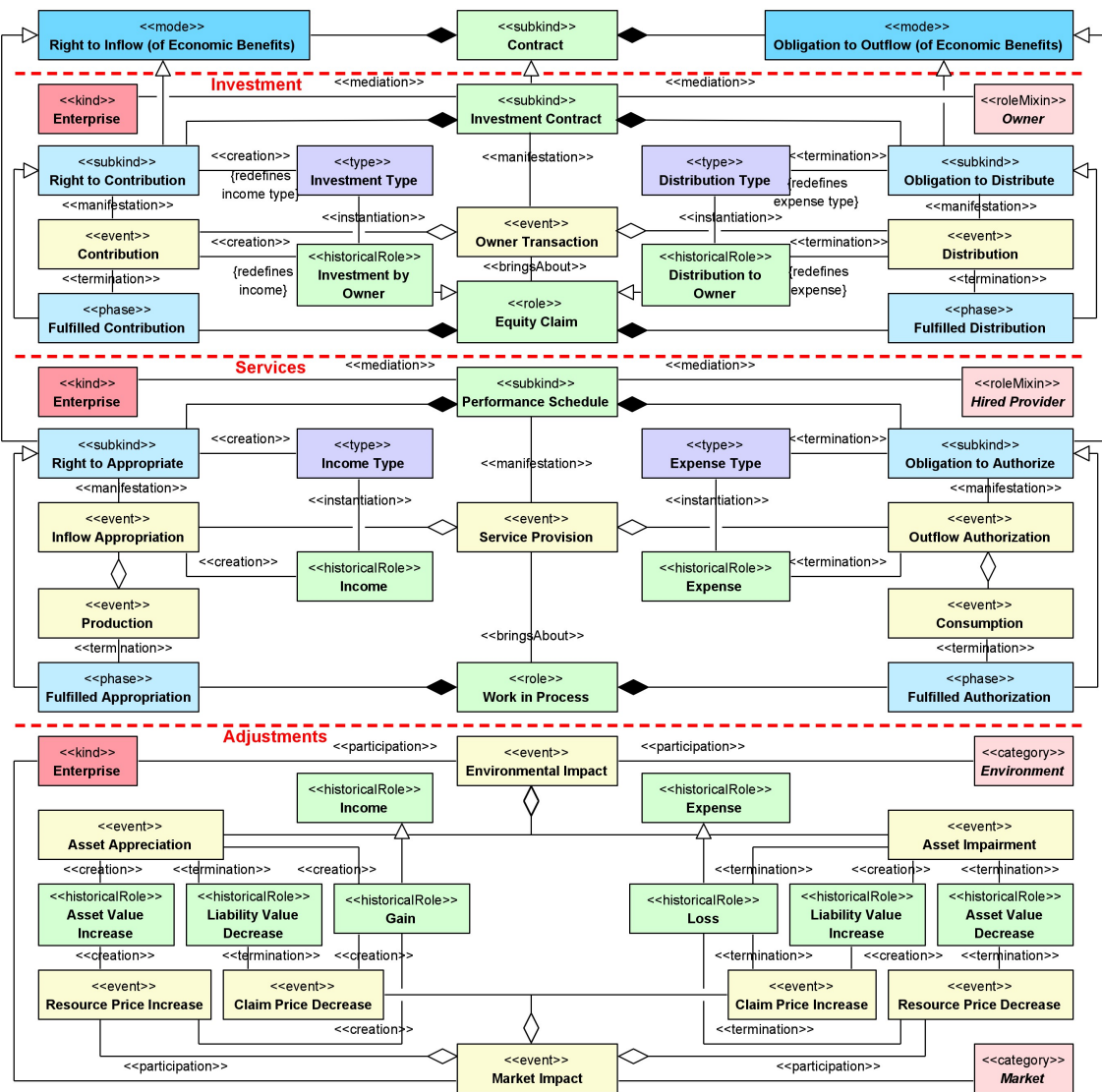


Figure 4: CF Ontology. OntoUML diagram of transactions and other events. Enterprise view.

The US GAAP CF in contrast with IFRS has special elements for owner transactions [2] that indicate some *construct deficit* in [1]. Besides these elements, the equity claim has *Income* and *Expense* components that are formed by other transactions and events regarded below. Owner transactions could be regarded and shared also from the perspective of the enterprise in the role of an owner.

Exchange contracts and non-reciprocal transfers and receipts [14:91] are directly modeled by transaction patterns. As described before, transaction events can involve service provisions.

The service provision becomes possible after the *Service Provider* (an employee or other market participant) is *hired* [13] and directed to execute actions within the service provision contract (a subtype of exchange contract) and by performance schedules. The service provider is authorized with the *Custody* of resources and claims of the enterprise and the other party essential for service provision [1:4.25].

*Performance Schedules specialize Contracts by Hired Providers specializing Other Parties. Service Provisions fulfill Performance Schedules and comprise Rights to Appropriate and Obligations to Authorize. Service Providers perform by Consumption of authorized Inflows, Resources (including rights for their services), and Claims, and Production of appropriated Resources, Claims, and Outflows.* The state and value of the schedule are tracked by the *Work in Process* which includes the fulfilled parts of appropriated rights and authorized obligations. The appropriation action results in the *Income* and the authorization action in the *Expense* element.

As noted above Service Provision can be involved in the actions of Contribution and Receipt whereby the other party provides service for the processing of the resource inflow, or in the actions of Distribution and Transfer whereby the enterprise provides service for the processing of the resource outflow. In transfer, the enterprise itself plays the agent role (that is the other party owns all outflow resources including services), while in receipt, the role of the principal (the enterprise owns all inflow resources). Service Provisions can also be regarded and shared from the perspective of the enterprise in the role of a hired provider. The shared perspective allows not only information sharing [10] about the service provision itself but also about Resources and Claims in Custody, thus advocating for their inclusion as core elements.

Other events include *Asset* and *Claim* categorization or value *Adjustments* [14:91].

The *Environment* changes the utility or substance of enterprise resources. *Environmental Impact* includes *Asset Appreciation, Asset Impairment,* and other reclassifications.

The *Market situation* plays a pivotal *role* in influencing fluctuations in price levels, as well as shaping the legislative landscape that impacts both assets and claims. Value measurement of the assets and claims in addition to initial recognition involves *Resource* and *Claim* market *Price Changes* for the *Fair Value Measurement Base, Interest Income* for the time value of money, *Onerousness Checks* for the claims [1:6.43], and *Circumstance* effects [2:24].

## 4. Enterprise value creation and cash flow cycle

Having elucidated the core concepts and events used in the Frameworks, we will now synthesize these elements within the value cycle of a production- and distribution-oriented enterprise.

The IFRS Management Commentary posits that "the value creation and cash flow cycle of an entity involves integrated processes through which the entity (1) acquires (a) inputs for its operations, (2) transforms these (a) inputs into (b) outputs, (3) sells these outputs, (a) delivers them to customers, and (b) collects cash [3]."

Figure 5 offers the OntoUML diagram that expands this description. An enterprise organizes the value cycle by forming and executing various contracts and schedules that change resources and claims. Additionally, external factors, such as environmental conditions or market situations, can also impact changes in value stocks.

*Cash specializes Economic Resource* as the *Right to Inflow* for which value equals its quantity. Cash is a liability of the (Central) *Bank*. Cash integrates all the instantaneous cash inflows and outflows of the enterprise. *Cash* as a *Resource Flow* affects *Cash* as an *Asset* thus simplifying cash flow depiction. Since values in our model are represented as attributes, so is the cash committed, claimed, paid, and received in Figure 5. IFRS Framework does not define the cash concept.

*Owner Contributions* and *Distributions* proceed as described in the previous section except that in this context they are usually done through cash receipts or cash accruals or payments.

In the *Economic Exchange* section, an enterprise *Purchase Contract specializes Contract* whereby a *Seller* specializes *Other Party. Payable* specializes *Obligation to Outflow,* and *Cash Payable* specializes *Resource Transferable* and *Asset Decrease Type.* Conversely, *Right to Receive* specializes *Right to Inflow, Input Asset* specializes *Asset Increase,* and *Receipt* specializes *Inflow.* Contract manifestation leads to (1) *Acquisition* comprising:

- *Rights to Receive* manifestation by *Inflows* bringing the contract into the *Contract Liability* or *Derecognized phase* by *termination* of the *Resources Received* and *creation of Input Assets;*

- *Payables manifestation* by *Payments* specializing *Outflows* resulting in *Cash termination* (or netting of *Payables* with *Receivables*), bringing the contract into the *Contract Asset* or eventually into the *Derecognized* phase.

In the *Production* section, consequently to (1), as agreed upon with the *Hired Providers*, *Performance Schedule manifestation* (2) leads to:

- *Obligations to Authorize manifestation* by *Authorizations* and *Consumptions* resulting in the *termination* of *Input Assets* and *creation* of *Resource Flow*; and
- *Rights to Appropriate manifestation* by *Productions* and *Appropriations* resulting in *termination* of *Resource Flow* and *creation* of *Output Assets*.

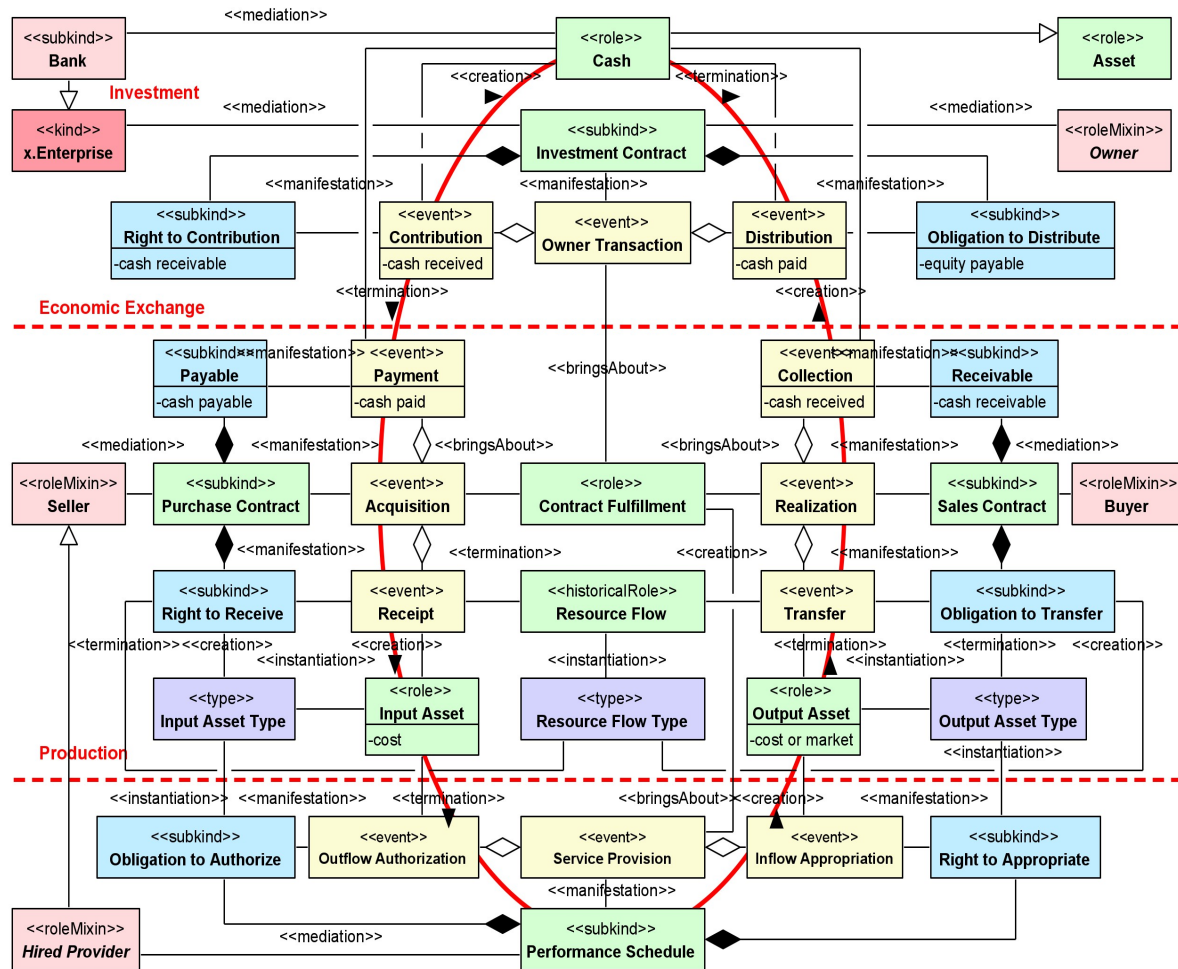


Figure 5: CF Ontology. Enterprise Value Creation and Cash Flow Cycle. Enterprise view.

Further, an enterprise *Sales Contract* specializes *Executory Contract* whereby a *Buyer* specializes *Other Party*, *Receivable* specializes *Right to Inflow*, and *Cash Receivable* specializes *Resource Receivable* and *Asset Increase Type*. Conversely, *Obligation to Transfer* specializes *Obligation to Outflow*, *Output Asset* specializes *Asset Decrease*, and *Transfer* specializes *Outflow*. *Contract manifestation* leads to a *Realization* (4) comprising:

- *Obligations to Outflow manifestation* by *Outflows* that bring the contract into the *Contract Asset* or *Derecognized* phase by *termination* of *Output Assets* valued at *Cost or Market*, and *creation* of *Resources Transferred* to the *Buyer* valued at *Transaction Price*; and
- *Receivables manifestation* by *Collections* specializing *Inflows* resulting in *Cash creation* (or netting of *Payables* with *Receivables*), bringing the contract into the *Contract Liability* or *Derecognized* phase.

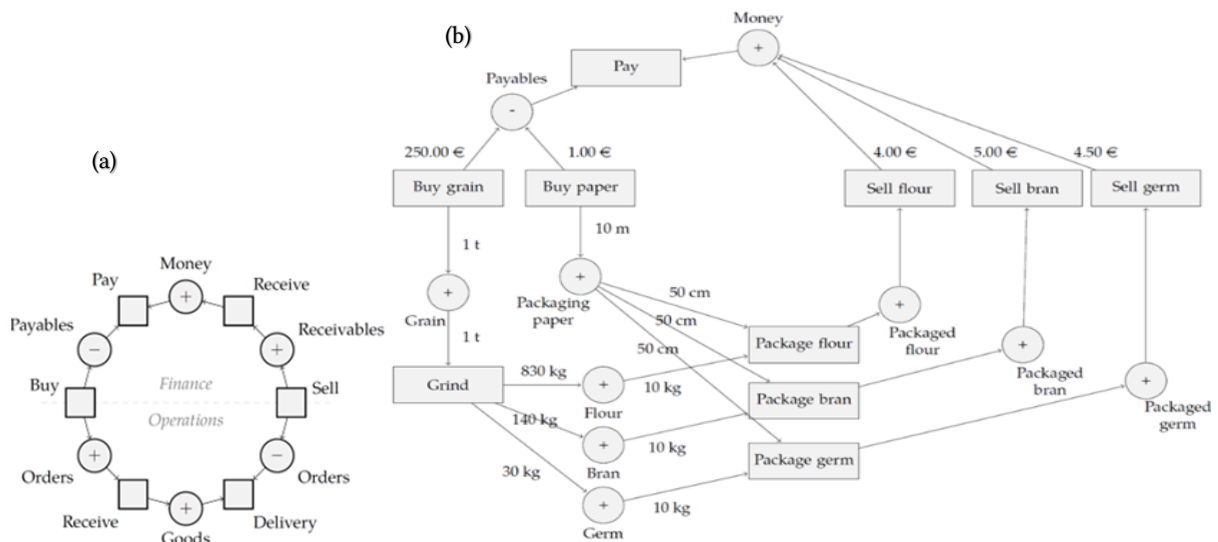
Outflows and Inflows shown in Figure 5 affect Equity. *Equity Claim manifestation* by Transfers of residual Assets brings the *Equity Claim* and eventually the *Enterprise* into the *Derecognized phase*.

## 5. Creating value cycle models for assurance - an example

The CF Ontology is primarily oriented towards creating standard subontologies by specializing the core ontology. However, the system of core concepts and events allows for wider use of the CF Ontology. A mandatory element of financial reporting is the audit. The audit uses the same Frameworks, so the concepts required for the assurance such as non-financial measures and inter-company reconciliation views need to be built into the model.

Given that the purpose of the reporting is to provide decision-useful information to the owners and creditors, we find it reasonable to regard the Dutch Owner-Ordered Audit Theory [15]. We align the audit and control Value Cycle Model (VCM) [15, 16] supported by Petri net and matrix language and reengineer their example model, see Figure 6, using the CF Ontology core concept stereotypes. The Petri net and matrix language can provide new views for the CF Ontology including concurrent activity treatment and unit of measure translation.

Figure 6(a) shows a Petri Net based expression of the VCM [16] for a trading company. The names for the concepts are similar to those used in our value cycle in Section 4, except *Orders* represent *Rights to Receive* or *Obligation to Transfer*. In contrast, the VCM combines contract formation and execution dynamics in *Buy* and *Sale* events. The grounding is limited to Colored Petri Nets concepts of buffers, tokens, and transactions. The flow resources, the service provision, the investment cycle, and the equity concept are not included.



**Figure 6:** (a) Top Value Cycle Petri Net Model of an Enterprise for a trading company, (b) The Value Cycle of a Miller. Adapted from [16].

As we can see from the example in 6(b) the exact quantities and values (or their proportions) for the actions are shown on the arcs as real numbers. They represent the flow when the resource type of the flow is the same as that of the stock. A crucial element in this model (deviating from current mainstream accounting), is that the goods stream is measured in physical units, as this is the only way to ensure robust traceability [15].

Let us regard an example depicted in Figure 6(b). The main characteristic of the example milling company VCM is that it grinds grain into flour, bran, and germ in reasonably fixed proportions. The main business of the milling company is to buy grain, grind it, and sell the result. The grind transition in the bottom left grinds grain in batches of one ton. A ton of grain is purchased for 250 EUR. Grinding the grain results in flour, germ, and bran. It is a property of grain that the ratio of these three products is 830:140:30. The miller also buys the paper to package the flour, bran, and germ. According to the

process model buying paper can occur independently, but normally it must occur in a certain ratio with the other transitions, just as the packing and sales. Measuring such minor flows and comparing them to major flows provides an opportunity to reveal anomalies in recordings [16].

When trying to use CF Ontology for modeling with accountants and software developers we found that the universality of grounding concepts and the stereotypes in OntoUML can be a challenge. By redefining core concepts into the core stereotypes like <<seller>>, <<transfer>>, <<resourceOutflow>>, and so on, we can make the models more appealing and accessible to users. However, a stereotype should not be interpreted as a superclass, but rather as a metaclass. For instance, a specialization of a seller, such as the "Grain Seller" depicted in Figure 7, should possess an applied stereotype of <<sellerType>><sup>3</sup>.

Illustrating this approach, consider the core stereotyped diagram for a miller in Figure 7. In this scenario, a ton of grain is procured from a grain seller, creating an input asset increase. Notably, there is no requirement for a separate receipt event no resource inflow modeling, as the inflow is consistent in type and quantity with the input asset increase. Following the grain acquisition, the milling process results in an increase of assets in the form of flour, germ, and bran, with the respective proportions highlighted in the diagram. Furthermore, the miller acquires paper for packaging, recognized as another input asset increase. The packaging process, involved in the cash sale to the baker, incurs a decrease in assets and generates resource outflows. In contrast, had the products been packaged prior to the sale, this process would be modeled as a separate production event producing stock, but not flow. This example also shows that the VCM can be depicted in the OntoUML diagram using CF Ontology and core stereotypes. The advantage to VCM is the opportunity to use wide categorization and mereology provided by UFO for specifying situations, causality, and proportions. The CF Ontology can gain abilities to use Petri net modeling and unit translation for improving models and assurance. As explained in [15, 16], one advantage of the Petri net modeling is that fraud scenarios can be generated automatically.

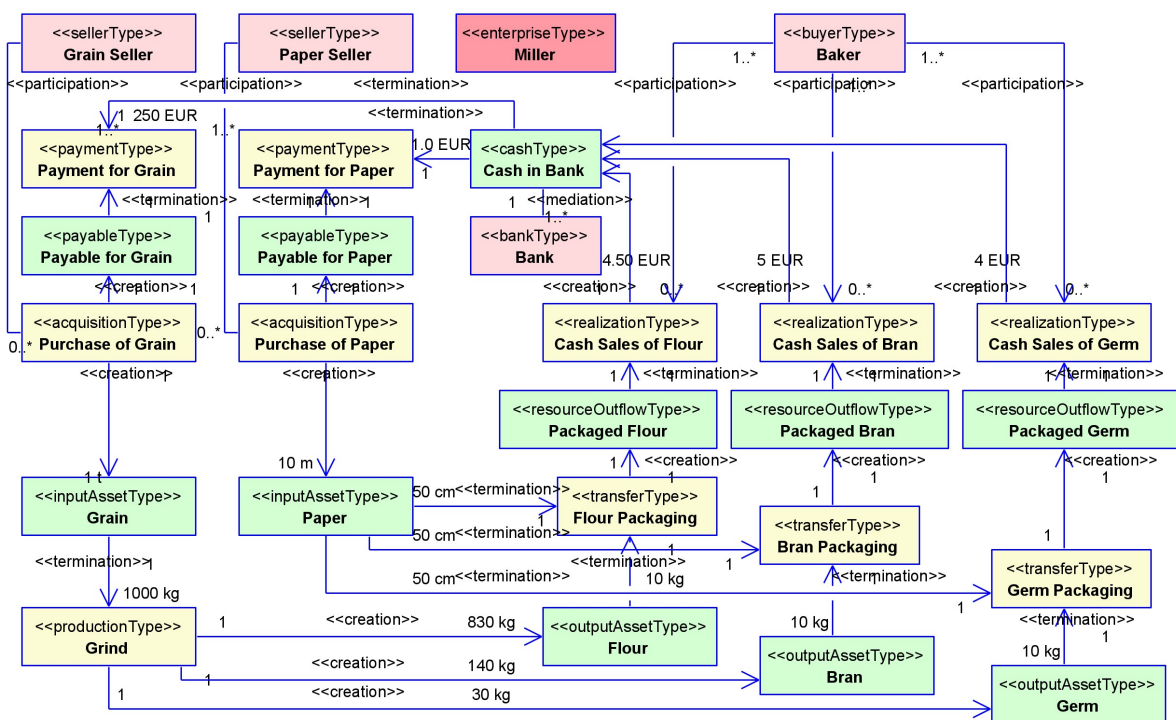


Figure 7: Core stereotyped diagram of the Miller example from Figure 6(b).

## 6. Conclusion and future work

<sup>3</sup> We are thankful to J.P.A. Almeida, one of the UFO and OntoUML developers, for raising this noteworthy point.

Grounding in UFO and COFRIS social endurants, events, and their *primitive* relations we have developed an ontology of the Conceptual Framework for Financial Reporting. This ontology is a novel attempt to describe the core transactions and other events, the elements for financial reporting and their synthesis in a value and cash flow cycle. It charts the path for setting standard ontologies through framework specialization, framework improvement via convergence, theory and technology adaptation, and standard generalization. In our development process, we have clarified the taxonomy and value cycle of economic events and expanded upon the roles and phases of economic resources and claims. We have also identified areas of construct overload, excess, redundancy, and deficit in the frameworks. The CF Ontology diagrams were syntactically verified using OntoUML tools. The successful development of the CF Ontology demonstrates the conceptual richness of the COFRIS ontology and its suitability as an ontological analysis tool.

COFRIS was used for two experimental applications. Our model and suggestions with technical improvements were utilized to develop IFRS-compliant Hyperledger Fabric-based transaction entry and financial reporting application [17]. The ontology can be further tested by ontologists, accountants, and shared-AIS developers for its utility across several policy and standard-setting, and implementation tasks. A notable example that we are working on includes its application as a foundation for building and analyzing subontology for IFRS 15 *Revenue from Contracts with Customers* [11] for this standard's post-implementation process project. The CF Ontology, IFRS 15, and other use cases are to be published in OntoUML/UFO Catalog.

The standard-setting process can benefit from the use of ontology engineering tools, anti-pattern recognition, and stereotype specialization, which help in reducing notable overlaps between Frameworks and Standards. Conversely, the development of core ontologies serves as a crucial validation mechanism for foundational ontologies.

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