Special Theory of Machine-based Automated Communication of Semantic Information of Financial Statements

Understanding how to interpret and otherwise interact with machine readable XBRL-based financial information explained in simple terms

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"An error does not become truth by reason of multiplied propagation, nor does truth become error because nobody sees it. Truth stands, even if there be no public support. It is self-sustained." *Mahatma Gandhi*

Executive summary:

- XBRL-based digital financial reports are machine-readable logical systems[1].
- Financial reports are fundamentally based on the double entry accounting model, the accounting equation, and are intentionally designed to have innate characteristics such as mathematical interrelationships to achieve the notion of articulation which is where one report element is intentionally defined on the bases of other elements in order to achieve the interconnectedness of the four primary financial statements.
- These characteristics provide significant leverage to software engineers designing computer software intended to work with XBRL-based digital financial reports.
- XBRL-based digital financial reports can be proven to be properly functioning logical systems that are consistent, precise, and complete using automated machine-based processes that take into account the inherent variability of financial reports.
- Demonstrably properly functioning XBRL-based digital financial reports provide empirical evidence as to how to effectively communicate the semantics of reported financial information.
- These demonstrably properly functioning logical systems do not prove all that is sufficient to provide a theory of how semantic information must be communicated; but it does prove what is necessary for such semantic information to be communicated effectively.
- Perhaps an academic or mathematician or more knowledgeable party can bridge the gap between what is necessary, which I have demonstrated, and what is sufficient.

[1] Charles Hoffman, CPA, *Understanding XBRL-based Digital Financial Reports in Six Images*, http://xbrl.squarespace.com/journal/2019/11/13/understanding-xbrl-based-digital-financial-reports-in-six-im.html

In their paper, *Towards a Theory of Semantic Communication*[2], Jie Bao et. al. lament that a generic model of semantic communication has still largely remained unexplored after six decades. They go on to point out that their paper may form a "foundation for a general theory of semantic communication."

I would tend to agree on both counts.

Further, I have pointed out[3] that there are numerous domains that have created methods and approaches to representing information in some sort of machine-readable form and exchanging that information with someone else for some purpose. Unfortunately, in my view, each of those domains tends to use different terminology for describing what amounts to the same process, describe how their systems work with differing levels of thoroughness and completeness, and none of these explanations is particularly approachable to nontechnical business professionals trying to understand the process.

Yet this capability to effectively automate the exchange of information using machine-based processes is of increasing importance in what people are calling "*The Fourth Industrial Revolution*[4]" or the "*Age of AI*[5]".

Being that AI (artificial intelligence) is driven by data and information; being that there is increased competition in this realm; being that achieving commercial quality information exchange capabilities appears quite useful to me; it just seems to me that business professionals would want to understand how to effectively enable reliable machine-based automated communication and to be able to discuss this topic effectively with information technology professionals.

And so, I am writing this paper to explain this topic as best as I can specifically for financial reporting. Granted, I am not a PhD in knowledge engineering or computer science or anything else for that matter. However, I do have some skill and extensive experience in this area and I am a professional accountant and understand financial reporting quite well. I would invite academics to do two things. First, I would invite them to more formally improve upon my informal attempt to explain this topic. Second, I would invite them to endeavor to tackle the

[2] Jie Bao et.al., *Towards a Theory of Semantic Communication*, page 1, https://pdfs.semanticscholar.org/fa34/3407847eea1f7e8bb8d3d7489b6945e2b0b2.pdf

[3] Charles Hoffman, CPA, *Brainstorming How to Describe Semantics of a Flexible Yet Finite Logical System*, http://xbrl.squarespace.com/journal/2019/9/10/brainstorming-how-to-describe-semantics-of-a-flexible-yet-fi.html

[4] Charles Hoffman, CPA, *Adapting to Changes Caused by the Fourth Industrial Revolution*, http://xbrl.squarespace.com/journal/2019/8/4/adapting-to-changes-caused-by-the-fourth-industrial-revoluti.html

[5] PBS, Frontline, In the Age of AI, https://www.pbs.org/video/in-the-age-of-ai-zwfwzb/

broader general theory of semantic communication which I wish that I could have leveraged 20 years ago when I started working with XBRL.

The objective of this paper is to provide a theory of semantic communication as it relates to financial statements in terms a professional accountant can understand. Then, I will give several financial statement related examples that help the reader understand how the theory works.

The approach is that of "standing on the shoulders of giants[6]" or "discovering truth by building on previous discoveries." I leverage systems theory, graph theory, model theory, set theory, and most importantly logic which is the basis for all of the other theories and is innately understandable to business professionals.

It is assumed that a reader of this document is familiar with the basics of financial reporting and basic mathematics. If you are not, I would recommend that you read *Essence of Accounting*[7] prior to reading this document.

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, rules 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.

[6] Wikipedia, *Standing on the Shoulders of Giants*, https://en.wikipedia.org/wiki/Standing_on_the_shoulders_of_giants
[7] Charles Hoffman, CPA, *Essence of Accounting*, http://xbrlsite.azurewebsites.net/2020/Library/EssenceOfAccounting.pdf

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[8].

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

This specific use case is clearly articulated in the conceptual frameworks of both US GAAP[9] and IFRS[10] and really cannot be disputed. Those less familiar with financial reporting may find my exploration of FASB's SFAC 6 *Elements of Financial Statements*[11] helpful.

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[12]. Simply stated, that model is: **DEBITS = CREDITS**. It is a mathematical model.
- *Second*, building on the double-entry accounting model is the accounting equation[13]: **Assets = Liabilities + Equity**.
- *Third*, every financial reporting scheme defines a core set of interrelated elements[14] 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[15]; Assets, Liabilities, Equity,

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[8] Charles Hoffman, CPA, *Computational Professional Services*, http://xbrlsite.azurewebsites.net/2020/library/ComputationalProfessionalServices.pdf
[9] Financial Accounting Standards Board (FASB), *Statement of Financial Reporting Concepts No. 6, Elements of a Financial Statement*, https://www.fasb.org/pdf/con6.pdf
[10] International Accounting Standards Board (IASB), *Conceptual Framework for Financial Reporting*, March 2018, https://www.ifrs.org/issued-standards/list-of-standards/conceptual-framework/
[11] Charles Hoffman, CPA, *Impediments to Creating Properly Functioning XBRL-based Reports (SFAC 6)*, http://xbrlsite.azurewebsites.net/2020/core/master-sfac6/Documentation.pdf
[12] 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
[13] Wikipedia, *Accounting Equation*, https://en.wikipedia.org/wiki/Accounting_equation
[14] *Comparison of Elements of Financial Statements*, http://xbrlsite.azurewebsites.net/2020/master/ElementsOfFinancialStatements.pdf
[15] Financial Accounting Standards Board (FASB), Statement of Financial Reporting Concepts No. 6, Elements of a Financial Statement, page 23, https://www.fasb.org/pdf/con6.pdf

Comprehensive Income, Investments by Owners, Distributions to Owners, Revenues, Expenses, Gains, Losses. Then, additional elements are defined based on that core set.

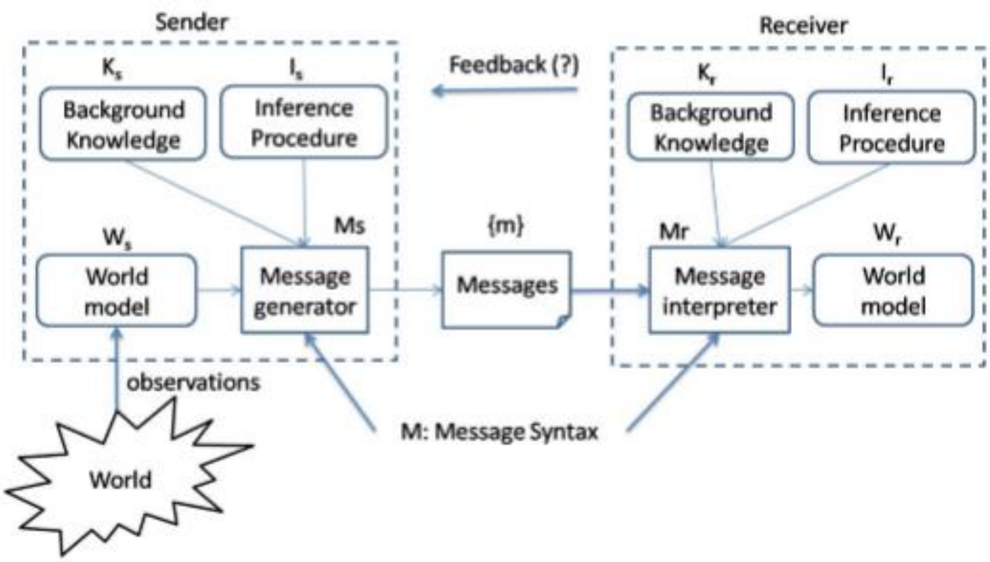
- *Fourth*, every financial reporting scheme has what is called "articulation". Articulation[16] is the notion that the elements of a financial statement are interrelated and therefore depend on one another and so the four core statements; the balance sheet, the income statement, the changes in equity and the cash flow statement are all mathematically interrelated. Articulation is explained very methodically by the FASB in SFAC 6[17].
- *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[18].

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

Graphic of Problem Statement

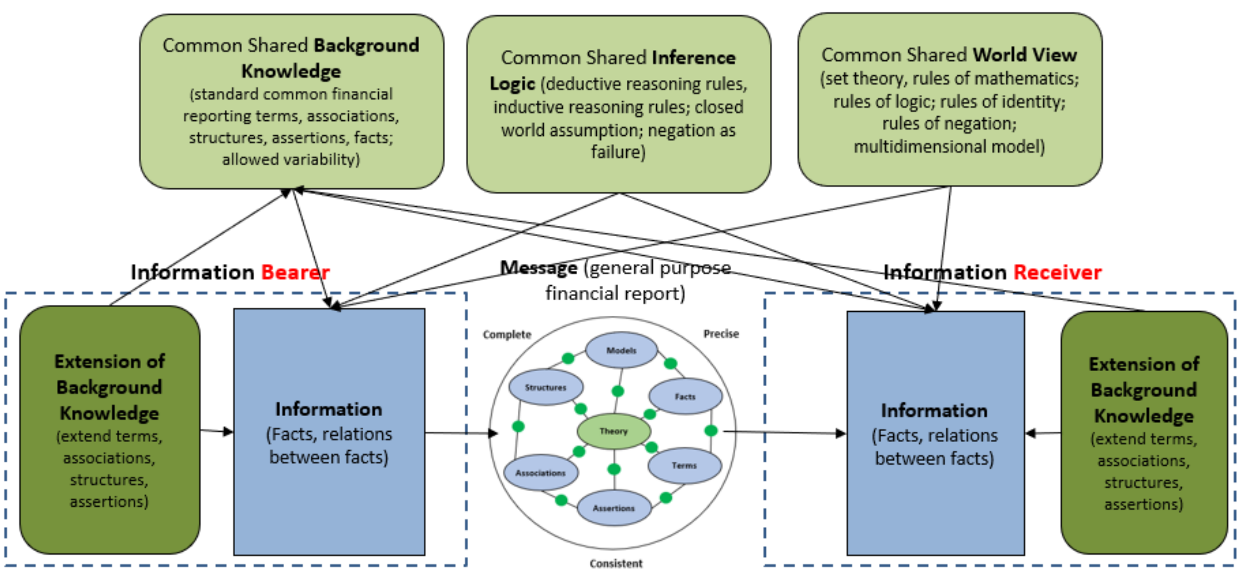
In their paper, *Towards a Theory of Semantic Communication*[19] , Jie Bao et. al. provide a visual description of the communications of information a copy of which I show below:

[16] Articulation, http://xbrlsite.azurewebsites.net/2021/reporting-scheme/proof/reference-implementation/PROOF_Articulation.jpg
[17] ibid, page 21 – 22, “Interrelation of Elements-Articulation”
[18] Ibid, page 47, paragraph 77.
[19] 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



In the diagram above, Bao. Et.Al. 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.:

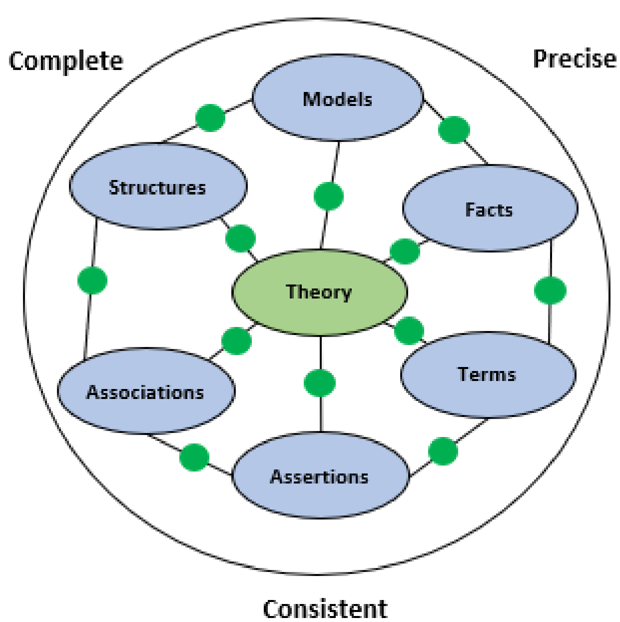


The general idea of my visual image is the same as Jie Boa et. al., however there are some specific differences that are intentional and make the communication of financial information easier.

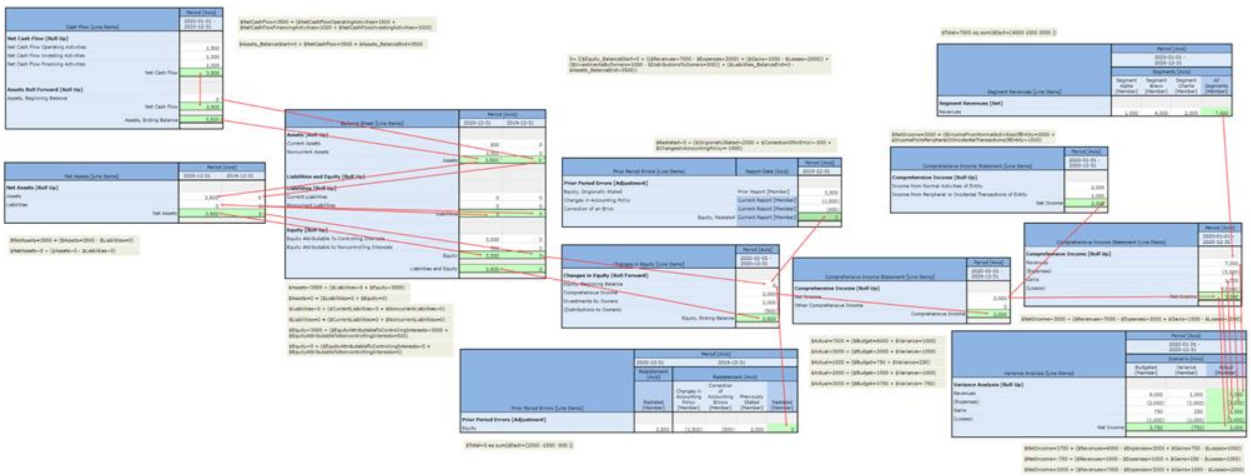
First, Jie Boa et. al. state that the world view of the information sender (W_s) and receiver (W_r) are perhaps different and then reconciled. This is similar for the inference procedure (I_s, I_r) and background knowledge (K_s, K_r).

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 common world view, common inference logic, and common background information in advance as part of the information exchange process. However, common 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 status and financial performance 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:



To make this more tangible to a business professional, consider the notion of articulation and how the facts reported within a financial report are interrelated to other facts if you consider only the mathematical computations of a rather basic general purpose financial report such as the following[20]:



I have demonstrated this by representing the accounting equation[21] and SFAC 6[22] in the XBRL technical syntax, walking through all the things that can impede the communication process, and mitigating each impediment. The proof representation[23] contains an inventory of the complexity of a financial report. Mastering XBRL-based financial reporting[24] examples and prototypes represent reports that increase in volume but the complexity of any report is the same as the proof representation for all practical purposes. A comprehensive analysis of the Microsoft 10-K financial report shows this to be the case[25].

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 provable 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.

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[20] PROOF example, Articulation, http://xbrlsite.azurewebsites.net/2021/reporting-scheme/proof/reference-implementation/PROOF_Articulation.jpg
[21] Charles Hoffman, CPA, *Impediments to Creating Properly Functioning XBRL-based Reports (AE)*, http://xbrlsite.azurewebsites.net/2020/core/master-ae/Documentation.pdf
[22] Charles Hoffman, CPA, *Impediments to Creating Properly Functioning XBRL-based Reports (SFAC 6)*, http://xbrlsite.azurewebsites.net/2020/core/master-sfac6/Documentation.pdf
[23] Proof, http://xbrlsite.azurewebsites.net/2021/reporting-scheme/proof/documentation/Index.html
[24] Mastering XBRL-based Digital Financial Reporting, http://xbrlsite.azurewebsites.net/2020/master/
[25] Knowledge Graph of Microsoft 10-K Financial Report, http://xbrl.squarespace.com/journal/2021/7/12/knowledge-graph-of-microsoft-10-k-financial-report.html

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 physical 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”.
- Each standards setter builds upon the double entry accounting model and some version of the accounting equation when they define their financial report elements.
- Catastrophic logical failures are to be avoided at all cost as they cause systems to completely fail.
- Nothing about processing information within this financial report logical system can be a “black box”. The innerworkings must be explainable and justifiable, providable in a human-readable manner. Information provenance must be knowable and traceable.

It would be, in my personal view, highly unlikely that anyone that fundamentally desires to effectively communicate machine-readable information and understands financial accounting to disagree with any of the very basic principles.

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.k.a. area of knowledge[26]).

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 can be explained by a logical theory. A logical theory is an abstract conceptualization[27] of specific details of some domain. The logical theory provides a way of thinking about a domain by means of deductive reasoning to derive logical consequences of the theory. A logical theory is made up of a set of models, structures, terms, associations, assertions, and facts[28] along with some finite set of mathematical operators. 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*[29] 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 rules 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 (area of knowledge) 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". (a.k.a. report elements)
    - **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 +

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[26] Accounting is an Area of Knowledge, http://xbrl.squarespace.com/journal/2021/2/8/accounting-is-an-area-of-knowledge.html
[27] Wikipedia, *Conceptual Model*, https://en.wikipedia.org/wiki/Conceptual_model
[28] 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
[29] Wikipedia, *Model Theory*, https://en.wikipedia.org/wiki/Model_theory

equity" or "an asset is a 'debit' and is 'as of' a specific point in time and is always a monetary numeric value". (a.k.a. relations)

- **Rules**: Rules are statements that describe expectations that tend to be IF…THEN…ELSE types of relationships such as "IF the economic entity is a not-for-profit THEN net assets = assets - liabilities; ELSE assets = liabilities + equity". (a.k.a. assertions or constraints)
- **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.k.a. items)

A financial report has a finite set of statements (structures, terms, associations, rules, 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. Here, I am referring to logical statements.)

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

A logical theory 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, rules, 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[30].

Finally, when information is exchanged it is important to agree on a **world view**. You can agree on the terms, structures, associations, rules and facts; but nothing tells us how each of these statements will be processed, understood, or managed within a specific system. This could be different in different systems. As such, some certain amount of the world view must be agreed

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

to, should be made common. Stakeholders should be conscious of these potential differences and agree on specific aspects of a common world view.

Finally, nothing about processing information within this logical system can be a "black box". The innerworkings must be provided in a human-readable manner. Information provenance must be knowable and traceable. Auditable algorithms are essentially ones that are explainable. Algorithms, including artificial intelligence, used by the enterprise or for accounting, reporting, auditing, and analysis needs to be explainable artificial intelligence[31]. Explainable AI (XAI) provides insight into how the software algorithms reached its conclusions, an understandable "line of reasoning".

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 good practices, 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. Testing and a conformance suite[32] which is agreed to by system stakeholders explains how the system works to business professionals. Business professionals decide if the system is working as expected.

A logical system[33] is a type of formal system[34]. To be crystal clear what I am trying to create is a **finite model-based deductive first-order logic system**[35]. "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-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. "Proof theory" because all of this can be proven mathematically which helps tune the system.

[31] ACCA, Narayanan Vaidyanathan, *Explainable AI: Putting the user at the core*, https://www.accaglobal.com/uk/en/professional-insights/technology/Explainable_AI.html
[32] Conformance suite, http://xbrlsite.azurewebsites.net/2019/Prototype/conformance-suite/Production/index.xml
[33] Wikipedia, *Logical Systems*, https://en.wikipedia.org/wiki/Logic#Logical_systems
[34] Wikipedia, *Formal System*, https://en.wikipedia.org/wiki/Formal_system
[35] Wikipedia, *First-order Logic, Deductive System*, https://en.wikipedia.org/wiki/First-order_logic#Deductive_systems

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[36] is a cohesive conglomeration of interrelated and interdependent parts that is either natural or man-made. Systems theory explains logical systems. Systems have patterns.
- **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 (ontology + rules). Theories describe patterns. (see the ontology spectrum[37])
- **Proof theory**: The ideas of proof theory[38] can be used to verify the correctness of logical systems and computer programs working with those machine-readable logical systems using mathematics[39]. Proofs verify theories.
- **Model theory**: Model theory is a way to think about flexibility. Safer finite model theory[40] is preferable to general model theory. Models provide flexibility.
- **Set theory**: Set theory is foundational to logic and mathematics. Axiomatic (Zermelo–Fraenkel) set theory[41] is preferred to naïve set theory.
- **Graph theory**: Directed acyclic graphs[42] 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[43] is a subset of first-order logic and is the basis for Prolog[44]. Datalog[45] is a subset of Horn logic (function free) which is immune from logical paradoxes should be used as contrast to more powerful but also more potentially 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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[36] Wikipedia, *Systems Theory*, https://en.wikipedia.org/wiki/Systems_theory
[37] *Difference between Taxonomy, Conceptual Model, Logical Theory*, http://xbrl.squarespace.com/journal/2018/12/11/difference-between-taxonomy-conceptual-model-logical-theory.html
[38] Stanford University, *The Development of Proof Theory*, *The Aims of Proof Theory*, https://plato.stanford.edu/entries/proof-theory-development/#AimProThe
[39] Samuel R. Buss, *An Introduction to Proof Theory*, https://math.ucsd.edu/~sbuss/ResearchWeb/handbookI/ChapterI.pdf
[40] Wikipedia, *Finite Model Theory*, https://en.wikipedia.org/wiki/Finite_model_theory
[41] Wikipedia, *Set Theory, Axiomatic Set Theory*, https://en.wikipedia.org/wiki/Set_theory#Axiomatic_set_theory
[42] Wikipedia, *Directed Acyclic Graph*, https://en.wikipedia.org/wiki/Directed_acyclic_graph
[43] Wikipedia, *Horn Logic*, https://en.wikipedia.org/wiki/Horn_clause
[44] Wikipedia, *Prolog*, https://en.wikipedia.org/wiki/Prolog
[45] Wikipedia, *Datalog*, https://en.wikipedia.org/wiki/Datalog

- **World view**: The following are common issues which appear when implementing logical systems which exchange information in machine-readable form, the safest and most reliable alternatives are:
    - closed world assumption[46] (used by relational databases) is preferred to the open world assumption which can have decidability issues;
    - negation as failure[47] (used by relational databases) should be explicitly stated;
    - unique name assumption[48] (used by relational databases) 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.

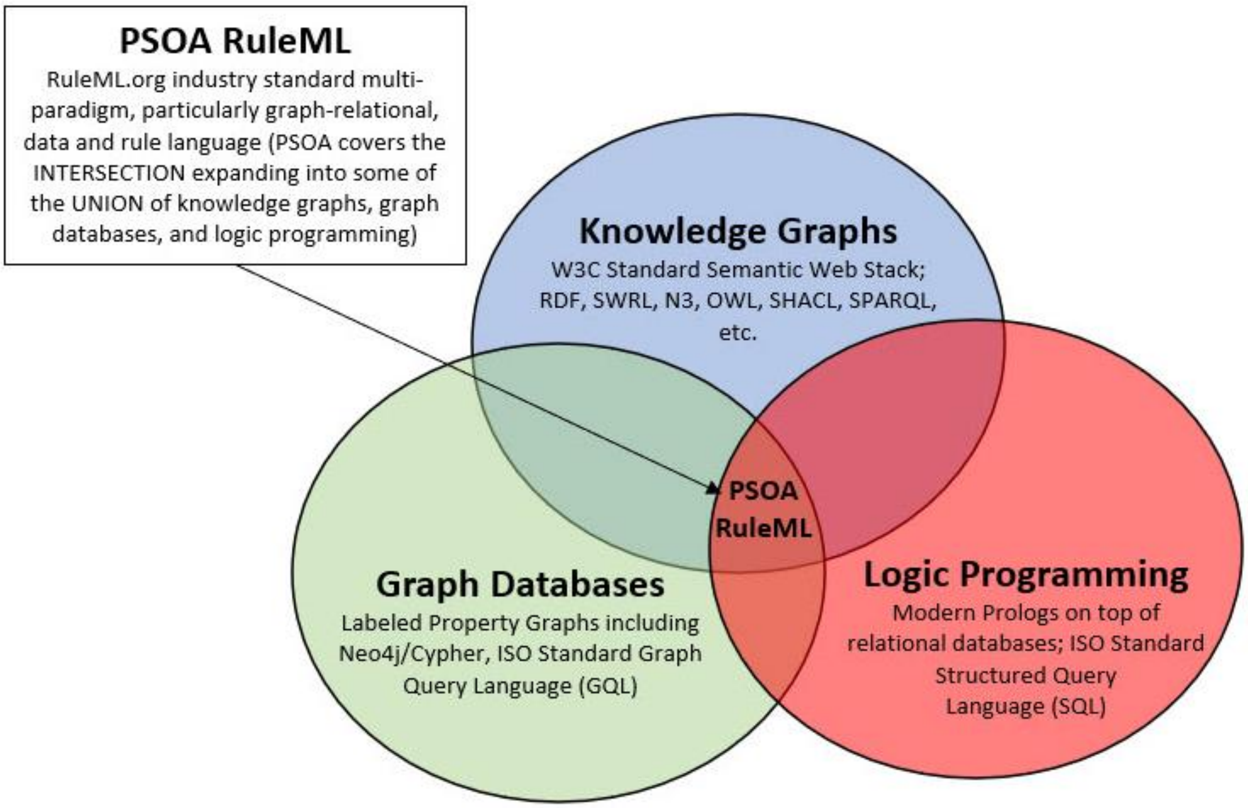
As such, we have made all of the above decisions which are consistent with modern logic programming paradigms such as Prolog[49], LPS[50], DataLog[51], Efficiently Computable Datalog[52], Why3[53], Alt-Ergo[54], HETS[55], and Answer Set Programming[56].

Per Harod Boley of RuleML[57], all these information processing approaches above can be distilled into one of the three fundamental problem solving logic paradigms[58]. I have made some slight modifications to Boley's graphic:

- Semantic Web (i.e. the W3C semantic web stack)
- Graph databases
- Logic Programming

[46] Wikipedia, *Closed World Assumption*, https://en.wikipedia.org/wiki/Closed-world_assumption
[47] Wikipedia, *Negation as Failure*, https://en.wikipedia.org/wiki/Negation_as_failure
[48] Wikipedia, *Unique Name Assumption*, https://en.wikipedia.org/wiki/Unique_name_assumption
[49] Wikipedia, *Prolog*, https://en.wikipedia.org/wiki/Prolog
[50] Imperial College, Department of Computing, LPS, http://lps.doc.ic.ac.uk/
[51] Wikipedia, Datalog, https://en.wikipedia.org/wiki/Datalog
[52] Nichola Leona et.al., *Efficiently Computable Datalog Programs*, https://www.mat.unical.it/kr2012/shy.pdf
[53] Charles Hoffman, CPA, *Why3*, http://xbrl.squarespace.com/journal/2020/4/13/why3.html
[54] OCamlPro, *Alt-Ergo*, https://alt-ergo.ocamlpro.com/
[55] Charles Hoffman, CPA, *HETS*, http://xbrl.squarespace.com/journal/2020/4/10/hets.html
[56] Charles Hoffman, CPA, *Understanding Answer Set Programming*, http://xbrl.squarespace.com/journal/2019/5/10/understanding-answer-set-programming.html
[57] RuleML, Harold Boley, *Graph-Relational Data, Ontologies, and Rules*, http://wiki.ruleml.org/index.php/Graph-Relational_Data,_Ontologies,_and_Rules
[58] Problem Solving Logic Paradigms, http://xbrl.squarespace.com/journal/2020/9/15/primary-problem-solving-logic-paradigms.html

Further, all of the logic represented by one of these problem solving logic paradigms should be reconcilable to the logic expressed by each of the other two problem solving logic paradigms. The "sweet spot" in terms of functionality is where this is possible. Saying this another way; the focus of information exchange should be the logic of the information, the technical format is simply the delivery and processing mechanism.



Business professionals can simply use this system if they desire to do so, they don't need to reinvent the wheel. It does not matter which technical implementation is used, what matters is the logic.

A logical system or logical theory can be made flexible precisely where they need to be flexible using model theory[59].

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[60], finite model theory[61], and the consciously and intentionally very safe finite first order model theory.

[59] Wikipedia, *Model Theory*, https://en.wikipedia.org/wiki/Model_theory
[60] Stanford University, *First Order Model Theory*, https://plato.stanford.edu/entries/modeltheory-fo/
[61] Wikipedia, Finite Model Theory, https://en.wikipedia.org/wiki/Finite_model_theory

It is not important to understand the specific details of model theory, although it is very helpful to have a basic understanding[62]. 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[63]. Several of these examples have also been represented using Prolog; the XBRL and Prolog language representations yielding the same result. All of this was distilled into a method that provably yields high-quality information exchange where report model creators can make adjustments to that report model[64].

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.

Think Knowledge Graph

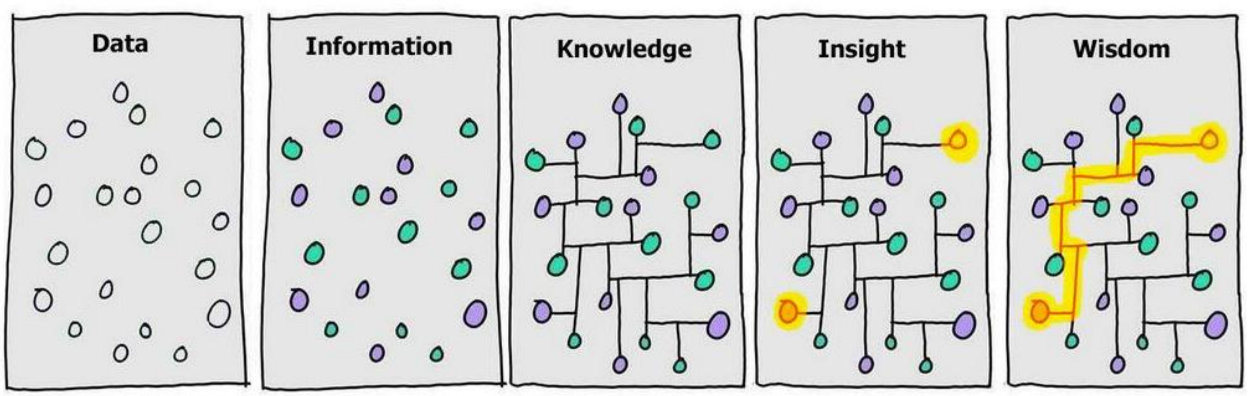
A **knowledge graph** is one approach to storing information about some area of knowledge within a knowledge base. The specific term "knowledge graph" is more of an analogy or buzz word dreamed up in 2012 to describe the functionality you get when you use a set of web standards. A knowledge graph is an approach to representing and storing information about entities, associations between those entities, rules related to entities and associations, and facts. Specifically when I say knowledge graph I mean directed acyclic knowledge graph.

Knowledge graphs is one of many different possible approaches to thinking about information.

[62] LessWrong, *Very Basic Model Theory*, https://www.lesswrong.com/posts/F6BrJFkqEhh22rFsZ/very-basic-model-theory
[63] Mastering XBRL-based Digital Financial Reporting, http://xbrlsite.azurewebsites.net/2020/master/
[64] Charles Hoffman, CPA, *Method – Terse Explanation*, http://xbrlsite.azurewebsites.net/2020/library/MethodTerse.pdf

For more information about knowledge graphs, I would recommend *The Knowledge Graph Cookbook: Recipes that Work*[65]. Different authors have different biases based on their preferences. Of one can see through these biases and look at this information in general terms and not per any specific technical implementation, one can get a very good understanding of how these systems work.

The graphic below helps one understand the difference between data, information, knowledge, insight, and wisdom[66]:



The objective is to create a mechanism that will augment a human's capability to perform work by enabling software to take over some of the repetitive, mundane, mindless tasks that must be performed.

Example Implementations in XBRL

Below I provide a handful of implementations that will be used to make some specific points about what is necessary to make the exchange of complicated information work effectively when the creator of a report model can adjust that model within permitted boundaries.

Each example progressively increases in complexity. Simple examples help the reader get their heads around the fundamentals. To have a comprehensive example, all the different information patterns must be fundamentally provided for.

Very Basic Model Example provided by Accounting Equation

The following is a very basic model of the accounting equation that I represented using XBRL and Prolog[67]:

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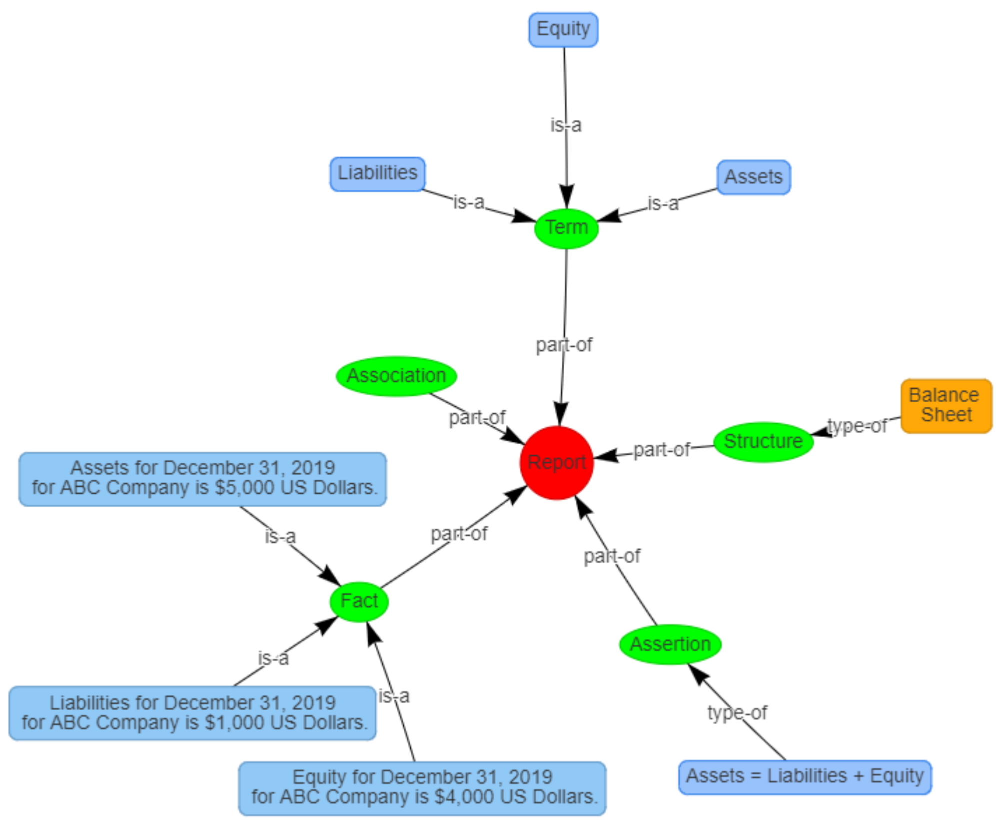
[65] *The Knowledge Graph Cookbook: Recipes that Work*, http://xbrl.squarespace.com/journal/2021/6/27/the-knowledge-graph-cookbook-recipes-that-work.html
[66] Tumblr, *Information vs Knowledge*, https://informationversusknowledge-blog.tumblr.com/
[67] Charles Hoffman, CPA, Accounting Equation, http://xbrlsite.azurewebsites.net/2020/Core/master-ae/

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[68]. 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".

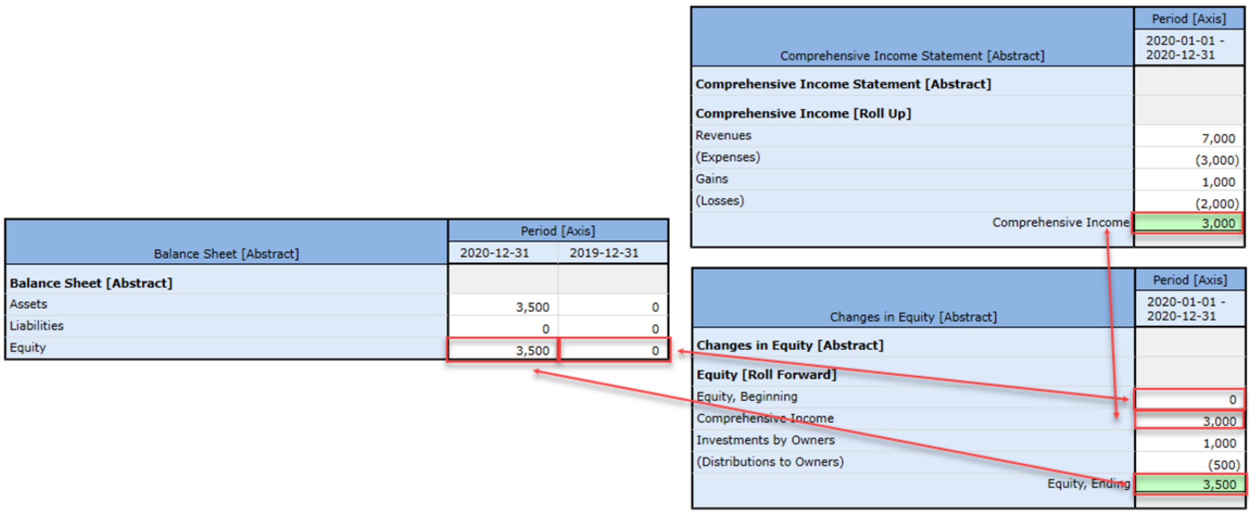
This very basic model example is not enough to create an actual financial statement but it does represent a demonstrably complete, precise, and consistent logical system. Here is an example of a knowledge graph for that logical system:



[68] Charles Hoffman, CPA, Accounting Equation Documentation, http://xbrlsite.azurewebsites.net/2020/Core/master-ae/Documentation.pdf

Slightly More Complex SFAC 6, 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[69]:



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

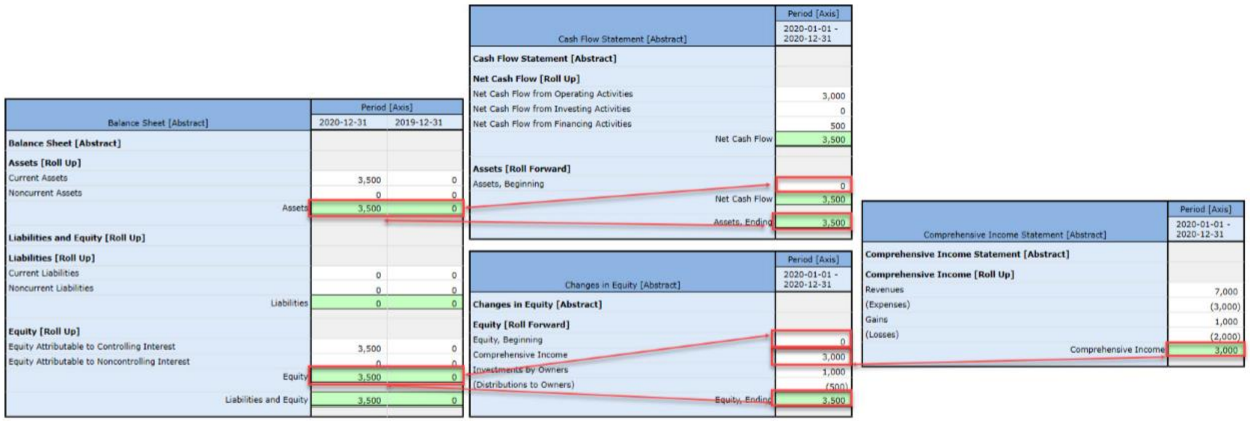
Again, the best way to understand all the details are to read the documentation[70]. The essence of the representation, again both in XBRL and Prolog, are three interconnected structures, ten terms, and three rules defined by SFAC 6.

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

Four Statement Model Example (Common Elements of Financial Statement)

The following is again another slightly more complex model[71], still pretty basic model that expands on the FASB's SFAC 6 adding additional elements that no professional accountant could really dispute:

[69] Charles Hoffman, CPA, SFAC 6, http://xbrlsite.azurewebsites.net/2020/Core/master-sfac6/
[70] Charles Hoffman, CPA, SFAC 6 Documentation, http://xbrlsite.azurewebsites.net/2020/Core/master-sfac6/Documentation.pdf
[71] 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[72]. What you see are four interconnected structures, 20 terms, four assertions, 29 facts, and a plethora of associations.

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[73] 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*[74]. 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.

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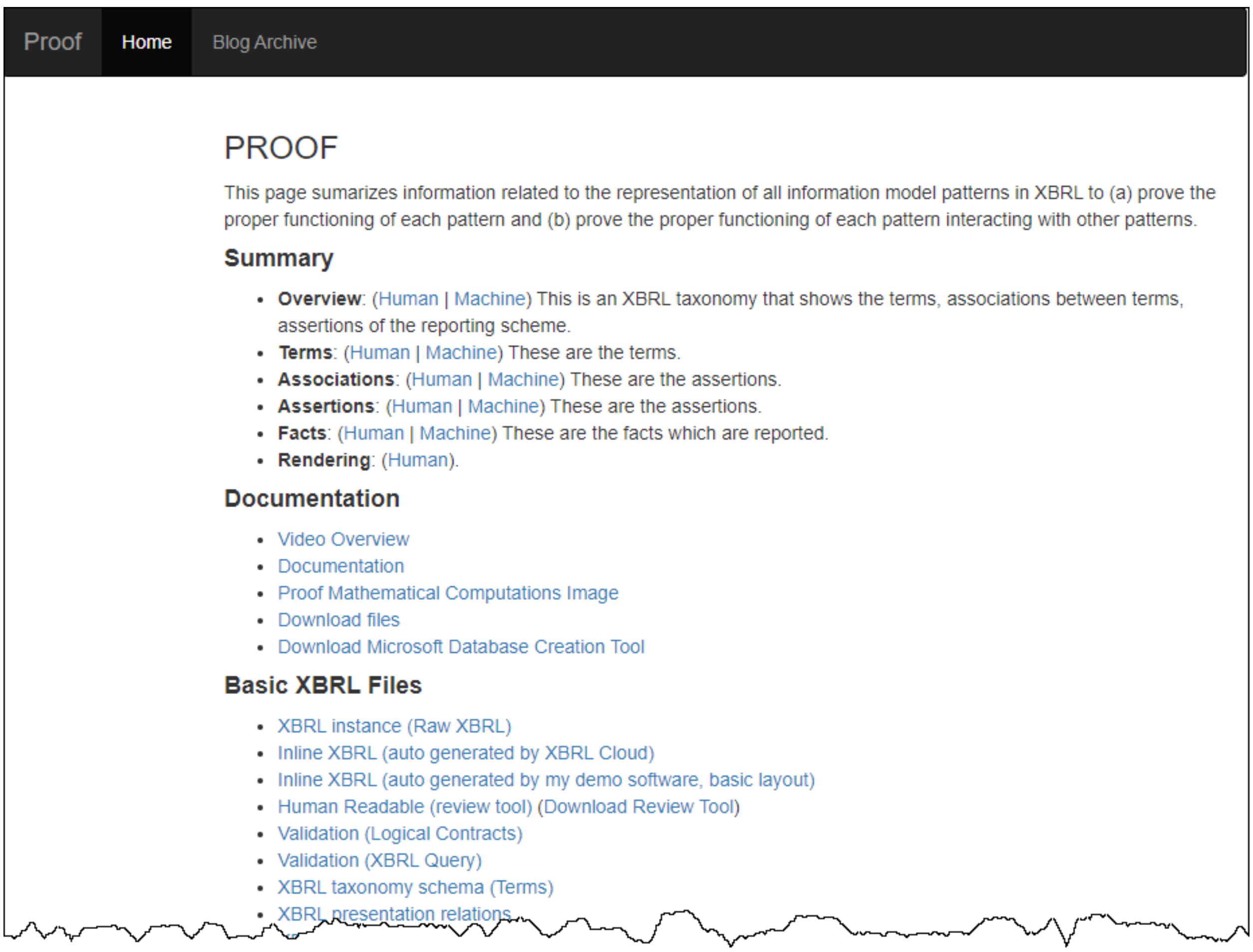
[72] Charles Hoffman, CPA, Common Elements of Financial Statement , http://xbrlsite.azurewebsites.net/2019/Core/master-elements/CommonElementsOfFinancialStatement.pdf
[73] Charles Hoffman, CPA, *MINI Financial Reporting Scheme*, http://xbrlsite.azurewebsites.net/2019/Prototype/mini/documentation/Index.html
[74] Charles Hoffman, CPA, *Proving Financial Reports are Properly Functioning Logical Systems*, http://xbrlsite.azurewebsites.net/2019/Library/ProvingFinancialReportAreProperlyFuncioning.pdf

Proof Representation

The Proof representation[75] contains all the information patterns that have been discovered from analyzing about 6,000 US GAAP financial reports and 400 IFRS financial reports that have been submitted to the U.S. Securities and Exchange Commission. The Proof representation takes all of those information patterns, represents them within an XBRL report model and XBRL report, tests that representation to make sure everything works logically as expected.

The Proof representation are the patterns that are documented by the logical conceptualization of a business report created per the Standard Business Report Model (SBRM).



[75] Proof representation, http://xbrlsite.azurewebsites.net/2020/master/proof/index.html

Patterns Documented with Standard Business Report Model (SBRM)

Examining the patterns[76] of the first four examples, an additional small financial reporting scheme representation[77], 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*[78], 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)*[79].

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 Describing Financial Report*[80] 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 type of line item as if were some different type
- 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 which 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

[76] YouTube, *The Science of Patterns*, https://www.youtube.com/watch?v=kh6KMW8J3RQ
[77] Charles Hoffman, CPA, MINI Financial Reporting Scheme, http://xbrlsite.azurewebsites.net/2019/Prototype/mini/documentation/Home.html
[78] Charles Hoffman, CPA, *Proving Financial Reports are Properly Functioning Logical Systems*, http://xbrlsite.azurewebsites.net/2019/Library/ProvingFinancialReportAreProperlyFuncioning.pdf
[79] *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
[80] *Logical Theory Describing Financial Report*, http://xbrl.squarespace.com/logical-theory-financial-rep/

of these impediments, the correction of the impediment, and the resulting properly functioning logical system, the XBRL-based digital financial report[81].

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.

Large Set of Specific 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 knowledge base.

For example, take this very simple form[82]:

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:

[81] YouTube.com, *Understanding the Financial Report Logical System*, https://www.youtube.com/playlist?list=PLqMZRUzQ64B7EWamzDP-WaYbS_W0RL9nt

[82] 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 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.

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 permitted 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 permitted 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 permitted or not permitted 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 permitted 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 permitted 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[83].

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[84]. 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 previously.

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:

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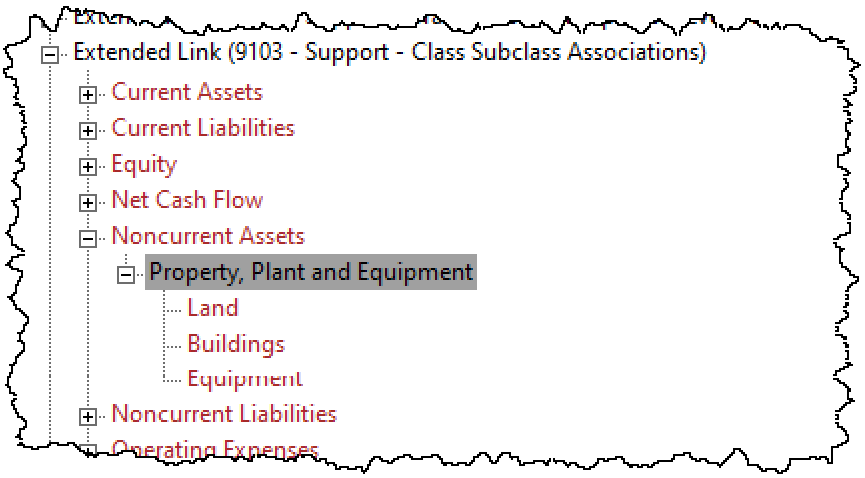
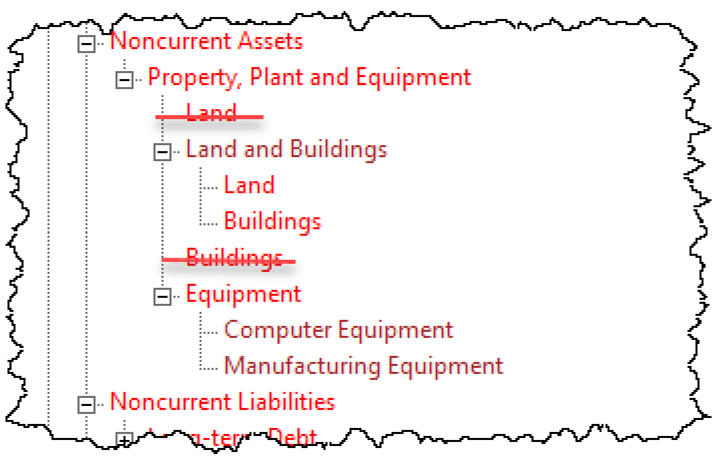
[83] *US GAAP Disclosures*, http://xbrlsite.azurewebsites.net/2020/reporting-scheme/us-gaap/documentation/Disclosures.html

[84] *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



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[85] and SFAC 6[86] examples. See the last page of the documentation.

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

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

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 permissible per financial reporting rules and practices are two different questions.

Proper Use of Subtypes

An XBRL taxonomy is not, or should not, be simply a list of terms. An XBRL taxonomy, at a very minimum, should provide a set of terms and 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”.

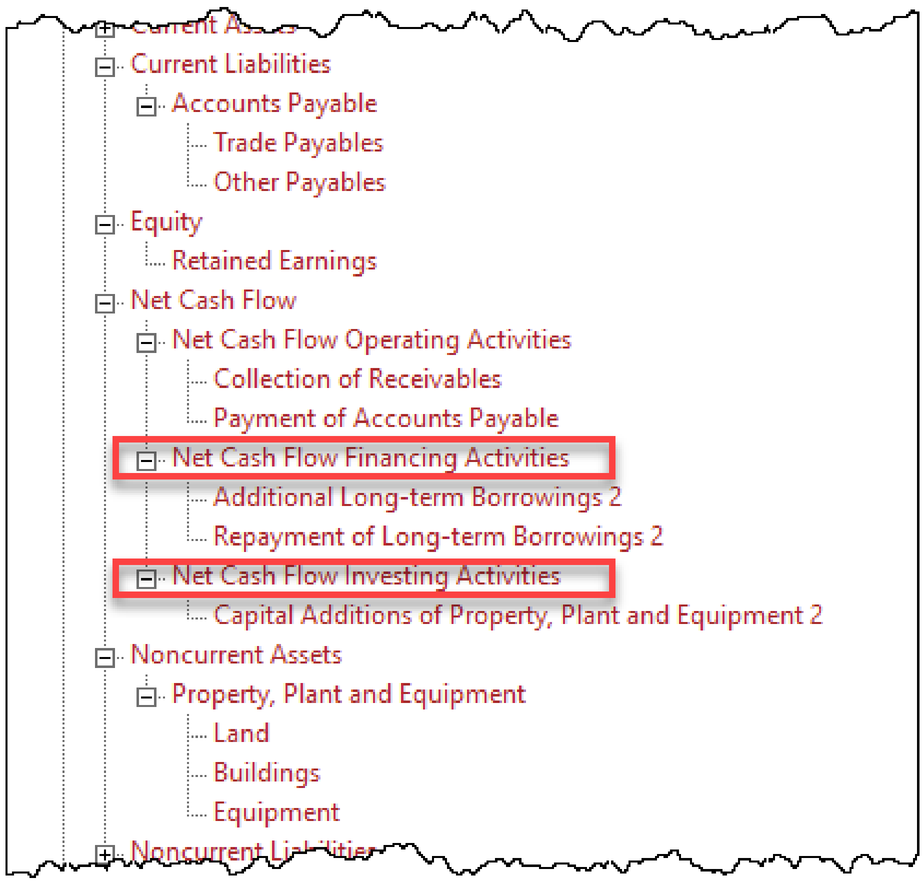
Cash Flow Statement [Line Items]	Period [Axis] 2018-01-01 - 2018-12-31
Cash Flow Statement [Roll Forward]	
Net Cash Flow [Roll Up]	
Net Cash Flow Operating Activities [Roll Up]	
Collection of Receivables	3,000
Payment of Accounts Payable	(2,000)
Net Cash Flow Operating Activities	1,000
Net Cash Flow 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 "type-subtype" 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.

Controlling Logical System and Keeping it Properly Functioning

All the examples work the same and distill down to what can be described by the statements of a financial report logical system. All such logical systems work the same regardless of the number of terms, associations, structures, assertions, and facts. The best example to describe the functioning of the system is the "Slightly More Complex, but still Basic Model Example" (FASB's SFAC 6 Elements of Financial Statements) because it is small enough to still get your head around but big enough to see what causes the logical system to be properly functioning, what causes the logical system to function improperly, and how to distinguish the difference[87].

Control of a system is described by classical control theory[88]. Systems can be open or systems can be closed. Advantages of closed systems is better control, stable performance, and guaranteed performance. Control of a financial report system and being able to define proper functioning system and keep such systems in control is desirable.

Based on all the things that can go wrong with the system, the following is the set of specific characteristics that can be employed to control the logical system and keep it properly functioning:

- Using the notion of "report element categories"
- Used the report element categories and organized them consistent with a set of strict "model structure rules"
- Used “derivation rules” (I used to call these impute rules) to overcome unreported financial report line items
- Used "consistency rules" to overcome contradictions or inconsistencies in reported facts
- Used "reporting styles" to facilitate model variability. (i.e. set of permissible models)
- Explicitly named “disclosures” so that they can be referred to.
- Using the notion of “information model” and "concept arrangement patterns".
- Using the notion of “disclosure mechanics rules” to specify the proper representation of a specific disclosure.
- Using the notion of “type-subtype” or “wider-narrower” or “general-special” relations to explicitly represent these relations.
- Using the notion of “mapping rules” to explicitly represent certain specific relations.
- Using the notion of “disclosure rule” or “reporting checklist” specifies the circumstances when each specific disclosure is required to be reported.

Use of these characteristics to control the logical system is demonstrated by the most current SFAC 6 *Elements of Financial Statements* representation in XBRL[89] and explained in the

[87] YouTube.com, Digital Financial Reporting, *Distinguishing Between Properly and Improperly Functioning Logical System*, https://youtu.be/MFxStNn1Tjw
[88] Wikipedia, *Classical Control Theory*, https://en.wikipedia.org/wiki/Classical_control_theory
[89] SFAC 6 Elements of Financial Statements Representation in XBRL, http://xbrlsite.azurewebsites.net/2020/core/master-sfac6/

document *Impediments to Creating Properly Functioning XBRL-based Reports*[90]. Details are explained in the video, *Compensating for US GAAP and IFRS XBRL Taxonomy Design Choices*[91].

As such, it was these specific features which are included in the Standard Business Report Model (SBRM)[92] in order to control a business report logical system to keep that system properly functioning.

Finally, in order to test 100% of the information model patterns that would exist within such a system and to prove that each information model pattern functioned as expected and interacted properly with other information model patterns, a proof was created as a comprehensive test[93].

Proof based on Empirical Evidence

When Rene van Egmond and I first created the *Financial Report Semantics and Dynamics Theory*[94] back in 2012 we offered a proof that provided empirical evidence for that theory. Today, we can offer an improved proof based on 10 years of 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[95]. 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 publicly

[90] Charles Hoffman, *Impediments to Creating Properly Functioning XBRL-based Reports (SFAC 6)*, http://xbrlsite.azurewebsites.net/2020/core/master-sfac6/Documentation.pdf
[91] *Compensating for US GAAP and IFRS XBRL Taxonomy Design Choices*, https://youtu.be/sKs02VjFJgw
[92] SBRM Progress Report, http://xbrl.squarespace.com/journal/2020/1/30/sbrm-progress-report.html
[93] Charles Hoffman, CPA, Digital Financial Reporting Proof of Semantics, http://xbrlsite.azurewebsites.net/2020/core/master-proof/Proof.pdf
[94] Charles Hoffman, CPA and Rene van Egmond, *Financial Report Semantics and Dynamics Theory*, http://xbrl.squarespace.com/fin-report-sem-dyn-theory/
[95] *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

available[96]. 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[97].
- 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[98].

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.

[96] Last 10-K submitted to SEC by public companies as of March 31, 2019, http://www.xbrlsite.com/site1/2018/10k/rss.xml
[97] Negative results from tests, http://xbrlsite.azurewebsites.net/2019/Library/2019-03-31_FAC-ErrorDetails.zip
[98] Excel-based extraction tool, http://xbrl.squarespace.com/journal/2018/1/11/further-updated-and-expanded-xbrl-based-financial-report-ext.html

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 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.

Conclusion

If a process cannot be controlled then the process simply cannot repeatedly and reliably output high-quality information. If process output is not high-quality information, automation cannot possibly be effective and therefore effective exchange of information is not possibly occur.

So, control of a process is necessary in order for the process to be effective. How do you control a process? You control a process using rules. Manual processes are controlled by rules that are read by humans and then humans figure out if the process is working properly. Automated processes are controlled by rules that are readable by both machines (i.e., to execute the process) and humans (i.e., to make sure the rules are right).

Who creates these machine-readable rules that are used to control processes that yield effective automation? For financial reporting, accountants must create these rules because the rules tend to be accounting oriented. Technical rules tend to relate to syntax and such technical rules can be hidden from business professionals. What is left is the business logic and accounting rules that are used to control information and control process workflow. As such, the creation of machine-readable rules must be “self-service”. Business professionals must be empowered to create, adjust, maintain, and otherwise manage the rules that are used to control and therefor effectively automate processes. Once you have the machine-readable rules, you need software that can process the rules; this is sometimes called a rules engine or reasoning engine or a semantic reasoner.

The Department of Philosophy of Texas State provides this excellent differentiation between a condition that is *necessary* and a condition that is *sufficient*[99]:

> 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 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 meaning of financial statements where you have complicated information and the financial report creators are permitted to modify the report model it is **necessary** to:

- Agree on a specific common background knowledge.
- Agree on a specific common shared inference logic.
- Agree on a specific common shared world view.
- Agree to extend the common background knowledge terms, associations, structures, and rules in understood and permissible ways.
- Communicate the semantics of facts using the above agreed specific items.
- Physically transport those logical statements (machine-readable structures, terms, associations, rules, 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.

In such financial reports, there is a specific knowable set of things that can go wrong that can be verified as to being correct or incorrect using automated machine-based processes. That set of things that can go wrong are:

1. Incorrect XBRL technical syntax or report semantics (i.e., anything verifiable per the XBRL technical specification rules).
2. Incorrect XBRL presentation associations. (not in the scope of XBRL rules)
3. Impermissible or inconsistent or contradictory fundamental accounting concept relations. (not in the scope of XBRL rules)
4. Impermissible type-subtype associations. (not in the scope of XBRL rules)

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

5. Impermissible disclosure mechanical structures. (not in the scope of XBRL rules)
6. Impermissible set of information reported. (not in the scope of XBRL rules)

All six categories of verification are necessary for a financial report to be proven to be a properly functioning logical system that is complete and consistent. All six categories are necessary, but they might not be sufficient to verify everything about the financial report. To the extent other items can be verified using automated processes is the extent to which entire processes can be automated. All non-automatable tasks must be verified using human powered verification steps.

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 logic within their area of knowledge within 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.

* * *

The following appendices below provide additional detailed information that supports statements made and provide additional details related to information conveyed in the body of this document above.

* * *

Appendix: Summary Table and Comparison of Results

The following is a table which summarizes and contrasts the results obtained by creating XBRL-based machine-readable information for each of the logical systems that were used to analyze the incremental logical systems and then synthesize an approach to controlling variability:

	Accounting Equation[100]	SFAC 6[101]	Common Elements[102]	MINI Reporting Scheme[103]	Microsoft 2017 10-K[104]
Terms	3	10	20	126	491
Structures	1	3	4	34	194
Rules	1	3	4	23	???
Facts	3	13	29	183	2,234
Terms defined	3	10	20	126	491
Structures defined	1	3	4	34	194
Rules defined	1	3	4	23	???
Facts provided	3	13	29	183	2,234

The following sections provide details of each increment in the analysis process and how each increment contributes to the synthesis of an approach to overcoming specific impediments and effectively control the variability inherent in a financial report.

Appendix: Understanding Errors that Can Occur which Method Detects and Prevents (Comparison of States)

You can understand the types of errors that can occur in the Microsoft 10-K or any US GAAP or IFRS based XBRL-based financial report by looking at the types of errors that can exist in the accounting equation representation. This section explains those error types.

The following is a comparison of 9 states of the same simple financial report logical system, the accounting equation[105]. The point of using such a simple financial report logical system is to explain specific things that can go wrong so that a reader can understand why each of the categories of rules are necessary. These 9 states can occur in any financial report with one fragment, two fragments, or 194 fragments like the Microsoft 10 K.

There are many ways to get a report wrong. Here is a summary of all nine states with the first state outlined in green being the only properly functioning logical system proven to be complete, consistent, and precise:

[100] Accounting equation represented using XBRL, http://xbrlsite.azurewebsites.net/2019/Core/master-ae/
[101] SFAC 6 represented using XBRL, http://xbrlsite.azurewebsites.net/2019/Core/core-sfac6/
[102] Common Elements of a Financial Report represented using XBRL, http://xbrlsite.azurewebsites.net/2019/Core/master-elements/
[103] Mini financial reporting scheme represented using XBRL, http://xbrlsite.azurewebsites.net/2019/Prototype/mini/documentation/Index.html
[104] Microsoft 2017 10-K submitted to SEC represented using XBRL, http://xbrl.squarespace.com/journal/2019/3/23/summary-of-human-readable-renderings.html
[105] Accounting equation, http://xbrlsite.azurewebsites.net/2020/master/ae/index.html

Consistent	Assets = 5,000
Complete	Liabilities = 1,000
	Equity = 4,000
Precise 1	Assets = Liabilities + Equity

Consistent	Assets = 5,000
Incomplete	Liabilities = 1,000
	Equity = 4,000
Precise 4	Assets = Liabilities + Equity

Consistent	Assets = 5,000
Incomplete	Liabilities = 1,000
	Equity = 4,000
Precise 2	Assets = Liabilities + Equity

Consistent	Assets = 5,000
Incomplete	Liabilities = 1,000
	Equity = 4,000
Precise 5	Assets = Liabilities + Equity

Inconsistent	Assets = 8,000
Complete	Liabilities = 1,000
	Equity = 4,000
Imprecise 3	Assets = Liabilities + Equity

Consistent	Assets = 5,000
Complete	Liabilities = 5,000
	Equity = 4,000
Imprecise 6	Assets = Liabilities

Consistent	Assets = 5,000
Incomplete	Payables = 1,000
	Equity = 4,000
Precise 7	Assets = Liabilities + Equity

Consistent	Assets = 5,000
Complete	Liabilities = 1,000
	Equity = 4,000
Precise	Assets = Liabilities + Equity
7′	**Payables** is a specialization of the more general term **Liabilities**.

Consistent	Assets = 5,000
Incomplete	Payables = 1,000
	Equity = 4,000
Precise 8	Assets = Liabilities + Equity

Consistent	Assets = 5,000
Complete	Liabilities = 1,000
	Equity = 4,000
Precise	Assets = Liabilities + Equity
8′	**Payables** is a specialization of the more general term **Liabilities**.

Balance Sheet

Consistent	Assets = 5,000
Incomplete	Liabilities = 1,000
	Net Assets = 4,000
Precise 9	Assets = Liabilities + Equity

Balance Sheet, Liquidation Basis

Consistent	Assets = 5,000
Complete	Liabilities = 1,000
	Net Assets = 4,000
Precise 9′	Net Assets = Assets - Liabilities

In the following sections I want to make some adjustments to the logical system which make the logical system either inconsistent, incomplete, or imprecise and explain why the system is then not a properly functioning logical system. I made videos that explain each of these impediments to a properly functioning logical system which you can see in this video playlist, *Understanding the Financial Report Logical System*[106].

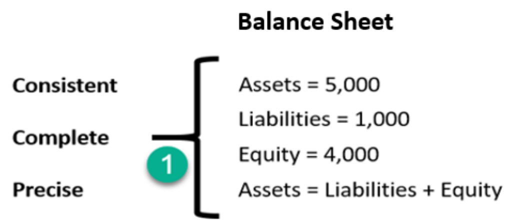
Before we get to the improperly functioning logical systems, let's take one final look at the properly functioning logical system so that you can use that as a baseline for comparing and contrasting the properly functioning and improperly functioning logical systems so that you can understand they sorts of errors that could occur in any XBRL-based financial report.

State 1: Properly Functioning Logical System

For completeness, I want to start by mentioning again our properly functioning logical system which is consistent, complete, and precise. It can be helpful to contrast other states to this state to understand the difference between properly functioning logical systems and improperly functioning systems.

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



Again, this is considered a properly functioning logical system because (a) all the statements within the system are **consistent**; (b) the set of statements that describe the system is **complete**; and (c) the information conveyed by the system is **precise** in its representation of reality. Further, we are formally declaring this "reality"[107] to be our base understanding.

Also, we need to be explicit. We defined three terms "Assets", "Liabilities", and "Equity".

Now, you may know what those three terms are; but a computer does not. You have to define what you work with relative to something that you know. Imagine our system defines four terms, "fac:Assets", "fac:Liabilities", "fac:Equity", and "fac:LiabilitiesAndEquity"[108]. You understand your system but you have to map every external system into your system[109]. Your internal system understands more that the accounting equation system (i.e. you have LiabilitiesAndEquity and the rule "LiabilitiesAndEquity = Liabilities + Equity"). You have to be

[106] Understanding the Financial Report Logical System, https://www.youtube.com/playlist?list=PLqMZRUzQ64B7EWamzDP-WaYbS_W0RL9nt
[107] YouTube, *Reality*, https://youtu.be/eq2Jw6waaCI
[108] Fundamental accounting concepts, http://xbrlsite.azurewebsites.net/2020/core/master-ae/fac.xsd
[109] Mapping from accounting equation to fundamental accounting concepts in our system, http://xbrlsite.azurewebsites.net/2020/core/master-ae/fac-mapping-definition.xml

able to compute that value based on some other system's information[110]. It is perfectly reasonable for our system to create a concept LiabilitiesAndEquity and compute that value even though the accounting equation logical system does not have that explicit value.

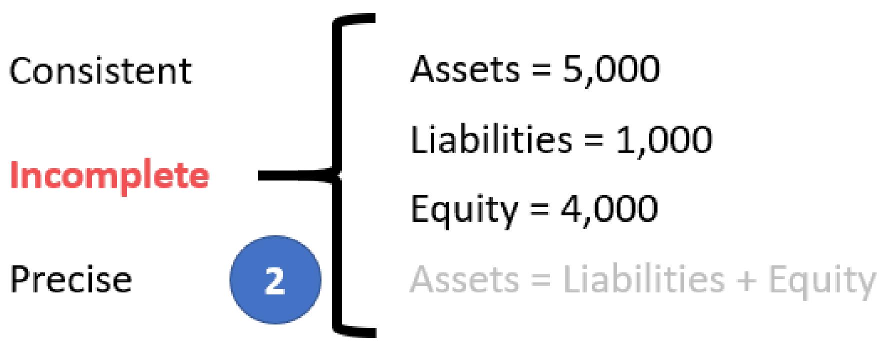
The point is that different economic entities have different models; but all models of a financial reporting scheme are reconcilable from/to one another in some manner[111].

State 2: Incomplete Coverage by Rules

The logical system #2 below is intended to show exactly the same information as our #1 properly functioning logical system, except that #2 leaves out the rule "Assets = Liabilities and Equity" which is showed as grayed out (i.e. because it is assumed to be missing from the logical system.

Coverage is a measure of how well you **do** or **can** represent a domain of information within a logical system. "Do" is about using the tools you have correctly and effectively. "Can" is about the capabilities of the tools you are using to represent the rule.

For example, if your logical system neglects to include the rule "Assets = Liabilities + Equity" or if your tools don't provide the capabilities to allow you to represent that rule; then there is the possibility that the facts being represented to be represented incorrectly and the system will not detect the inconsistency. As such, that logical system has **incomplete coverage**.



While this specific state #2 does have the Assets, Liabilities, and Equity facts consistent with the absent rule; the system is still incomplete because the coverage can be improved by adding the missing rule. If that missing rule is added, then the logical system can be considered complete again.

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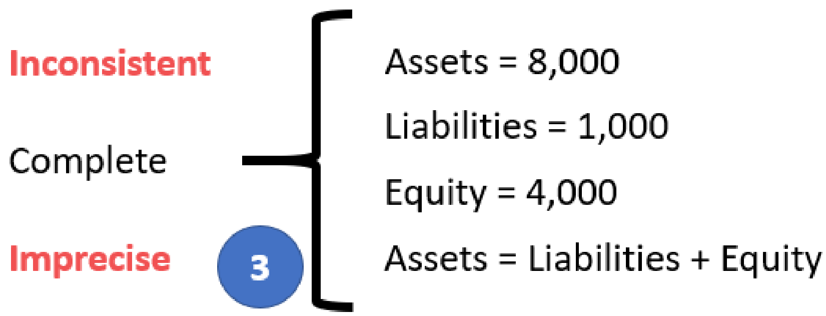
[110] XBRL Formula to derive the value for LiabilitiesAndEquity, http://xbrlsite.azurewebsites.net/2020/core/master-ae/fac-ImputeRule-LiabilitiesAndEquity-formula.xml

[111] Charles Hoffman, CPA, *Special Theory of Machine-based Automated Communication of Semantic Information of Financial Statements*, http://xbrl.squarespace.com/journal/2019/12/30/special-theory-of-machine-based-automated-communication-of-s.html

State 3: Inconsistent and Imprecise

All the statements in the system must be consistent for the logical system to be considered properly functioning. If statements are inconsistent, the logical system is not properly functioning. In this system #3, the values for Assets, Liabilities, and Equity are inconsistent with the rule "Assets = Liabilities + Equity". From looking at the information provided, it is impossible to know exactly which of the three facts are incorrect; it is only possible to understand that the statements made within the logical system is inconsistent. It could be the case that the rule is incorrect.



However, given that we know from state #1 that the value for Assets is 5,000 and not 8,000; the facts in this system is imprecise because the fact for Assets does not reflect reality. (We have, for the purposes of explaining these examples, defined reality and in that reality Assets = 5,000.)

State 4: Unreported Facts

In state #4, the situation is that the economic entity representing information in their report neglected to include the fact for Liabilities. Whether it is the case that a fact can, or cannot, be left unreported is a decision that can be made by the stakeholders of the system.

If it is the case that it is decided that the fact "Liabilities" can be omitted if both Assets and Equity are reported; then you must provide a rule to derive the value of Liabilities when that fact is not reported.

Below you see that the system has been adjusted in state #4' to add the rule "IF Assets exists and if Equity exists; THEN Liabilities = Assets - Equity"[112]. *(NOTE that this rule should actually be "IF Assets exists and if Equity exists and if not(exists) Liabilities; THEN Liabilities = Assets - Equity")*

[112] Here is the impute or derivation rule that would be added to the accounting equation logical system for this situation, http://xbrlsite.azurewebsites.net/2020/core/master-ae/ImputeRule-Key-1-Code-BS-Impute-01-formula.xml

Consistent
Incomplete
Precise
4

Assets = 5,000
Liabilities = 1,000
Equity = 4,000
Assets = Liabilities + Equity

Consistent
Complete
Precise
4′

Assets = 5,000
Liabilities = 1,000
Equity = 4,000
Assets = Liabilities + Equity

If Assets exists and if Equity exists; THEN Liabilities = Assets - Equity

If it were likewise true that either Assets[113] or Equity[114] could also be left unreported, similarly derivation rules could be created for each of those facts. Note that XBRL Formula chaining[115] can be used to physically derive unreported facts if any one of these three facts remain unreported. Note that it is impossible to derive missing information if any two of the facts remain unreported. Adding the derivation rule makes the system complete.

Allowing certain line items of a report to go unreported specifies the need to create rules to derive missing information. Or saying this another way, omitting the possibility of unreported facts negates the need for creating derivation rules.

A second downside of allowing unreported facts is that you lose the parity check or cross check if facts can go unreported. Said another way, it would be considered good or best practice to not leave important high-level financial report line items to go unreported.

State 5: Incomplete

Similar to state #4, in state #5 the logical system is incomplete because both (a) the fact Liabilities is unreported and also (b) the consistency rule "Assets = Liabilities + Equity" is missing from the logical system. Because both a fact and the rule are missing from the logical system, it would be impossible to deduce the value of Liabilities in this case. There is not enough information in the logical system to allow Liabilities to be derived.

At a minimum, a consistency crosscheck rule[116] plus the derivation rule to impute Liabilities[117] would be necessary.

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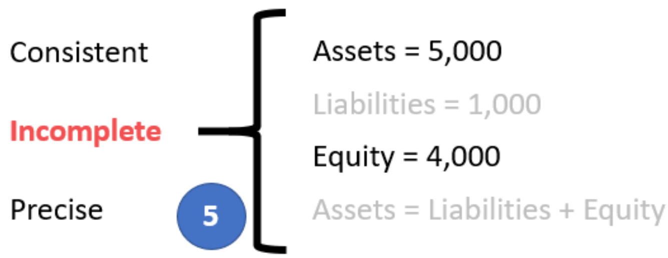
[113] XBRL Formula rule for deriving Assets, http://xbrlsite.azurewebsites.net/2020/core/master-ae/ImputeRule-Key-3-Code-BS-Impute-03-formula.xml

[114] XBRL Formula rule for deriving Equity, http://xbrlsite.azurewebsites.net/2020/core/master-ae/ImputeRule-Key-2-Code-BS-Impute-02-formula.xml

[115] Deriving Facts Using XBRL Formula Chaining (Example), http://xbrl.squarespace.com/journal/2019/4/24/deriving-information-using-xbrl-formula-chaining-example.html

[116] XBRL Formula consistency crosscheck rule Assets = Liabilities + Equity, http://xbrlsite.azurewebsites.net/2020/core/master-ae/Consistency-5-Code-BS01-formula.xml

[117] XBRL Formula derivation rule to impute Liabilities, http://xbrlsite.azurewebsites.net/2020/core/master-ae/ImputeRule-Key-1-Code-BS-Impute-01-formula.xml

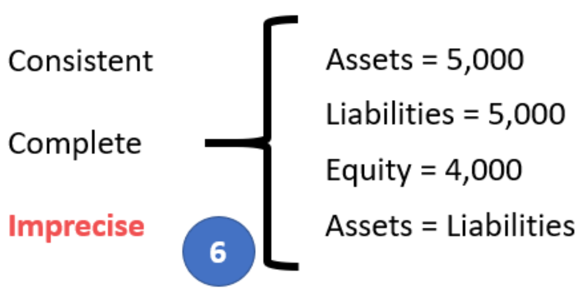


Again, consistent with state #4; Assets and Equity would require similar rules and there is no parity check of reported information.

State 6: Imprecise

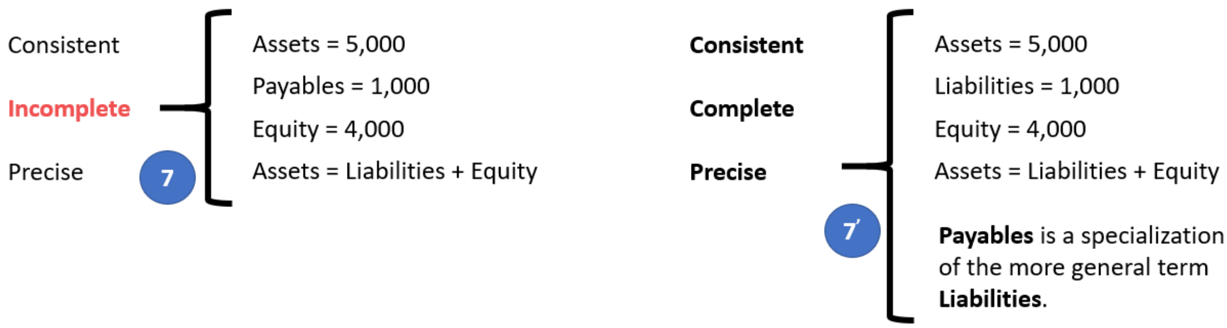
A logical system is a true and fair representation of some agreed upon realism within some area of knowledge. **Precision** is a measure of how precisely you do or can represent the information of a domain within a logical theory. The reality that we formalized in state #1 indicates that "Assets = Liabilities + Equity". Yet, in the state #6 example, the rule "Assets = Liabilities" was provided. Further, the values of Assets and Liabilities are, in fact, consistent with the rule that has been provided.

Remember that in state #1 we formalized our truth to be that "Assets = Liabilities + Equity". As such, this logical system can be described as being imprecise. To make this logical system precise, all that needs to be done is to fix the rule "Assets = Liabilities" and make that rule consistent with our reality which states that "Assets = Liabilities + Equity".

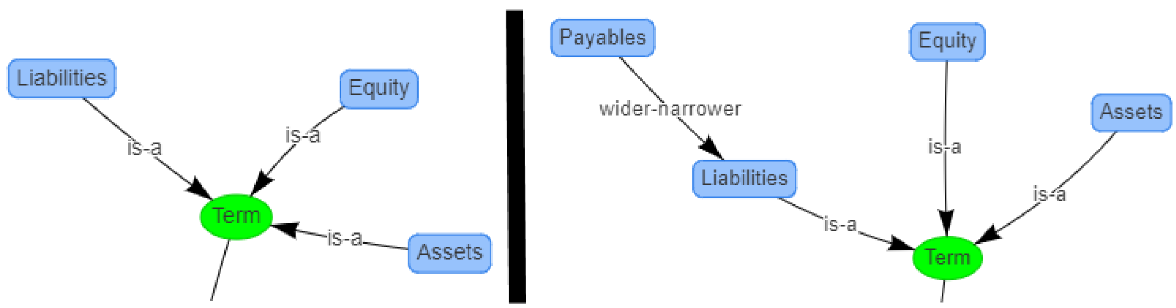


State 7: Extension Concept

In state #7 on the left, what we are trying to convey is that the economic entity reported the fact for Liabilities using the extension concept "Payables" that it had created. If a fact is represented using an extension concept created by a reporting entity; then a "general-special" or "wider-narrower" or "class-equivalentClass" association must be created to indicate to software applications of the relationship so that information can be used correctly. State #7' on the right, the rule "Payables is a specialization of the more general term Liabilities" has been added to the logical system which allows the system to operate effectively[118].



And so, the graphic below shows a fragment of the knowledge graph on page 9 above before and after the information that "Payables is a specialization of the more general term Liabilities," was added. On the left you see State 7, the taxonomy before the information was added and on the right you see "Payable" being added as an extension concept indicating that there is a "wider-narrower" relationship between Payables and Liabilities. Therefore, a machine based process can utilize the information per State 7' because the process understands Liabilities in the taxonomy, understands the "wider-narrower" relationship therefore knowing that "Payables" is a type of Liability.



State 8: Base Taxonomy Wider/Narrower Concept Use

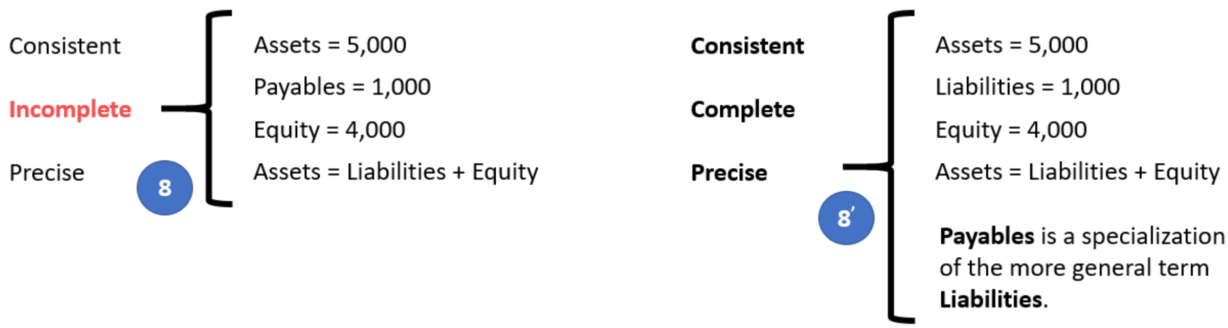
State #8 on the left below is similar to state #7 in that a different concept is used to report a fact; but while state #7 focuses on using an extension concept; state #8 points out that using a wider or narrower base taxonomy concept gives exactly the same result.

Now, our base state #1 does not have the concept "Payables"; but let's assume for a moment that it does have the concept "Payables". Also suppose that there was no information in the

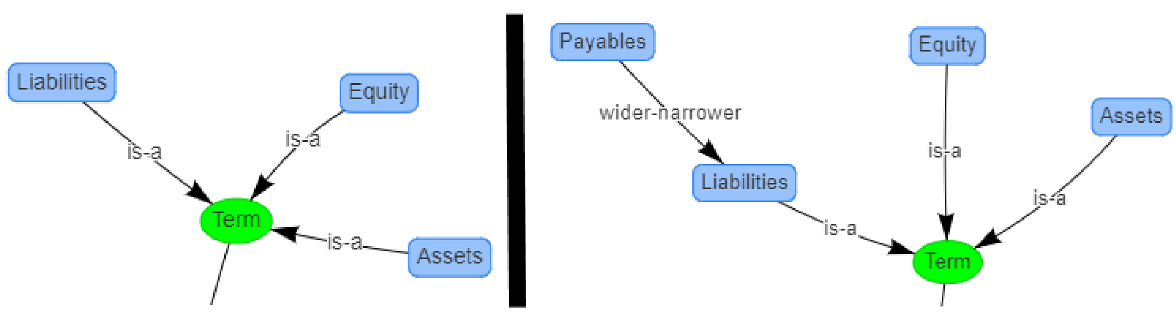
[118] XBRL Definition relations showing example of a mapping rule, http://xbrlsite.azurewebsites.net/2020/core/master-ae/fac-mapping-definition.xml

base logical system indicating the relationship between "Payables" and any other concept. If a fact is represented using a BASE TAXONOMY CONCEPT by a reporting entity; then a "general-special" or "wider-narrower" or "class-equivalentClass" association must exist in that base taxonomy to indicate that some concept is a permissible alternative for some other concept.

State #8' on the right adds the rule "Payables is a specialization of the more general term Liabilities"[119].



And so, the graphic below shows a fragment of the knowledge graph on page 9 above before and after the information that "Payables is a specialization of the more general term Liabilities," was added. On the left you see State 8, the base taxonomy before the information was added and on the right you see "Payable" being added as an extension concept indicating that there is a "wider-narrower" relationship between Payables and Liabilities. Therefore, a machine based process can utilize the information per State 8' because the process understands Liabilities in the base taxonomy, understands the "wider-narrower" relationship therefore knowing that "Payables" is a type of Liability, and therefore can understand what you are conveying.



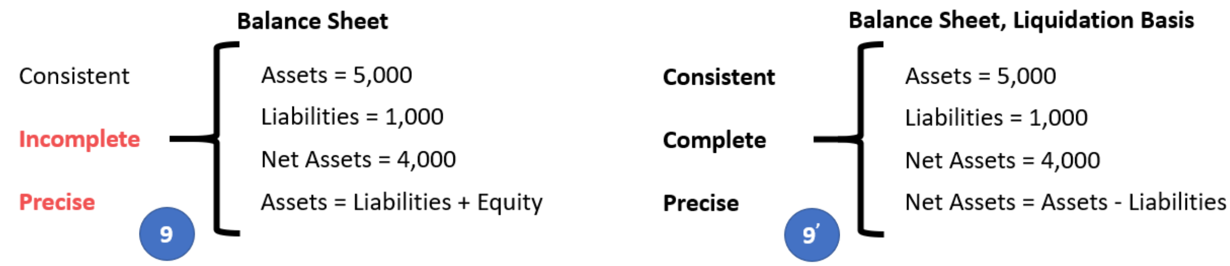
State 9: Defining a Completely New Structure

State #9 below on the left focuses on the structure as contrast all the prior examples which focused on the terms and rules. If a new structure is created, the new structure must be referenced to the base taxonomy and the new structure needs to be explained using machine-

[119] XBRL Definition relations showing example of a mapping rule, http://xbrlsite.azurewebsites.net/2020/core/master-ae/fac-mapping-definition.xml

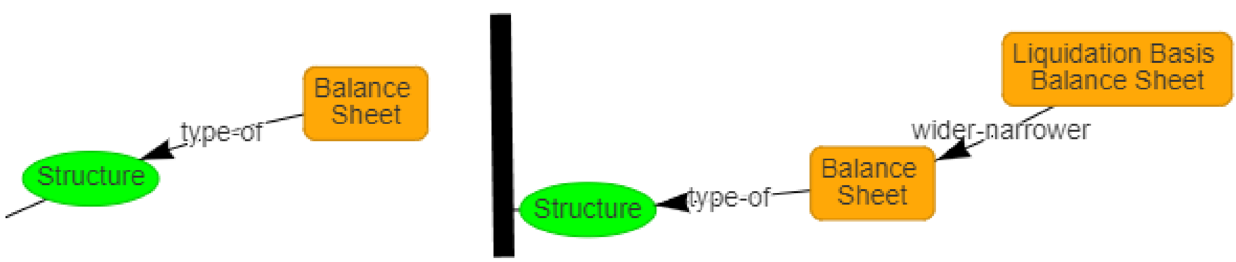
readable rules[120]. Even base taxonomy structures need to be defined in order to be referred to[121]. When you say "Balance Sheet" you know what that means. But a machine does not know.

A base taxonomy should (a) provide all necessary structures separately, not intermingle different models in the same set of associations and (b) define what each structure must look like. Remember, computers are like babies and need to be led by the hand in order to understand the details you need them to understand.



Finally, in our case we have only one disclosure, the Balance Sheet. In our case, the Balance Sheet is always required to be reported per this logical system. As such, that rule is stated in a machine-readable reporting checklist[122]. Other logical systems with more disclosures will have more rules relating to when a disclosure is required to be provided in a report.

Similar to how "Payables" was added as an extension of the terms in the logical system; we can extend the structures to include a "Liquidation Basis Balance Sheet" structure which is a specialization of a Balance Sheet:



And such, an automated process will be able to understand the new structure because it is related to an existing structure. Other structures could be added in this same manner and only identified as a type of structure. But if you want to understand what that structure is, you need

[120] XBRL Definition relations used to represent structure rules, http://xbrlsite.azurewebsites.net/2020/core/master-ae/dm-1355-rules-def.xml
[121] XBRL taxonomy schema used to define "Balance Sheet", http://xbrlsite.azurewebsites.net/2020/core/master-ae/disclosures.xsd
[122] XBRL Definition relations used to represent a reporting checklist or disclosure rules, http://xbrlsite.azurewebsites.net/2020/core/master-ae/reporting-checklist-rules-def.xml

to associate any newly defined structure relative to some existing structure. Humans will only understand the difference by reading the documented associated with the new structure.