1. Exchanging Complex Financial Information

This section provides a summary of issues and concerns related to representing and exchanging complex information using machine-based processes. After all, the fundamental purpose of a general purpose financial report is to communicate information about the financial status and financial performance of an economic entity.

Fundamentally, an XBRL-based report provides a mechanism to represent and exchange complex information reliably and with high-quality.

The document *Special Theory of Machine-based Automated Communication of Semantic Information of Financial Statements*[1] provides a theory of semantic communication as it relates to financial statements in terms a professional accountant can understand. This section summarizes that important information.

1.1. Understanding the Problem

The following problem description was inspired by a similar sort of description by Harry S. Delugach, Associate Professor of Computer Science, in a presentation, *Common Logic Standards Development*, (page 7). Fundamentally, a financial statement serves this purpose:

> Two economic entities, A and B, each have information about their financial position and financial performance. They must communicate their information to an investor who is making investment decisions which will make use of the combined information so as to draw some conclusions. All three parties (economic entity A, economic entity B, investor) are using a **common set of basic logical principles** (facts, statements, deductive reasoning, etc.), **common financial reporting standard terms and associations between terms** (terms, associations, structures, assertions for a reporting scheme US GAAP, IFRS, IPSAS, etc.), and a **common world view** so they should be able to communicate this information fully, so that any inferences which, say, the investor draws from economic entity A's information should also be derivable by economic entity A itself using common basic logical principles, common financial reporting standards (terms, associations, structures, assertions), and common world view; and vice versa; and similarly for the investor and economic entity B.

This problem has been effectively solved for hundreds of years via the use of paper-based and human readable general-purpose financial statements. Today there is a new opportunity. That new opportunity is to automate this process using machine-readable financial information.

To be crystal clear, financial statements I am describing are not, should not, and need not be forms. Rather, financial reporting schemes used to create the financial statements I am describing intentionally allow variability in how economic entities provide the quantitative and qualitative information about the economic entity.

[1] *Special Theory of Machine-based Automated Communication of Semantic Information of Financial Statements*, http://xbrlsite.azurewebsites.net/2019/Library/SpecialTheoryOfSemanticCommunicationOfFinancialInformation.pdf

Report creators are allowed to "reshape" or "alter" or other such modifications within a specific set of boundaries.

This specific use case is clearly articulated in the conceptual frameworks of both US GAAP[2] and IFRS[3] and really cannot be disputed.

Finally, it is worth pointing out that financial reporting schemes have five things in common that can be leveraged in the communication of financial statement information and are unique to financial reporting schemes:

- *First*, at the foundation of every financial reporting scheme is the double-entry accounting model[4]. Simply stated, that model is: **DEBITS = CREDITS**. It is a mathematical model. (If you don't understand this model, this video is helpful[5]!)
- *Second*, building on the double-entry accounting model is the accounting equation[6]: **Assets = Liabilities + Equity**.
- *Third*, every financial reporting scheme defines a core set of interrelated elements of a financial statement that are fundamentally grounded in some form of the accounting equation. For example, the Financial Accounting Standards Board (FASB) defines these ten elements of a financial statement in SFAC 6[7]; Assets, Liabilities, Equity, Comprehensive Income, Investments by Owners, Distributions to Owners, Revenues, Expenses, Gains, Losses. Then, additional elements are defined based on that core set.
- *Fourth*, every financial reporting scheme has what is called "articulation". Articulation is the notion that the elements of a financial statement are interrelated and therefore depend on one another and so the four core statements; the balance sheet, the income statement, the changes in equity and the cash flow statement are all mathematically interrelated. Articulation is explained very methodically by the FASB in SFAC 6[8].
- *Fifth*, every financial report has inherent variability that is the result of explicitly allowing intermediate components of a financial report (i.e. subtotals) to be combined in appropriate but perhaps different ways depending on the needs of the reporting economic entity. Again, this is explained in detail within SFAC 6[9].

These five special characteristics of a financial reporting scheme and therefore of a financial statement created using such a financial reporting scheme offers benefits above and beyond the general communication of words and numbers. As such, this paper focuses on the special case of communication of financial statement information as contrast to the more general communication of information.

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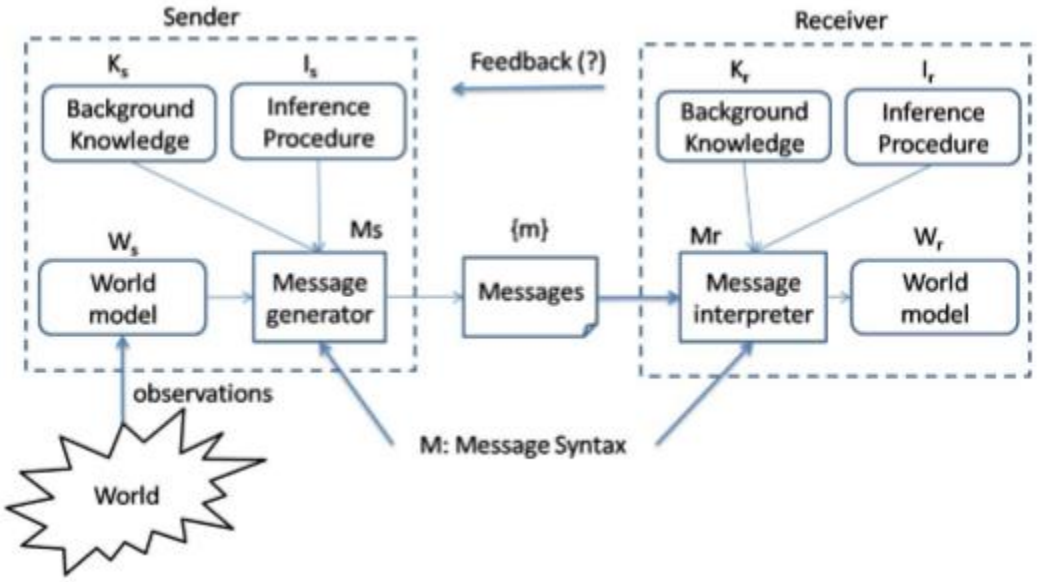
[2] Financial Accounting Standards Board (FASB), *Statement of Financial Reporting Concepts No. 6, Elements of a Financial Statement*, https://www.fasb.org/pdf/con6.pdf
[3] International Accounting Standards Board (IASB), *Conceptual Framework for Financial Reporting*, March 2018, https://www.ifrs.org/issued-standards/list-of-standards/conceptual-framework/
[4] David P. Ellerman, *The Mathematics of Double Entry Bookkeeping*, Mathematics Magazine, http://www.ellerman.org/wp-content/uploads/2012/12/DEB-Math-Mag.CV_.pdf
[5] YouTube, *2016 Debit Credit Theory Accounting Rap Song from O'Neill High School*, https://www.youtube.com/watch?v=PHanSCcMb_I
[6] Wikipedia, *Accounting Equation*, https://en.wikipedia.org/wiki/Accounting_equation
[7] ibid, page 23.
[8] ibid, page 21 – 22, "Interrelation of Elements-Articulation"
[9] Ibid, page 47, paragraph 77.

However, it is believed that general communication of semantic information can also benefit from the ideas presented in this paper.

1.2. Graphic of Problem Statement

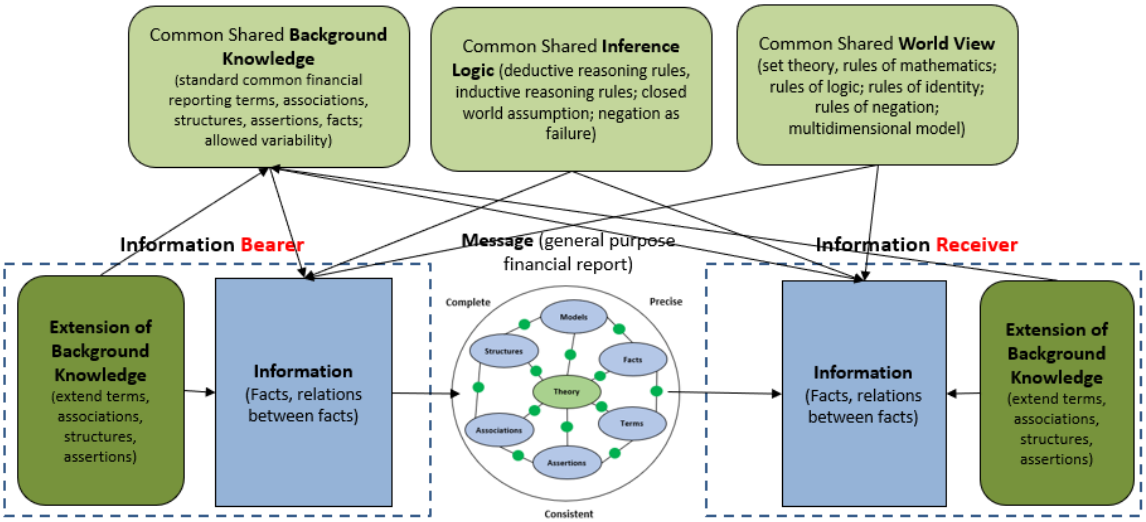
In their paper, *Towards a Theory of Semantic Communication*[10] , Jie Bao et. al. provides a visual description of the communications of information a copy of which I show below:



In the diagram, they assign variables and work through the mathematics of the problem of exchanging information from a sender to a receiver successfully. I will make the problem of communicating financial information (a) more representative of how communication of XBRL-based financial information works today and (b) easier for business professionals to understand.

The following is my visual description of the communication of financial information that is inspired by the description provided by Jie Bao. Et.al.:

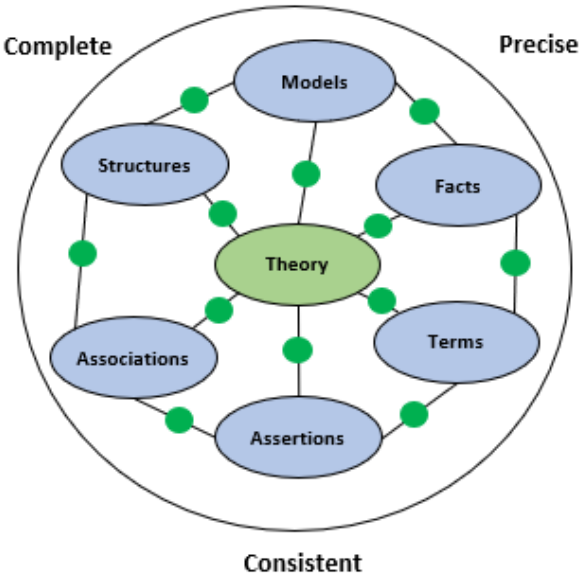
[10] Jie Bao et.al., *Towards a Theory of Semantic Communication*, page 5, Fig. 2. Semantic Information Source and Destination, https://pdfs.semanticscholar.org/fa34/3407847eea1f7e8bb8d3d7489b6945e2b0b2.pdf



The general idea of my visual image is the same as Jie Boa et. al., however there are some specific differences that are intentional and make the communication of financial information easier.

First, Jie Boa et. al. state that the world view of the information sender (W_s) and receiver (W_r) are perhaps different and then reconciled. This is similar for the inference procedure (I_s, I_r) and background knowledge (K_s, K_r). What I am trying to communicate is the notion that as many differences as possible would be eliminated from the communications problem. As such, the "World View", the "Inference Logic" and as much of the "Background Knowledge" as possible would be agreed to in advance of any financial statement information exchange. Both the information bearer and information receiver agree on the world view, inference logic, and background information in advance as part of the information exchange process. However, information can be extended but the extension information is carefully associated with the common shared background knowledge.

The "message" of this overall system is the general-purpose financial report which is likewise a man-made logical system. There is nothing natural about a general-purpose financial report, the idea was created by humans to serve a purpose. That purpose is to effectively exchange information about the financial position and financial condition of an economic entity. Initially, that was done on clay tablets. Then on papyrus. Then paper. Then e-paper. Now XBRL-based digital format. That digital format, the logical system, is consciously configured to make it machine-readable by software applications. Graphically, the "message", the general-purpose financial report, is a provably properly functioning logical system (a.k.a. logical theory) which is consistent, complete, and precise:



Fundamentally, it is the conscious intension of this logical system to safely, reliably, and otherwise successfully communicate financial information. The stakeholders fundamentally agree to eliminate all possible features that introduce potential failure and to leverage all possible features that lead to success. Fundamentally, the goal is to succeed. This is done by agreeing to agree. The specifics of how new information is carefully added to the common shared background knowledge is explained in a later section.

1.3. Principles

Principles help you think about something thoroughly and consistently. Overcoming disagreements between stakeholders and even within groups of stakeholders is important and principles can help in that communications process. The following principles make clear important considerations when communicating financial information in machine-readable form:

- A general-purpose financial report is a high-fidelity, high-resolution, high-quality information exchange mechanism. Its intension is to, as best as practical, to faithfully represent a set of claims made by an economic entity about the financial position and financial performance of an economic entity. (i.e. a financial report is not arbitrary, is not random, is not illogical)
- Prudence dictates that using information from a financial report should not be a guessing game.
- All formats conveying the same set of financial information should convey the exact same meaning regardless of the information format be that format paper, e-paper, or some machine-readable format.
- Explicitly stated information or reliably derived information from information bearers is preferable to requiring information receivers to make assumptions.
- The double entry accounting model enables automation of processes that allow for the detection of information errors and to distinguish errors (unintentional) from fraud (intentional).

- The accounting equation, "Assets = Liabilities + Equity" is the foundation of every financial reporting scheme. There are various other forms of this equation which are semantically equivalent including, "Net Assets = Assets – Liabilities"
- Catastrophic logical failures are to be avoided at all cost as they cause systems to completely fail.

It would be, in my personal view, highly unlikely that anyone that fundamentally desires to effectively communicate machine-readable to disagree with any of the principles.

1.4. Logical Systems (a.k.a. Logical Theory)

There are many approaches which can be used to describe something logically. A **logical system** (a.k.a. logical theory) is one such approach which enables a community of stakeholders trying to achieve a specific goal or objective or a range of goals/objectives to agree on important common models, structures, and statements for capturing meaning or representing a shared understanding of and knowledge in some universe of discourse.

A financial report is a logical system. Financial reports represent economic phenomena in words and numbers. A financial report is a faithful representation of a set of claims made by an economic entity about the financial position and financial performance of an economic entity. (i.e. a financial report is not arbitrary, is not random, is not illogical).

A logical system or logical theory is made up of a set of models, structures, terms, associations, assertions, and facts[11]. In very simple terms,

- **Logical theory**: A *logical theory* is a set of models that are consistent with and permissible per that logical theory.
- **Model**: A *model* is a set of structures. A model is a permissible interpretation of a theory.
- **Structure**: A *structure* is a set of statements which describe the associations and assertions of the structure. (A structure provides context.)
- **Statement**: A statement is a proposition, claim, assertion, belief, idea, or fact about or related to the universe of discourse to which the logical theory relates. There are four broad categories of statements:
  - **Terms**: Terms are statements that define ideas used by the logical theory such as "assets", "liabilities", and "equity".
  - **Associations**: Associations are statements that describe permissible interrelationships between the terms such as "assets is part-of the balance sheet" or "operating expenses is a type-of expense" or "assets = liabilities + equity" or "an asset is a 'debit' and is 'as of' a specific point in time and is always a monetary numeric value".
  - **Assertions**: Assertions are statements that describe expectations that tend to be IF…THEN…ELSE types of relationships such as "IF the

[11] Charles Hoffman, CPA, Explanation of a Financial Report Logical System in Simple Terms, http://xbrl.squarespace.com/journal/2019/11/1/explanation-of-a-financial-report-logical-system-in-simple-t.html

economic entity is a not-for-profit THEN net assets = assets - liabilities; ELSE assets = liabilities + equity".

- **Facts**: Facts are statements about the numbers and words that are provided by an economic entity within their financial report. For example, "assets for the consolidated legal entity Microsoft as of June 20, 2017 was $241,086,000,000 expressed in US dollars and rounded to the nearest millions of dollars.

A financial report has a finite set of statements (structures, terms, associations, assertions, and facts) within the report. The set of statements is definite. That definite set of statements forms a model. (With any field of knowledge, the critical concepts of the field are embedded in the definitions of the field's technical terms. The term 'statement' in financial reporting is different than that same term 'statement' as is being used here.)

A logical system is said to be **consistent** if there are no contradictions with respect to the statements made by the logical system.

A logical system can have high to low **precision** and high to low **coverage**. *Precision* is a measure of how precisely the information within a logical system has been represented as contrast to reality for the universe of discourse. *Coverage* is a measure of how completely information in a logical system has been represented relative to the reality for a universe of discourse.

If the models, structures, terms, associations, assertions, and facts have high precision and high coverage, and if all the statements within the logical system are consistent; then the logical system can be proven to be properly functioning. If you have a properly functioning logical system then you can create a chain of reasoning[12].

1.5. Distilling Problem Down to Logic and Math

Rather than look at all the different moving pieces of this puzzle as being from different silos; I choose to leverage the best practices, safest practices, and create a solid, powerful, practical, and reliable system that business professionals can effectively understand and leverage by using other proven systems. Business professionals need not understand each individual theory, only that the theory has been proven. Equilibrium is achieved by weaving the appropriately selected other systems based on the goals and objectives agreed to by the stakeholders of the information exchange mechanism.

A logical system[13] is a type of formal system[14]. To be crystal clear what I am trying to create is a **finite model-based deductive first-order logic system**[15]. "Finite" as opposed to "infinite" because finite systems can be explained by math and logic, infinite systems cannot. "Model-based" is the means to address the necessary variability inherent in the required system. "Deductive", or rule-based, as contrast to inductive which is probability based which is not appropriate for this task. "First-

[12] Charles Hoffman, CPA, *Constructing a Chain of Reasoning*, http://xbrl.squarespace.com/journal/2019/9/26/constructing-a-chain-of-reasoning.html

[13] Wikipedia, *Logical Systems*, https://en.wikipedia.org/wiki/Logic#Logical_systems

[14] Wikipedia, *Formal System*, https://en.wikipedia.org/wiki/Formal_system

[15] Wikipedia, *First-order Logic, Deductive System*, https://en.wikipedia.org/wiki/First-order_logic#Deductive_systems

order logic" because first-order logic can be safely implemented within software applications and higher order logics are unsafe. "System" because this is a system.

The point is to create a logical system that has high expressive capabilities but is also a provably safe and reliable system that is free from catastrophic failures and logical paradoxes which cause the system to completely fail to function. To avoid failure, computer science and knowledge engineering best practices seems to have concluded that the following alternatives are preferable:

- **Systems theory**: A system[16] is a cohesive conglomeration of interrelated and interdependent parts that is either natural or man-made. Systems theory explains logical systems. Systems have patterns.
- **Representation theory**: Representation theory[17] is a way of taking complicated objects and "representing" them with simpler objects.
- **Logical theory**: (a.k.a. logical system) There are many approaches to representing "ontology-like things" in machine-readable form, a logical theory being the most powerful. Theories describe patterns. (see the ontology spectrum[18])
- **Proof theory**: The ideas of proof theory[19] can be used to verify the correctness of logical systems and computer programs working with those machine-readable logical systems using mathematics[20]. Proofs verify theories.
- **Model theory**: Model theory is a way to think about flexibility. Safer finite model theory[21] is preferable to general model theory. Models provide flexibility.
- **Set theory**: Set theory is foundational to logic and mathematics. Axiomatic (Zermelo–Fraenkel) set theory[22] is preferred to naïve set theory.
- **Graph theory**: Directed acyclic graphs[23] are preferred to less powerful "trees" and graphs which contain cycles that can lead to catastrophic problems caused by those cycles.
- **Logic**: Logic is a formal communications tool. Horn logic[24] is a subset of first-order logic which is immune from logical paradoxes should be used as contrast to more powerful but also more problematic first order logic features. Note that deductive reasoning is leveraged for the process of creating a financial report and not inductive reasoning (i.e. machine learning).

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[16] Wikipedia, *Systems Theory*, https://en.wikipedia.org/wiki/Systems_theory

[17] Representation theory, http://xbrl.squarespace.com/journal/2021/1/11/representation-theory.html

[18] *Difference between Taxonomy, Conceptual Model, Logical Theory*, http://xbrl.squarespace.com/journal/2018/12/11/difference-between-taxonomy-conceptual-model-logical-theory.html

[19] Stanford University, *The Development of Proof Theory*, *The Aims of Proof Theory*, https://plato.stanford.edu/entries/proof-theory-development/#AimProThe

[20] Samuel R. Buss, *An Introduction to Proof Theory*, https://math.ucsd.edu/~sbuss/ResearchWeb/handbookI/ChapterI.pdf

[21] Wikipedia, *Finite Model Theory*, https://en.wikipedia.org/wiki/Finite_model_theory

[22] Wikipedia, *Set Theory, Axiomatic Set Theory*, https://en.wikipedia.org/wiki/Set_theory#Axiomatic_set_theory

[23] Wikipedia, *Directed Acyclic Graph*, https://en.wikipedia.org/wiki/Directed_acyclic_graph

[24] Wikipedia, *Horn Logic*, https://en.wikipedia.org/wiki/Horn_clause

- **World view**: The following are common issues which appear when implementing logical systems in machine-readable form, the safest and most reliable alternatives are:
    - closed world assumption[25] which is used by relational databases is preferred to the open world assumption which can have decidability issues;
    - negation as failure[26] should be explicitly stated;
    - unique name assumption[27] should be explicitly stated;

Business professionals are (a) not capable of having precise discussions of these sorts of issues with software engineers, (b) don't care to have such technical discussions about these sorts of issues with software engineers, (c) are not interested in the theoretical or philosophical or religious debates that commonly exist related to these alternatives, (d) if the alternatives were ***appropriately articulated to a business professional***, who tend to be very practical, they would most often error on the side of safety and reliability. As such, we have made all of the above decisions which are consistent with modern logic programming paradigms such as Prolog, Datalog, and Answer Set Programming[28]. Business professionals can simply use this system if they desire to do so, they don't need to reinvent the wheel.

A logical system or logical theory can be made flexible precisely where they need to be flexible using model theory[29]. Model theory essentially allows for any number of permissible interpretations of the logical theory, referred to as models. There are various forms of model theory including first order model theory[30], finite model theory[31], and the consciously and intentionally very safe finite first order model theory.

It is not important to understand the specific details of model theory, although it is very helpful to have a basic understanding[32]. I am not trying to prove the mathematics or logic of model theory; as I understand it that has already been proven.

What I am trying to do is apply the most powerful but also the safest, most reliable version of system theory, graph theory, model theory, set theory, logic, etc. in order to have the most expressive system possible that is also very safe and well behaved.

I can provide empirical evidence in the form of working representations of what I would call a finite model-based deductive first-order logic system using the global standard XBRL technical syntax language. Several of these examples have also been represented using Prolog; the XBRL and Prolog language representations yielding the same result.

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[25] Wikipedia, *Closed World Assumption*, https://en.wikipedia.org/wiki/Closed-world_assumption

[26] Wikipedia, *Negation as Failure*, https://en.wikipedia.org/wiki/Negation_as_failure

[27] Wikipedia, *Unique Name Assumption*, https://en.wikipedia.org/wiki/Unique_name_assumption

[28] Charles Hoffman, CPA, *Understanding Answer Set Programming*, http://xbrl.squarespace.com/journal/2019/5/10/understanding-answer-set-programming.html

[29] Wikipedia, *Model Theory*, https://en.wikipedia.org/wiki/Model_theory

[30] Stanford University, *First Order Model Theory*, https://plato.stanford.edu/entries/modeltheory-fo/

[31] Wikipedia, Finite Model Theory, https://en.wikipedia.org/wiki/Finite_model_theory

[32] LessWrong, *Very Basic Model Theory*, https://www.lesswrong.com/posts/F6BrJFkqEhh22rFsZ/very-basic-model-theory

All the characteristics of the logical system that I point out are "necessary" meaning that they *must exist* within the logical system. What I cannot prove is that the characteristics are "sufficient" to prove that the logical system is provably consistent, precise, and complete. Perhaps a mathematician can provide this proof. But, in my view, the empirical evidence goes a long way towards proving this logical theory. Whether it goes far enough is up to others to determine.

1.6. Think Knowledge Graph

A **knowledge graph** is one approach to storing information within a knowledge base. Knowledge graph is more or an analogy or buzz word dreamed up by in 2012 to describe the functionality you get when you use a set of web standards. A knowledge graph has four core building blocks:

- **Resolvable Identity**: a unique web address is assigned to each term in the form of an individual resource identifier (IRI). The IRI becomes the Rosetta stone for identity resolution allowing anyone to link data wherever it resides to one master identifier, eliminating the need to continually map information.
- **Ontologies**: data modeling is a communications process to ensure a shared understanding of requirements between business stakeholders and applications developers. The Web standard uses conceptual data models (ontologies) to describe what the information means as well as how terms are connected (associations). These ontologies link the meaning of information to business glossaries that can be directly translated into physical information structures.
- **Triple Expression**: the triple expression method (subject-predicate-object) is similar to classical conceptual modeling approaches. The subject denotes a resource, the predicate denotes traits or aspects of the resource, and expresses a relationship between the subject and the object. As such, information is defined at its most granular level.
- **Business Rules**: Data quality and structural business rules are linked to the ontologies to ensure that meaning is shared. The logic of these rules is captured and expressed as executable models and consistently enforced across all systems and processes.

Knowledge graphs is one of many different possible implementation approaches. Imagine a knowledge graph that exists within a digital distributed ledger and can be edited somewhat like a wiki.

1.7. Very Basic Model Example

The following is a very basic model of the accounting equation that I represented using XBRL and Prolog[33]:

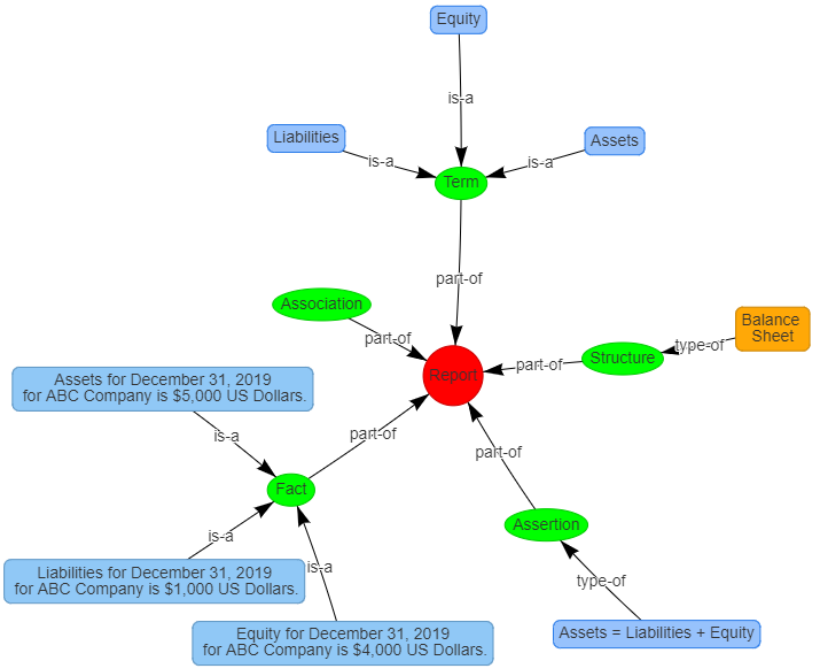
[33] Charles Hoffman, CPA, Accounting Equation, http://xbrlsite.azurewebsites.net/2019/Core/master-ae/

Balance Sheet [Abstract]	Period [Axis]
	2020-12-31
Balance Sheet [Abstract]	
Assets	5,000
Liabilities	1,000
Equity	4,000

Result	Rule
Pass	$Assets = $Liabilities + $Equity

To understand this very basic model in detail, please read the documentation[34]. The essence of what you see is one structure defined using the functional term "Balance Sheet [Abstract]" that has three simple terms "Assets", "Liabilities", and "Equity", and one assertion "Assets = Liabilities + Equity".

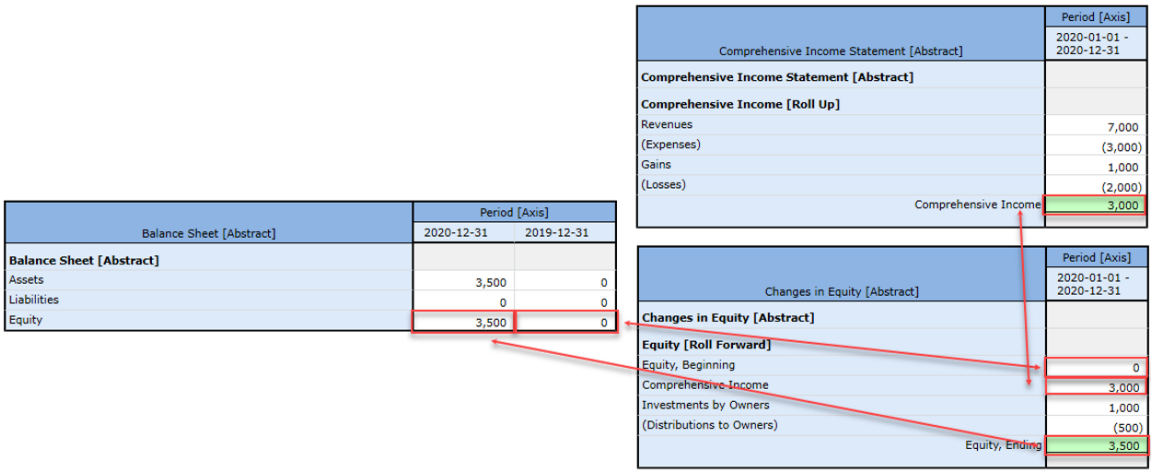
This very basic model example is not enough to create an actual financial statement but it does represent a demonstrably complete, precise, and consistent logical system. Here is an example of this information expressed as a knowledge graph:



[34] Charles Hoffman, CPA, Accounting Equation Documentation, http://xbrlsite.azurewebsites.net/2019/Core/master-ae/Documentation.pdf

1.8. Slightly More Complex, but still Basic Model Example

The following is a slightly more complex, but still pretty basic model that represents what is articulated by the FASB in SFAC 6 related to the elements of a financial statement[35]:



Balance Sheet [Abstract]	Period [Axis] 2020-12-31	2019-12-31
Balance Sheet [Abstract]		
Assets	3,500	0
Liabilities	0	0
Equity	3,500	0

Comprehensive Income Statement [Abstract]	Period [Axis] 2020-01-01 - 2020-12-31
Comprehensive Income Statement [Abstract]	
Comprehensive Income [Roll Up]	
Revenues	7,000
(Expenses)	(3,000)
Gains	1,000
(Losses)	(2,000)
Comprehensive Income	3,000

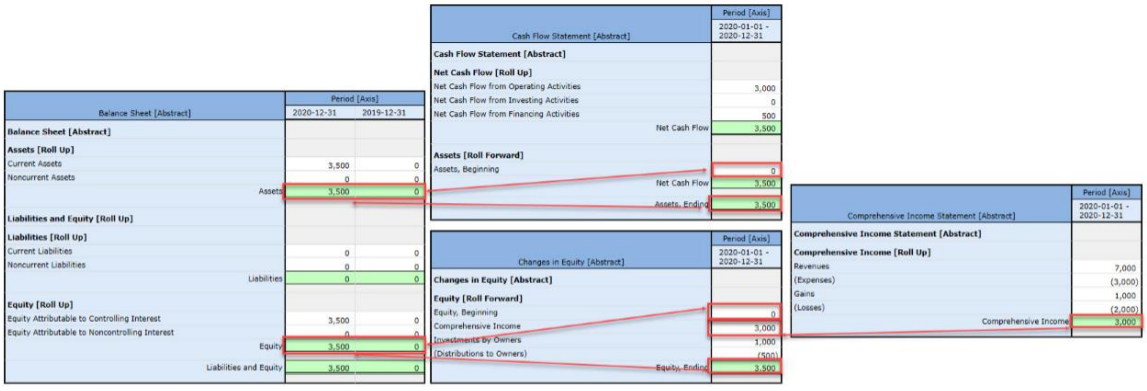
Changes in Equity [Abstract]	Period [Axis] 2020-01-01 - 2020-12-31
Changes in Equity [Abstract]	
Equity [Roll Forward]	
Equity, Beginning	0
Comprehensive Income	3,000
Investments by Owners	1,000
(Distributions to Owners)	(500)
Equity, Ending	3,500

Again, the best way to understand all the details are to read the documentation[36]. The essence of the representation, again both in XBRL and Prolog, are three interconnected structures, ten terms, and three rules defined by SFAC 6.

Again, this slightly more complex, but still pretty basic model is a demonstrably complete, precise, and consistent logical system.

1.9. Four Statement Model Example (Common Elements of Financial Statement)

The following is again another slightly more complex model[37], still pretty basic model that expands on the FASB's SFAC 6 adding additional elements that no professional accountant could really dispute:



[35] Charles Hoffman, CPA, SFAC 6, http://xbrlsite.azurewebsites.net/2019/Core/core-sfac6/

[36] Charles Hoffman, CPA, SFAC 6 Documentation, http://xbrlsite.azurewebsites.net/2019/Core/core-sfac6/Documentation.pdf

[37] Charles Hoffman, CPA, Common Elements of Financial Statement (Four Statement Model), http://xbrlsite.azurewebsites.net/2019/Core/master-elements/

Again, the documentation provided helps one understand the representation in detail[38]. What you see are four interconnected structures, 20 terms, four assertions, 29 facts, and a plethora of associations.

1.10. MINI Financial Reporting Scheme

The accounting equation example, the SFAC 6 example, and the Four Statement Model example were created because they are grounded in well understood accounting ideas but were small enough to understand all the moving pieces of the puzzle without the need of automated processing to prove that everything works as would be expected. Humans can simply look and see that everything works as expected.

The MINI Financial Reporting Scheme example[39] takes a significantly larger step toward what an actual financial report might look like. While the MINI Financial Reporting Scheme might look relatively small, don't be fooled by its simplicity. The MINI example contains 100% of the use cases that one will ever find in an XBRL-based digital financial report. The example was intentionally engineered to be a comprehensive test of XBRL-based financial reports. This example is explained in the document, *Proving Financial Reports are Properly Functioning Logical Systems*[40]. It is also compared and contrasted to the smaller examples and then to a complete 10-K financial report of Microsoft. I believe that this helps the reader bridge the gap between the smaller examples and larger, actual financial reports.

Looking at these examples, patterns emerge.

1.11. Patterns Documented with Standard Business Report Model (SBRM)

Examining the patterns[41] of the first four examples, an additional small financial reporting scheme representation[42], and reconciling all examples to a full 10-K financial statement of a public company in the document *Proving Financial Reports are Properly Functioning Logical Systems*[43], shows that all of these financial report related representations (a) follow the documented logical system of a financial report and (b) point out an even more detailed model of a business report and financial report that is documented in the forthcoming OMG standard, *Standard Business Report Model (SBRM)*[44].

While the more detailed patterns are quite helpful at arriving at the fundamental description of a logical theory of a financial report; it is the logical theory of a

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[38] Charles Hoffman, CPA, Common Elements of Financial Statement , http://xbrlsite.azurewebsites.net/2019/Core/master-elements/CommonElementsOfFinancialStatement.pdf

[39] Charles Hoffman, CPA, *MINI Financial Reporting Scheme*, http://xbrlsite.azurewebsites.net/2019/Prototype/mini/documentation/Index.html

[40] Charles Hoffman, CPA, *Proving Financial Reports are Properly Functioning Logical Systems*, http://xbrlsite.azurewebsites.net/2019/Library/ProvingFinancialReportAreProperlyFuncioning.pdf

[41] YouTube, *The Science of Patterns*, https://www.youtube.com/watch?v=kh6KMW8J3RQ

[42] Charles Hoffman, CPA, MINI Financial Reporting Scheme, http://xbrlsite.azurewebsites.net/2019/Prototype/mini/documentation/Home.html

[43] Charles Hoffman, CPA, *Proving Financial Reports are Properly Functioning Logical Systems*, http://xbrlsite.azurewebsites.net/2019/Library/ProvingFinancialReportAreProperlyFuncioning.pdf

[44] *OMG Standard Business Report Model (SBRM) Initial Submission Information*, http://xbrl.squarespace.com/journal/2019/11/15/omg-standard-business-report-model-sbrm-initial-submission-i.html

financial report itself which explains how to effectively communicate semantic information. That high-level theory explains what statements must be communicated and that those statements must be consistent, complete, and precise.

Finally, the impediments to a properly functioning logical system document the properties that must exist within a logical system for it to be considered proper functioning.

- Improper XBRL presentation relations associations
- Improper use of a class of line item as if were some different class
- Inconsistent or contradictory reported information
- Improper structure of disclosures
- Machine-readable reporting checklist of required disclosures

When all of these impediments are overcome, then semantic information can be effectively communicated. Note that (a) improper language syntax, in this case XBRL, is a given and (b) does not tend to be a problem because of the rigorous conformance suite used with effectively guarantees interoperability because 100% of the conformance suite is automated.

And so, to effectively communicate semantic information the five impediments described above simply need to be mitigated. Empirical evidence exists that shows the reliable detection of these impediments, the correction of the impediment, and the resulting properly functioning logical system, the XBRL-based digital financial report.

But none of this necessarily guarantees that *every model* that needs to be created can be created and how to control would could be an arbitrarily large set of finite models.

1.12. Arbitrarily Large Set of Finite Models

No one would really dispute that it is possible to effectively exchange information from some sender to some receiver if the machine-readable message is a form and both the sender and receiver of the information have exactly the same world view, use the inference logic (basically no inference logic is really necessary), and have the same knowledgebase.

For example, take this very simple form[45]:

[45] Company 1, http://xbrlsite.azurewebsites.net/DigitalFinancialReporting/mini/repository/company1/evidence-package/contents/index.html#Rendering-PropertyPlantAndEquipmentDetail-mini_PropertyPlantAndEquipmentSubclassificationsHypercube.html

Property, Plant and Equipment Subclassifications [Line Items]	Period [Axis]	
	2018-12-31	2017-12-31
Property, Plant and Equipment [Roll Up]		
Property, Plant and Equipment, Gross [Roll Up]		
Land	1,000	1,000
Buildings	1,000	0
Equipment	4,000	0
Property, Plant and Equipment, Gross	6,000	1,000
Accumulated Depreciation	0	0
Property, Plant and Equipment	6,000	1,000

If every economic entity were required to report the roll up of property, plant, and equipment subclassifications in exactly the same manner using exactly the same concepts and still used the same world view and inference assumptions I think it would be easy to understand that the communication of such information in machine-readable form would be trivial.

However, that is not the way financial reporting schemes work. For example, the following is a possible allowed interpretation of what amounts to the breakdown of the subclassifications of property, plant and equipment:

Property, Plant and Equipment Subclassifications [Line Items]	Period [Axis]	
	2018-12-31	2017-12-31
Property, Plant and Equipment [Roll Up]		
Property, Plant and Equipment, Gross [Roll Up]		
Land and Buildings	2,000	1,000
Computer Equipment	2,000	0
Manufacturing Equipment	2,000	0
Property, Plant and Equipment, Gross	6,000	1,000
Accumulated Depreciation	0	0
Property, Plant and Equipment	6,000	1,000

What is different between the first example and the second example is the subclassifications of the line items that are actually disclosed. Note that in the above representation the subclassifications "Land" and "Buildings" have been combined and that "Equipment" has been disaggregated and "Computer Equipment" and "Manufacturing Equipment" have been reported.

This sort of variability is common in financial reports and can make it more challenging for those who desire to make use of the information reported to do so effectively. Even though one could effectively argue that the two examples of property, plant, and equipment disclosures would be quite easy to compare; it is easy to grasp that if, say, the sub total and the grand total concepts were also changed that could make using the information more challenging.

So, the fact that for the past 10 years thousands of U.S. public companies have created literally tens of thousands of reports using XBRL and have submitted the reports to the U.S. Securities and Exchange Commission is evidence that it is possible to represent both models of the subclassifications of things such as property, plant, and equipment effectively.

However, can the information be used effectively by financial analysts?

Complains about information quality, the excessive use of extension concepts, and other such complaints that tend to be rather general in nature (as compared to very precise and specific complains). Also, the goal is not to complain; rather, the objective is to effectively communicate financial information between the sender/creator of the information and the receiver/analyst that would like to actually make use of the reported financial information.

The next section shows that it is possible to reliably extract information from a digital financial report if the appropriate machine-readable statements are provided within the financial report logical system.

1.13. Extending Models and Providing Important Properties

Essentially, the primary financial statements and the related policies and disclosures provided in the disclosure notes can be represented using any allowed alternative model. This does not mean that disclosures can be "random" or "illogical" or completely "arbitrary". Rational thinking does play a role here. What is allowed can be a bit subjective because the existing financial reporting standards can be ambiguous in some areas. But, given some interpretation of the financial reporting standards whether a disclosure is allowed or not allowed can be quantified into some finite set of possible disclosures. That finite set of possible disclosures can be represented using the XBRL technical syntax.

So intuitively, one could imagine that it is possible to represent the finite set of possible information representations into some number of what would amount to forms for each possible representation alternative allowed for each possible disclosure. Potentially a lot of work, but certainly possible.

But how do those that wish to use the information reported within a specific disclosure actually locate that specific allowed alternative disclosure within the set of all disclosures which make up a financial statement? It is possible to actually physically name each of those possible disclosures[46].

And so how does XBRL-based financial reporting satisfy both the needs of economic entities reporting information and the needs of analysts to consume that information? The short answer is consciously, skillfully, and consistently.

The ESMA's use of "wider-narrower" association and "anchoring" is one possible approach[47]. Although, this approach has always existed in XBRL via the "general-special" association. So, for example, two things are necessary to satisfy the property, plant, and equipment example shown.

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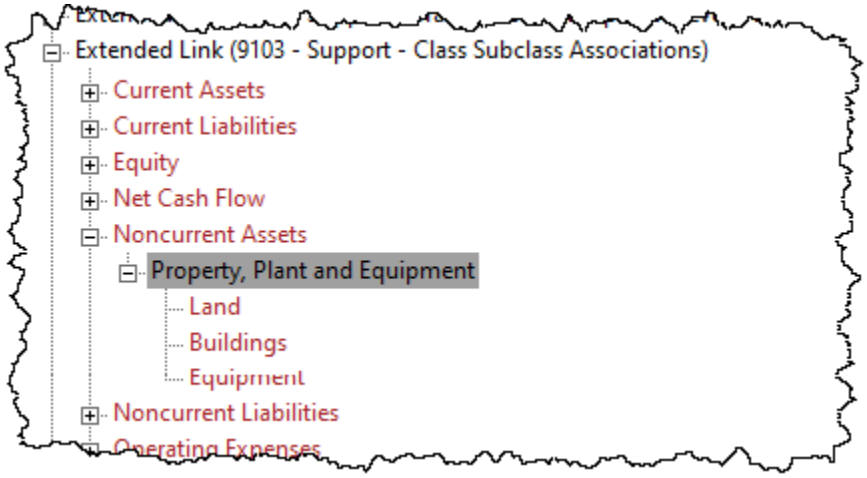
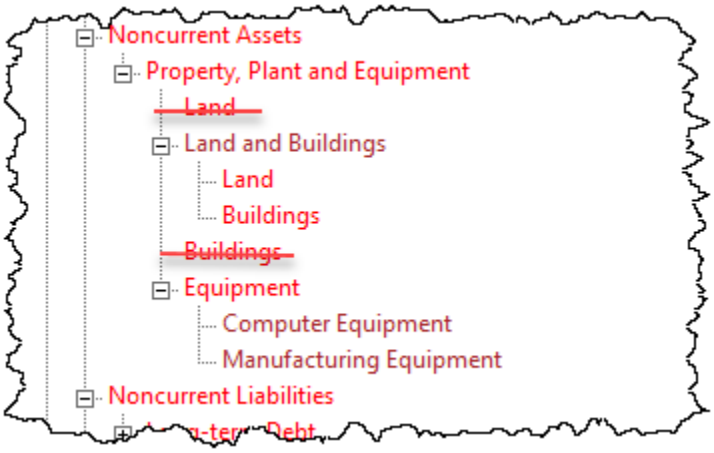
[46] *US GAAP Disclosures*, http://xbrlsite.azurewebsites.net/2020/reporting-scheme/us-gaap/documentation/Disclosures.html

[47] *ESMA Explains Anchoring and 2020 ESEF Implementation Requirement*, http://xbrl.squarespace.com/journal/2019/3/1/esma-explains-anchoring-and-2020-esef-implementation-require.html

First, some explicit structure is necessary to anchor to. For example, here are a set of "general-special" relations represented in a prototype XBRL taxonomy:



Then second, once the context is clear (i.e. which structure you are working within), then new associations can be established per the model of the reporting economic entity relative to the base model of the financial reporting scheme:



In this manner, any extended concept that is defined relative to some existing base model concept can be understood correctly per the "wider-narrower" or "general-special" association and anchoring to that existing concept.

That works when there is some base taxonomy report element that can be anchored to. But what about a completely new structure?

This is a completely new structure which has an existing report element from the base taxonomy as part of that new structure.

Finished Goods Subclassifications [Line Items]	Period [Axis]	
	2018-12-31	2017-12-31
Finished Goods [Roll Up]		
Product Foxtrot	300	550
Product Golf	100	50
Product Hotel	100	50
Product India	100	50
Finished Goods	600	700

Finally, below you see a completely new structure that is in no way associated with any existing report element that is defined within the base financial reporting scheme model:

Etiam [Roll Up]	Period [Axis]	
	2018-12-31	2017-12-31
Etiam [Roll Up]		
Eu eleifend augue	600	700
Est aliquet ante	200	100
Nunc mattis aliquam	200	200
Etiam	1,000	1,000

But just because some new completely new structure with completely new report elements does not mean that nothing is known about the new structure.

When a new extension is created, there are exactly four possibilities of how that new idea can be associated to some potentially existing idea:

- More general idea
- More specific idea
- Similar idea
- Completely new Idea

Even if the idea is completely new, because of the fundamental primitive building blocks of XBRL-based reports, every completely new thing must be (per XBRL syntax rules as restricted by SEC EDGAR Filing manual rules) represented using one of the primitive building blocks provided by XBRL.

Below you see those primitive building blocks:

- **Term (primitive or atomic term)**
  - Dimension (a.k.a. Axis)
  - Member
  - Primary Items (a.k.a. Line Items)
  - Abstract
  - Concept
    - Level 1 Note Text Block
    - Level 2 Policy Text Block
    - Level 3 Disclosure Text Block
    - Level 4 Detail
- **Structure (functional term)**
  - Network
    - Document
    - Statement
    - Disclosure
    - Schedule
  - Hypercube (a.k.a. Table)
- **Associations**
  - Parent-child
  - Summation-item
  - Essence-alias
  - General-special
  - Other associations
  - Property associations
    - Concept-label
    - Label-role
    - Concept-reference
    - Reference-role
    - Reference-part
- **Assertion**
  - XBRL Formula or XBRL Calculation
- **Fact**

For brevity, some possibilities are not shown. But this makes the point that there is a finite set of primitive structures that can be used to create anything that is possible to add to a financial reporting scheme. No XBRL-based model can add any new ideas at the first two layers. It is only below those first to layers that creators of an extension can work with.

I have provided mappings of the XBRL-based report objects to the hierarchy above for both the accounting equation[48] and SFAC 6[49] examples. See the last page of the documentation.

[48] Accounting Equation example, Documentation, page 13, http://xbrlsite.azurewebsites.net/2019/Core/master-ae/Documentation.pdf#page=13

[49] SFAC 6 example, Documentation, page 21, http://xbrlsite.azurewebsites.net/2019/Core/core-sfac6/Documentation.pdf#page=21

1.14. Modifying Existing Associations

In addition to creating a new disclosure by extending the information of a base taxonomy with new information, it is possible to modify existing associations, correctly or incorrectly, and represent disclosures using alternative approaches.

For example, consider the following long-term debt maturities disclosure:

Long-term Debt Maturities [Line Items]	Period [Axis]	
	2018-12-31	2017-12-31
Long-term Debt Maturities [Roll Up]		
Matures in One Year	1,000	
Matures in Two Years	1,000	
Matures in Three Years	1,000	
Matures in Four Years	1,000	
Matures in Five Years	1,000	
Matures Thereafter	1,000	
Long-term Debt	6,000	1,000

Above the disclosure is represented as a roll up of a set of items to a total.

Below you see an alternative representation based on the fact that numerous public companies represent this same disclosure by modifying the set of associations, dropping the total, and simply providing information about the maturities without the total:

Long-term Debt Maturities [Line Items]	Period [Axis]
	2018-12-31
Long-term Debt Maturities	
Matures in One Year	1,000
Matures in Two Years	1,000
Matures in Three Years	1,000
Matures in Four Years	1,000
Matures in Five Years	1,000
Matures Thereafter	5,000

The point is not about whether either the version of the disclosure with the roll up total or the version without the total are both allowed or not. The point is that per model theory, it is possible to represent both representations or any other alternative that a public company creating this disclosure might come up with.

Representing the disclosure effectively and whether a represented disclosure is or is not allowed are two different questions.

1.15. Proper Use of Subclassifications

A taxonomy is not, or should not, be simply a list of terms. An XBRL taxonomy, at a very minimum, should provide a comprehensive set or sets of associations between

terms that document the proper use of the term. Consider this example of a cash flow statement:

Cash Flow Statement [Line Items]	Period [Axis] 2018-01-01 - 2018-12-31
Cash Flow Statement [Roll Forward]	
Net Cash Flow [Roll Up]	
Net Cash Flow Operating Activities [Roll Up]	
Collection of Receivables	3,000
Payment of Accounts Payable	(2,000)
Net Cash Flow Operating Activities	1,000
Net Cash Flow Financing Activities [Roll Up]	
Additional Long-term Borrowings 2	6,000
Repayment of Long-term Borrowings 2	(1,000)
Net Cash Flow Financing Activities	5,000
Net Cash Flow Investing Activities [Roll Up]	
Capital Additions of Property, Plant and Equipment 2	(5,000)
Net Cash Flow Investing Activities	(5,000)
Net Cash Flow	1,000
Cash and Cash Equivalents, Beginning Balance	3,000
Cash and Cash Equivalents, Ending Balance	4,000

Note that in the example above, the line items "Additional Long-term Borrowings" and "Repayment of Long-term Borrowings" are part of "Net Cash Flow Financing Activities". Contrast that to the example below which uses those two-line items as part of "Net Cash Flow from Investing Activities".

Cash Flow Statement [Line Items]	Period [Axis] 2018-01-01 - 2018-12-31
Cash Flow Statement [Roll Forward]	
Net Cash Flow [Roll Up]	
Net Cash Flow Operating Activities [Roll Up]	
Collection of Receivables	3,000
Payment of Accounts Payable	(2,000)
Net Cash Flow Operating Activities	1,000
Net Cash Flow Financing Activities [Roll Up]	
Capital Additions of Property, Plant and Equipment 2	(5,000)
Net Cash Flow Financing Activities	(5,000)
Net Cash Flow Investing Activities [Roll Up]	
Additional Long-term Borrowings 2	6,000
Repayment of Long-term Borrowings 2	(1,000)
Net Cash Flow Investing Activities	5,000
Net Cash Flow	1,000
Cash and Cash Equivalents, Beginning Balance	3,000
Cash and Cash Equivalents, Ending Balance	4,000

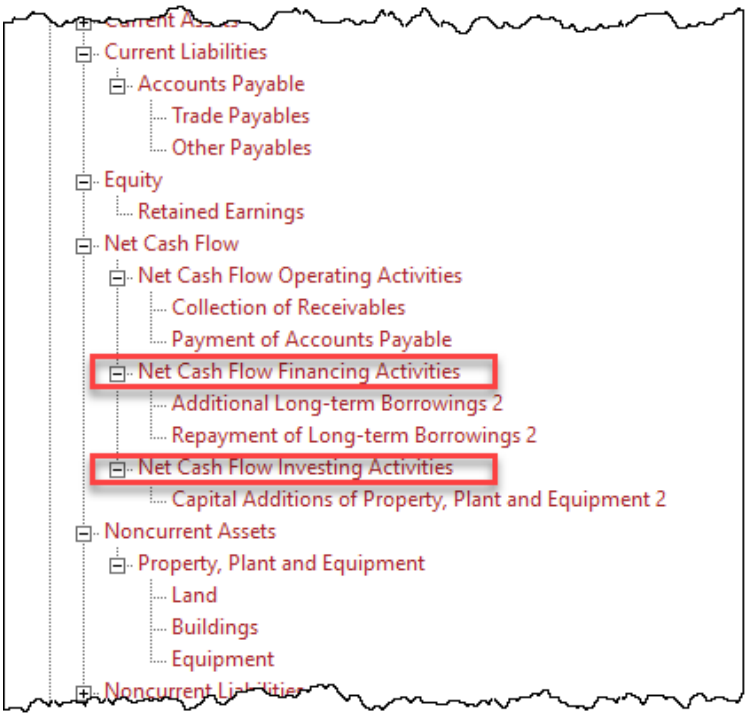
While for this specific example it is probably the case that every professional accountant would recognize that additional borrowings and repayments should be part of financing activities and not investing activities. But the obvious mistake was used to make a specific point.

How exactly do you communicate within an XBRL taxonomy where line items can, and cannot, be used? How do you know that something is a current asset and not a noncurrent asset?

Taxonomies have long been tools for representing this sort of information in the form of a hierarchy of "general" and "special" relations or perhaps "wider" or "narrower" concepts in the form of a thesaurus.

The same information can, should, and in fact must be articulated within an XBRL taxonomy or any other logical system that hopes to be effective and have the remotest chance of working effectively to communicate information represented in machine-readable form. For example, consider the following XBRL definition relations that represent "general-special" relations between concepts in order to assist users creating extension taxonomies and software engineers to assist in the

process of using the right line items within the right associations within a financial report.



And so, the proper use of subclassifications or "general-special" relations or "wider-narrower" relations are necessary to create quality financial report scheme relations and likewise financial reports that are correctly represented per that financial reporting scheme.

1.16. Proof based on Empirical Evidence

When Rene van Egmond and I first created the *Financial Report Semantics and Dynamics Theory*[50] back in 2012 we offered a proof that provided empirical evidence for that theory. Today, we can offer an improved proof based on empirical evidence.

There are two similar, but separate, sets of XBRL-based reports that are used to prove that the logical theory of an XBRL-based report works as is expected.

The **first set** is a set of 10-K and 10-Q XBRL-based financial reports of 5,716 public companies that have been submitted to the U.S. Securities and Exchange Commission and are all publicly available[51]. These were used to test the fundamental accounting concept relations of the financial reports.

The **second set** is the last 10-K financial report of 5,555 public companies that have been submitted to the U.S. Securities and Exchange Commission and are likewise all

[50] Charles Hoffman, CPA and Rene van Egmond, *Financial Report Semantics and Dynamics Theory*, http://xbrl.squarespace.com/fin-report-sem-dyn-theory/

[51] *Quarterly XBRL-based Public Company Financial Report Quality Measurement (March 2019)*, http://xbrl.squarespace.com/journal/2019/3/29/quarterly-xbrl-based-public-company-financial-report-quality.html

publicly available[52]. These were used to test the disclosure mechanics and reporting check list of each report.

The **first set** shows that of the 5,716 reports:

- Over 99.9% of all reports were valid XBRL technical syntax.
- 99.24% (124,790 relations) of all fundamental accounting relations were consistent with expectation.
- .76% (962 relations) were not consistent with expectation and each of the errors was manually examined and determined to be an error in the facts reported by the public company[53].
- 89.1% of all reports were 100% consistent with each of the fundamental accounting concept relations rules.

Excel-based extraction tools were created for 4,060 reports or 68% so anyone can rerun these tests[54].

For this first set, there are exactly six causes of errors and each error has a specifically identifiable task that would cause the error to be corrected and then be consistent with expectation:

1. **Fact** error in report. A report contained one or more errors in the facts reported within the report. To make this logical system consistent, the fact in the report simply needs to be corrected.
2. **Assertion** error in knowledge base**.** While we are unaware of any assertion errors in the knowledge base containing assertions (i.e. because all such errors were fixed because they were under our control); if there were an error in the assertion used to test facts, the assertion would be in error. To make this logical system consistent, the assertion in the knowledge base simply needs to be corrected.
3. **Association** error in knowledge base. A report contained one or more association errors in either the base taxonomy or the extension taxonomy. To make this logical system consistent, the association simply needs to be corrected.
4. **Structure** error in knowledge base (i.e. reporting style used is incorrect). A report could use the wrong structure (reporting style) to evaluate the report. To make this logical system consistent, the structure (reporting style) simply needs to be corrected.
5. **Rules engine** error. The rules engine used to process the report and test its facts against the knowledge base could be flawed. To make this logical system consistent, the rules engine algorithms simply need to be corrected.
6. **Structure** missing (i.e. reporting style does not exist). A report could be unique and a reporting style does not exist for the report. To make this

[52] Last 10-K submitted to SEC by public companies as of March 31, 2019, http://www.xbrlsite.com/site1/2018/10k/rss.xml

[53] Negative results from tests, http://xbrlsite.azurewebsites.net/2019/Library/2019-03-31_FAC-ErrorDetails.zip

[54] Excel-based extraction tool, http://xbrl.squarespace.com/journal/2018/1/11/further-updated-and-expanded-xbrl-based-financial-report-ext.html

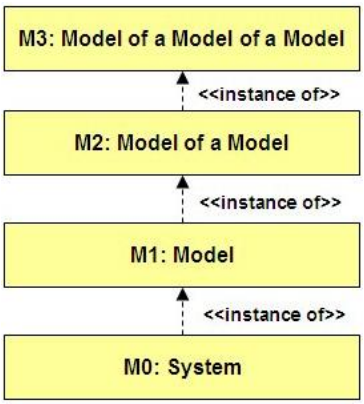
logical system consistent, a new structure (reporting style) simply needs to be added and then used by the report.

Once the terms, associations, structures, assertions, and facts are brought into equilibrium for a report; then the report would be consistent and a properly functioning logical system. This process is repeated for each report.

For the **second set**, there are more possibilities for inconsistencies and only approximately 68 disclosures were tested in each 10-K of the anticipated perhaps 500 to 1,500 possible disclosures. So, the testing is not as complete. And, the testing is not based on sound statistical testing so I cannot say that a sampling of disclosures was tested. However, there is no evidence to lead me to believe that I am missing something important. And so, what testing was done did show that, similar to the first set, there are specifically identifiable errors and specifically identifiable tasks that would cause the errors to be corrected and then cause the report fact to be consistent with the knowledge base. The categories of error are very similar and so they will not be repeated here.

1.17. Objects, Models, Meta-models, and Meta-meta-models

Object Management Group (OMG) publishes something called the **Meta Object Facility** (MOF)[55]. Basically, the MOF explains the distinction between an "Object", a "Model", a "Meta Model", or a "Meta-meta Model". These ideas are commonly confused, are not generally understood by business professionals, often not understood by technical people, but are critically important to getting business professionals what they really want/need. A model is essentially a pattern in a system.



What we don't need is every individual regulator, standards setter, and/or enterprise creating their own "meta model" when one common model will do. What we need is for, say, ESMA and the SEC and other regulators and others to use the SAME META-META MODEL where possible. If they could, why would they not?

Generally, the answer to that question is ignorance as to the benefits of a common meta-meta model. All this is why OMG is so interested in what I have done with my framework and method and why OMG quickly understood it and creates the ***Standard Business Report Model*** (SBRM)[56] which is a syntax independent logical conceptualization of a business report.

[55] Wikipedia, *Meta Object Facility*, https://en.wikipedia.org/wiki/Meta-Object_Facility

[56] OMG, Standard Business Report Model (SBRM), https://www.omg.org/intro/SBRM.pdf

OMG calls SBRM a "model" but it is actually a "meta-meta model" in my view. An economic entity defines objects, puts the objects into a model, which needs to conform to some regulator model (meta model) so that the regulator can collect models from many, many economic entities and be able to compare each different economic entity's information. All regulator models fit into one common meta-meta model, SBRM.

XBRL provides the technical syntax format which physically transports the information, US GAAP or IFRS or other financial reporting scheme provides the meaning, that meaning is represented using the XBRL syntax, SBRM provides the one common model that all reporting economic entities use.

The relationships go like this:

1. An economic entity creates a report, they put their "Objects" into the report which forms the report "Model" for that economic entity.
2. The economic entity can create their own "Objects" (extension Objects) and associate them with some "Model" financial reporting scheme such as the US GAAP or IFRS taxonomies (base Objects).
3. Every economic entity creating their report "Model" must fit into some "Meta model", today ESMA and the SEC have very similar "Meta Models", but they are slightly different (unnecessarily).
4. Rather than each regulator and/or economic entity or others creating their own "Meta model"; I have created a "Meta Model" that anyone can simply pick up and use which (a) is consistent with both ESMA and the SEC (b) adds more information to make sure the reports are properly functioning (consistent, complete, precise), and (c) adds information that is specific to financial reporting.
5. My "Meta-Model" fits into the OMG Standard Business Report Model (SBRM) which is a "Meta-meta Model" for BUSINESS reporting. A financial report is a specialization of the more general business report.

So, XBRL does has a "business report meta-meta-model". It is just that XBRL International explains it rather poorly. The *Open Information Model 1.0*[57] is an attempt to define a business report meta-meta model. Further, I expanded the SBRM adding additional metadata related specifically to financial reporting using the *Logical Theory Describing Financial Report*[58].

1.18. Conclusion

The Department of Philosophy of Texas State provides this excellent differentiation between a condition that is *necessary* and a condition that is *sufficient*[59]:

> A **necessary condition** is a condition that must be present for an event to occur. A **sufficient condition** is a condition or set of conditions that *will produce the event*. A necessary condition must be there, but it alone does not

[57] XBRL International, *Open Information Model 1.0*, https://specifications.xbrl.org/work-product-index-open-information-model-open-information-model.html

[58] *Logical Theory Describing Financial Report*, http://xbrl.squarespace.com/logical-theory-financial-rep/

[59] Texas State, Department of Philosophy, *Confusion of Necessary with a Sufficient Condition*, https://www.txstate.edu/philosophy/resources/fallacy-definitions/Confusion-of-Necessary.html

provide sufficient cause for the occurrence of the event. Only the sufficient grounds can do this. In other words, all of the necessary elements must be there.

To effectively communicate the semantics of financial statements it is **necessary** to:

- Agree on a specific common shared world view.
- Agree on a specific common shared inference logic.
- Agree on a specific common background knowledge.
- Agree to extend the common background knowledge terms, associations, structures, and assertions properly.
- Communicate the semantics of facts using the above agreed specific items.
- Physically transport those logical statements (structures, terms, associations, assertions, facts) using some syntax effectively.
- Prove that the logical statements are consistent, complete, precise and therefore that the financial statement is a properly functioning logical system.

Any lack of agreement or flaws will require additional steps to be taken in order to effectively communicate the semantics of financial information and to use that communicated information effectively. "Hope" and "wishful thinking" or "good intensions" are not sound engineering principles and will never help in achieving successful communication of semantic information. Effective engineering creates the possibility of successful communication of information. Business professionals should not need to be concerned with the engineering details, they simply need to use the system and the system should be reliable and safe.

Empirical evidence, in my view, seems to prove what is necessary to exchange semantic information, the "words" and "numbers", contained in financial reports. Since general business reports are likewise made up of "words" and "numbers" this proof may likewise apply to general business reports.