Auditing XBRL-based Financial Reports

Extending the audit role to machine-readable financial reports

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"It must be remembered that there is nothing more difficult to plan, more doubtful of success, nor more dangerous to manage than a new system. For the initiator has the enmity of all who would profit by the preservation of the old institution and merely lukewarm defenders in those who gain by the new ones." *Niccolò Machiavelli*

"He who loves practice without theory is like the sailor who boards a ship without a rudder and compass and never knows where he may cast." *Leonardo da Vinci*

"I skate to where the puck is going to be, not where it has been." *Wayne Gretzky*, legendary Canadian hockey star

Executive summary:

- A financial report is an allowed interpretation of an expression of the financial position and financial performance of an economic entity per some set of statutory and regulatory rules.
- The statements made by such a report form a logical system.
- Logic programming software can test to see if the statements that form the logical system constitute a properly functioning logical system.
- Similar to double-entry accounting, the statements including the description and the facts provide what amounts to a "parity check" or a logical "check sum".
- This capability leads to a solid audit strategy that can be applied to XBRL-based financial reports.
- Similar functionality is also useful for general business reports that are XBRL-based.

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A financial report is an allowed interpretation of an expression of the financial position and financial performance of an economic entity per some set of statutory and regulatory rules. Here-to-for, that expression has been in a form that is only readable by humans. However, XBRL and other machine-readable formats change that, making those expressions readable by both humans and by machine-based processes.

Single-entry accounting is how 'everyone' would do accounting. In fact, that is how accounting was done before double-entry accounting was invented. Double-entry accounting was the invention of medieval merchants and was first documented by the Italian mathematician and Franciscan Friar Luca Pacioli.

Double-entry accounting adds an additional important property to the accounting system, that of a clear strategy to identify errors and to remove the errors from the system. Even better, double-entry accounting has a side effect of clearly firewalling errors as either accident or fraud[1]. This then leads to an **audit strategy**. Double-entry accounting is how professional accountants do accounting.

An XBRL-based financial report is not only a machine-readable format; it also is a machine-readable logical system and has the potential to be a well-defined and fully expressed logical system. A well-defined logical system, when fully expressed, will be properly functioning and demonstrably consistent, valid, sound, and complete. These properties can be leveraged to offer a systematic **audit strategy for XBRL-based financial reports**.

Essentially, an XBRL-based financial report is a set of declarative statements provided in global standard XBRL format. Logic programming software applications such as Prolog, Datalog, Clips, and Answer Set Programming can provide feedback as to whether these statements are consistent, valid, sound, complete and otherwise properly functioning. Even XBRL processors and XBRL formula processors can effectively prove that XBRL-based financial reports are properly functioning to a large degree.

Statements

A financial report makes statements about the financial position and financial performance of an economic entity. Consider the name, "financial statements". Some of those statements might be organized into the form of a table or tabular presentation of information; for example, a balance sheet. But fundamentally, a financial report makes statements about the financial position and financial performance of an economic entity. Some statements may be quantitative in nature, other statements may be qualitative in nature.

[1] Ian Grigg, *Triple Entry Accounting*, https://iang.org/papers/triple_entry.html

Historically, those statements and the meaning they convey have been readable by human-based processes. With the introduction of XBRL this changes. XBRL-based financial reports are readable by both humans and by machine-based processes.

But how do professional accountants creating these reports make sure they convey the information, more make the statements, that they desire and intend to make? How does an internal auditor review such reports? How does an independent auditor confirm such reports are conveying meaning appropriately? How do financial analysts extracting and using information do so appropriately?

Current Audit Guidance

While the AICPA's *Principles and Criteria for XBRL-Formatted Information*[2] lays a good foundation for thinking about how to create XBRL-based financial reports correctly, review a report that another has created, provide attestation services related to such a report, or providing agreed-upon consulting services; the AICPA's guidance state (emphasis added):

> "The quality of XBRL files is an important concern to users of these files. Errors in the XBRL files will have varying consequences. During the development of the XBRL principles and criteria, potential errors that could occur when preparing XBRL files were considered, and ***it is believed*** that the ***criteria addresses many of these errors***. Further, the principles and criteria meet the requirements under AT section 101, as previously discussed in paragraphs .11-.13, and, thus are ***considered suitable*** for practitioners to perform an attestation engagement."

Hope is not a solid systems engineering principle. Clearly, those creating such XBRL-based reports need to **make sure no errors exist**. Accountants and auditors cannot "*believe*" that such a report is correct using a process that "*addresses many of these errors*". Accountants and auditors need to make sure no errors exist. Two auditors looking at the same XBRL-based report should be able to reach the same conclusion about the subjective mechanical, structural, mathematical, and other logical considerations related to such reports. Without this capability, XBRL-based reports really cannot be considered reliable, yet alone auditable.

Many professional accountants and auditors do not understand how to interact with XBRL-based financial reports because they don't have important background necessary to do so[3].

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[2] American Institute of Certified Public Accountants, 2017, *Principles and Criteria for XBRL-Formatted Information*, https://www.aicpa.org/InterestAreas/FRC/AccountingFinancialReporting/XBRL/DownloadableDocuments/aicpa-principles-and-criteria-for-xbrl-formatted-information.pdf

[3] Charles Hoffman, CPA, *Artificial Intelligence and Knowledge Engineering Basics in a Nutshell*, http://xbrlsite.azurewebsites.net/2019/Library/KnowledgeEngineeringInNutShell.pdf

Trying to understand XBRL-based financial reports using old outdated mental maps will be unsatisfying to say the least.

Two academic papers discuss how to audit XBRL-based financial reports: Srivastava, Rajendra Prasad and Kogan, Alex, *Assurance on XBRL Instance Document: A Conceptual Framework of Assertions* (September 9, 2009)[4] and J. Efrim Boritz and Won Gyun No *Computer-Assisted Functions for Auditing XBRL-Related Documents*[5]. Journal of Emerging Technologies in Accounting. Both papers point to the need for a framework and methodology to audit the information contained within an XBRL-based financial report.

Myths and Misconceptions Related to the "Audit of XBRL"

There are many myths and misconceptions professional accountants, professional auditors, and others have about the "audit of XBRL".

The first misconception is that XBRL is audited at all. XBRL is a technical format. The XBRL technical format can be verified 100% by automated software tests. That is the purpose of the XBRL International XBRL conformance suite tests[6]. Those conformance suite tests are used to build automated machine-based processes to be sure the XBRL technical syntax is right in all details. But XBRL conformance suite tests do not, and cannot, check to see if the meaning conveyed by the XBRL-formatted information is correct.

Second, when one "audits" the financial information represented in the form of paper you are not auditing the paper, you are auditing the information represented on the paper. The meaning conveyed by the XBRL-formatted information and the meaning conveyed by paper-based information including electronic forms of paper or "e-paper" like HTML and PDF convey the exact same meaning.

Third, the purpose of an audit is to provide an independent third-party opinion as to whether reported information about the financial condition and financial performance of an economic entity is being represented fairly by the information provided in a financial report. The audit is about the *independent third-party opinion* as to the fairness of that information. Financial

[4] Srivastava, Rajendra Prasad and Kogan, Alex, *Assurance on XBRL Instance Document: A Conceptual Framework of Assertions* (September 9, 2009). Available at SSRN: https://ssrn.com/abstract=1289467
[5] J. Efrim Boritz and Won Gyun No (2016) Computer-Assisted Functions for Auditing XBRL-Related Documents. Journal of Emerging Technologies in Accounting: Spring 2016, Vol. 13, No. 1, pp. 53-83, https://www.aaapubs.org/doi/10.2308/jeta-51436
[6] XBRL International, *XBRL 2.1*, https://specifications.xbrl.org/work-product-index-group-base-spec-base-spec.html

reporting managers still need to represent information in their XBRL-based reports correctly even if those reports are not audited.

Fourth, external financial reporting managers need to create true and fair representations of their financial information. The team that works with the external financial reporting manager needs to make sure the financial report is true and fair. Internal auditors that work for a company to make sure the external financial reporting manager is doing their job correctly need to make sure the information is true and fair. Finally, the CFO that signs off on the report needs to make sure the financial report information is true and fair. The point here is that there are lots of people who care that the information contained in a financial report is represented appropriately, not just auditors.

Describing a Logical System

A **logical system**[7] (logical theory) 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 logical system or logical theory is made up of a set of **models**, **structures**, **terms**, **associations**, **assertions**, and **facts**. In very simple terms,

- **Logical theory**: A logical theory is a set of *models* that are consistent with that logical theory.
- **Model**: A model is a set of *structures*. A model is an interpretation of a theory.
- **Structure**: A structure is a set of *statements* which describe the structure.
- **Statement**: A statement is a proposition, claim, assertion, belief, idea, or fact about or related to the universe of discourse. There are four broad categories of statements:
    - **Terms**: Terms are statements that define ideas used by the logical theory such as “assets”, “liabilities”, and “equity”.
    - **Associations**: Associations are statements that describe permissible interrelationships between the terms such as “assets is part-of the balance sheet” or “operating expenses is a type-of expense” or “assets = liabilities + equity” or “an asset is a ‘debit’ and is ‘as of’ a specific point in time and is always a monetary numeric value”.

[7] Charles Hoffman, CPA, *Understanding and Expressing Logical Systems*, http://xbrl.squarespace.com/journal/2019/9/25/understanding-and-expressing-logical-systems.html

- **Assertions**: Assertions are statements that describe what 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"
- **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 logical system can have high to low **precision** and high to low **coverage**. *Precision* is a measure of how precisely the information within a logical system has been represented as contrast to reality for the universe of discourse. *Coverage* is a measure of how completely information in a logical system has been represented relative to the reality for a universe of discourse.

Proving the Logical System is Properly Functioning

A financial report is a set of statements. That set of statements on paper or "e-paper" (HTML, PDF) is a man-made logical system. But that logical system is only understandable by humans who read the set of statements.

An XBRL-based report is a machine-readable logical system. Said another way, financial reports are not arbitrary, haphazard, illogical, or random.

Logic programming[8] is a way of processing those statements reliably using automated machine-based processes.

Predicate logic[9] is based on and extends propositional logic[10]. Propositional logic which is also known as statement logic is based on the truth value of some set of one to many propositions or statements. A statement is defined as "a proposition, claim, assertion, belief, idea, or fact about or related to the universe of discourse." A financial report is a logical system that contains a set[11] of statements[12]. That set of statements is essentially a "chain" or chain of reasoning[13].

[8] Wikipedia, *Logic Programming*, https://en.wikipedia.org/wiki/Logic_programming
[9] Wikipedia, *First-order Logic*, https://en.wikipedia.org/wiki/First-order_logic
[10] Wikipedia, *Propositional Calculus*, https://en.wikipedia.org/wiki/Propositional_calculus
[11] Wikipedia, *Set Theory*, https://en.wikipedia.org/wiki/Set_theory
[12] Charles Hoffman, CPA, *Understanding and Expressing Logical Systems*, http://xbrl.squarespace.com/journal/2019/9/25/understanding-and-expressing-logical-systems.html
[13] Charles Hoffman, CPA, *Constructing a Chain of Reasoning*, http://xbrl.squarespace.com/journal/2019/9/26/constructing-a-chain-of-reasoning.html

And so, a **logical system is the set of statements** that can be chained together using logical connectors. These statements represented as sets of models, structures, terms, assertions, associations, and facts are all forms of statements or propositions[14]. The set of statements can be proven to be consistent, valid, sound, complete, and fully expressed; then the financial report logical system can be proven to be properly functioning. The financial report is then in equilibrium. If one statement within the system is changed in some way, it is typically the case that some other statement likewise must be changed in order to keep the financial report logical system of statements in equilibrium.

A well-defined logical system, when **fully expressed** and in equilibrium, should be properly functioning and demonstrably **consistent**, **valid**, **sound**, and **complete**. The following are definitions of these terms:

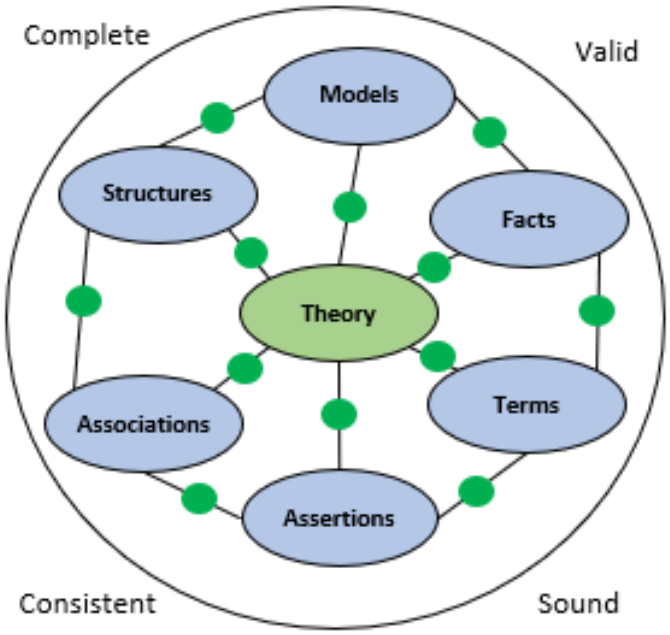
- **Consistent**: No statement of the logical system contradicts another statement within that same logical system.
- **Valid**: No false inference (logical deduction of a statement) from a true premise is possible.
- **Complete**: If a statement is true, then that statement can be proven; i.e. all statement exists in the system.
- **Sound**: If any statement is a theorem (an IF…THEN assertion) of the logical system; then the theorem is true.
- **Fully expressed**: If an important term exists in the real world; then the term can be represented within the logical system.

It is desirable to have a well-defined logical system that is fully expressed that is proven to be properly functioning and demonstrably consistent, valid, sound, and complete. This equilibrium is similar to the equilibrium of double-entry accounting.

Understanding the System is Properly Functioning

Depicting all that I am trying to articulate graphically, perhaps it might look something like this:

[14] Charles Hoffman, CPA, *Understanding and Expressing Logical Systems*, http://xbrl.squarespace.com/journal/2019/9/25/understanding-and-expressing-logical-systems.html



Properly Functioning System

Now, this graphic communicates an idea, not a logical thing that can be measured. I would like to come up with a better graphic.

Think of this as a *complete* set of statements that have to be *consistent* and everything has to be *valid* and if you achieve this then the system is *sound*. If all those four constraints are met and the system is *fully expressed*, then the **system is functioning properly**. Two different people can look at the same set of statements and reach the same conclusion.

What is more, you can prove that the system is functioning properly, the full set of statements is like a "parity check" or a "check sum".

While I cannot provide a graphic that visually proves that a logical system can be verified to be properly functioning, software applications exist which can and more importantly the notion of properly functioning is not a new or novel idea. Implementations of logic systems such as Prolog[15], Datalog[16], Clips[17], and Answer Set Programming[18] all perform this task and provide the general idea that all this can be proven. XBRL processors and XBRL formula processors can

[15] Wikipedia, *Prolog*, https://en.wikipedia.org/wiki/Prolog
[16] Wikipedia, *Datalog*, https://en.wikipedia.org/wiki/Datalog
[17] Wikipedia, *Clips*, https://en.wikipedia.org/wiki/CLIPS
[18] Wikipedia, *Answer Set Programming*, https://en.wikipedia.org/wiki/Answer_set_programming

effectively be used to detect specific logical errors if trying to verify one single specific report but tend to not be as effective and efficient as general logic programming applications[19].

To be crystal clear, when I say logical system, I mean the most safe and reliable logical system that can be achieved and also with the maximum expressiveness[20] that is achievable.

Specifically, I mean a **finite deductive first-order logic system**[21]. 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. This is done by consciously and carefully selecting the specific pieces that make up that system:

- Axiomatic (Zermelo–Fraenkel) set theory[22] is used as contrast to naïve set theory[23].
- All associations are expressed as directed acyclic graphs[24] that do not cause cycle problems.
- The closed world assumption[25] is made so that decidability is not a problem and to be consistent with relational databases.
- Negation as failure[26] is assumed to be clear and avoid known problems with alternative approaches.
- The unique name assumption[27] is made to be clear and to avoid known problems.
- Horn logic[28] to avoid logical paradoxes.

Terms that I have heard that describe this sort of rock-solid, sound system are stable model semantics[29] and well-founded semantics[30]. Basically, technical people have been trying to get all this stuff to work for the past 50 years and that knowledge needs to be understood and leveraged.

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[19] Charles Hoffman, CPA, *Specific Deficiencies in Capabilities of Existing XBRL Formula Processors*, http://xbrl.squarespace.com/journal/2016/9/26/specific-deficiencies-in-capabilities-of-existing-xbrl-formu.html
[20] Charles Hoffman, CPA, *Revisiting the Knowledge Representation Spectrum*, http://xbrl.squarespace.com/journal/2019/10/9/revisiting-the-knowledge-representation-spectrum.html
[21] Wikipedia, *First-order Logic, Deductive System*, https://en.wikipedia.org/wiki/First-order_logic#Deductive_systems
[22] Wikipedia, *Set Theory, Axiomatic Set Theory*, https://en.wikipedia.org/wiki/Set_theory#Axiomatic_set_theory
[23] Wikipedia, *Naïve Set Theory*, https://en.wikipedia.org/wiki/Naive_set_theory
[24] Wikipedia, *Directed Acyclic Graph*, https://en.wikipedia.org/wiki/Directed_acyclic_graph
[25] Wikipedia, *Closed World Assumption*, https://en.wikipedia.org/wiki/Closed-world_assumption
[26] Wikipedia, *Negation as Failure*, https://en.wikipedia.org/wiki/Negation_as_failure
[27] Wikipedia, *Unique Name Assumption*, https://en.wikipedia.org/wiki/Unique_name_assumption
[28] Wikipedia, *Horn Logic*, https://en.wikipedia.org/wiki/Horn_clause
[29] Wikipedia, *Stable Model Semantics*, https://en.wikipedia.org/wiki/Stable_model_semantics
[30] Wikipedia, *Well-founded Semantics*, https://en.wikipedia.org/wiki/Well-founded_semantics

I am not saying that I have 100% of the details precisely correct, but I do believe that the intent of what I am trying to achieve is clear and can be understood. Further, all this is provable by using software applications that exist today.

Logical Statements, Not XBRL Technical Syntax

Within an XBRL-based report, every statement is a logical statement (i.e. nothing is technical); you never interact with the XBRL technical syntax. This is done by using a logical theory that explains how a financial report works[31] and a framework[32] for implementing that logical theory within software applications. When you interact with software created using this framework, XBRL literally disappears into the background and professional accountants interact with the software using terms they understand[33].

Further, while some prefer the XBRL technical syntax, others might prefer the Semantic Web Stack[34] of technologies. OMG is even taking steps with their *Standard Business Report Model (SBRM)*[35] to create a logical conceptualization of a business report that is technical syntax agnostic. Another technical syntax alternative is JSON. Fads, trends, and arbitrary personal preferences, point to the need to support multiple technical syntax alternatives. All these alternative technical syntax alternatives have one thing in common: logic.

Logic of Financial Statements

The basic high-level model of a financial report follows double-entry accounting and is described by the accounting equation which is a logical statement[36]:

Assets = Liabilities + Equity

Standards setters create financial reporting schemes which provide further details which expand on the accounting equation. By definition a standards setter cannot violate the accounting equation. The financial reporting scheme essentially defines a core set of *classes* of

[31] Charles Hoffman, CPA and Rene van Egmond, *Financial Report Semantics and Dynamics Theory*, http://xbrlsite.azurewebsites.net/2016/Library/Theory-2017-06-26.pdf
[32] Charles Hoffman, CPA, *Open Source Framework for Implementing XBRL-based Digital Financial Reporting*, http://xbrlsite.azurewebsites.net/2019/Framework/FrameworkEntitiesSummary.html
[33] Charles Hoffman, CPA, *Narrative Explaining Logical Conceptualization of a Financial Report*, http://xbrlsite.azurewebsites.net/2019/Framework/NarrativeConceptualization.pdf
[34] Wikipedia, *Semantic Web Stack*, https://en.wikipedia.org/wiki/Semantic_Web_Stack
[35] OMG, *Standard Business Report Model* (SBRM), https://omgwiki.org/SBRM/doku.php
[36] Charles Hoffman, CPA, *Accounting Equation*, http://xbrlsite.azurewebsites.net/2019/core/core-ae/Documentation.pdf

elements[37] used by that financial reporting scheme which reconciles to the accounting equation. The elements of financial statements are the building blocks, or ***classes*** of defined elements, with which financial statements are constructed by an economic entity reporting per some financial reporting scheme.

The ***items*** in the financial statements of a specific economic entity represent in words and numbers certain entity resources, claims against those resources, and the effects of transactions and events, circumstances, and other phenomenon that result in changes in those resources and claims. Those words and numbers are statements the economic entity makes to describe their financial position and financial performance.

These classes of building blocks are **intentionally interrelated mathematically** within the four core statements that make up a financial report; this is called 'articulation'.

Intermediate components, i.e. subtotals, can be used to represent the items of an economic entity within the items that comprise a financial report of the economic entity. However, these intermediate components and the items must fit into the core framework of the classes of elements that are the building blocks of any financial report created using a specific reporting scheme.

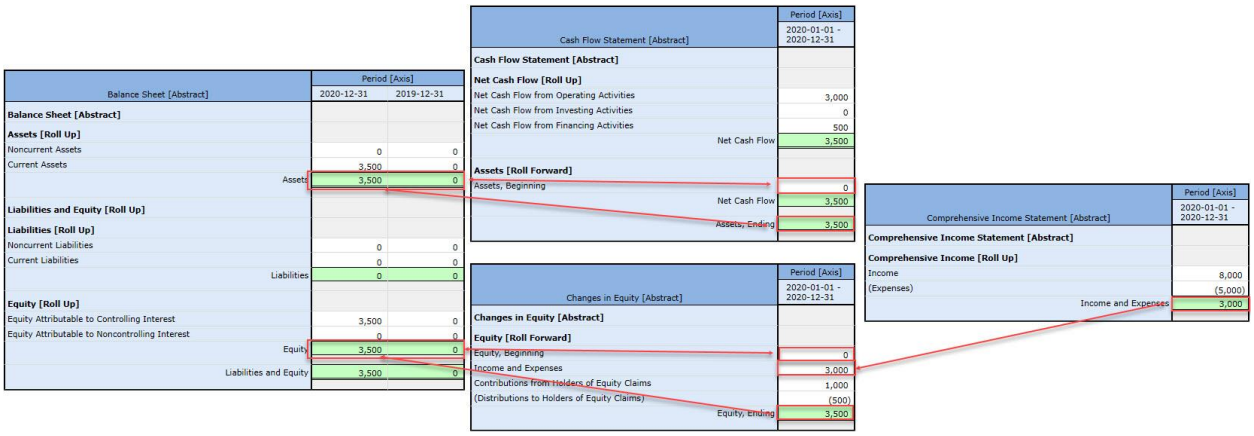
The ***balance sheet*** provides a roll up of assets, a roll up of liabilities and equity, and is bound by the rule “Assets = Liabilities + Equity”. The ***income statement*** is used to compute the roll up total “Net Income” and there are rules for how the intermediate components (i.e. subtotals) of Net Income roll up. Net income then flows to the ***statement of changes in equity*** which is a roll forward which reconciles beginning and ending equity on the current and prior balance sheets. The ***cash flow statement*** is a roll up of Net Cash Flow, rules that specify how the intermediate components (i.e. subtotals) of net cash flow roll up, and a roll forward of the asset Cash and Cash Equivalents which reconciles the beginning and ending balance of that asset on the balance sheet[38].

And so, the primary financial statements are explained by:

1. The accounting equation.

[37] Charles Hoffman, CPA, *Comparison of Elements of Financial Statements*, http://xbrlsite.azurewebsites.net/2019/Core/ElementsOfFinancialStatements.pdf
[38] Four statement model, http://xbrlsite.azurewebsites.net/2019/Core/core-ifrs/FourStatements_IFRS.jpg

2. Some set of elements of the financial statements[39] such as those for IFRS[40]: Assets, Liabilities, Equity, Contributions from Holders of Equity Claims, Distributions to Holders of Equity Claims, Income and Expenses, Income, Expenses.
3. The fundamental relations between the elements where T0 is the beginning balance sheet date, T1 is the ending balance sheet date, and P1 is the current period that reconciles the beginning and ending balance sheet: 0 = $Equity^{T0}$ + $Income^{P1}$ - $Expenses^{P1}$ + $ContributionsFromHoldersOfEquityClaims^{P1}$ – $DistributionsToHoldersOfEquityClaims^{P1}$ + $Assets^{T1}$ – $Liabilities^{T1}$



While the model shown above which is based on “Assets = Liabilities and Equity”; some economic entities use different sorts of models. For example, some economic entities report using a liquidation basis style balance sheet where “Assets - Liabilities = Net Assets”. “Net Assets” and “Equity” are two different labels for what is the same concept.

Using the rules of mathematics, the equation “Assets = Liabilities + Equity” can be converted to “Assets - Liabilities = Equity”.

So, while a financial report is not a static form it is not random either. Financial reports follow patterns and these patterns can be explained using specific models to account for and manage the variability inherent in a financial report. Each set of items in the financial report of an economic entity must follow the accounting equation and the elements of a financial statement defined by some financial reporting scheme.

[39] Charles Hoffman, CPA, *Comparison of Elements of Financial Statements*, http://xbrlsite.azurewebsites.net/2019/Core/ElementsOfFinancialStatements.pdf
[40] Core Elements of Financial Statements (IFRS), http://xbrlsite.azurewebsites.net/2019/Core/core-ifrs/

Similarity to Double-entry Accounting

I see this as having similarities to the double-entry accounting system. The double-entry accounting approach offers a "parity check" by basically requiring two entries for each transaction. Essentially, double-entry accounting is concurrently using two single-entry ledgers in order to detect errors and tying that ledger with the accounting equation, "Assets = Liabilities and Equity".

This approach is similar in that all of the statements describing the financial report and the facts that are provided within that report are tested using automated machine-based processes to be sure the mechanical details are all appropriate.

This is not to say that automated processes can verify that 100% of the report details are appropriate, that is not currently possible and might never be possible. Verifying a report will always be a collaboration between a human and a machine that is providing assistance where it can. The actual third-party verification provided by an auditor still needs to be performed to verify the truth of each statement that exists. The logical system can only tell you if the statements that do exist are consistent with one another and other such details.

An XBRL-based financial report which is comprised of an XBRL taxonomy plus an XBRL instance can borrow this idea from double-entry accounting. While the notion of a "double-entry XBRL taxonomy" is not a perfect one (and might even make knowledge engineers cringe), it does make an important point between allowed variability and the rules necessary to control and manage that variability. When information is added to an XBRL taxonomy, other information must also be added in order to control, manage, and ultimately channel business professionals to success.

And so, if a new term is added; then one or more new associations or assertions will likely also need to be added.

More importantly, if business professionals can reliably create such machine-readable logical systems that will very likely have a very positive and significant impact on the functioning of an enterprise just as double-entry accounting had a significant impact on the enterprise. With the ever-increasing complexity and volume of information, being able to leverage machines effectively to help humans perform work is important.

Reconciling Logic Terms to Common Audit Terms

The five terms I used to describe a logical system that is functioning properly are not my terms. These terms are taken from logic and the definition of a logical system[41]: complete, consistent, valid, sound, fully expressed. Further, I have changed the definitions slightly in order to make the definitions consistent with the terms I used to explain the components of logical systems.

Below, I have provided similar terms that are more common to professional accountants and auditors when thinking about financial reports:

- **Completeness**: All relevant statements have been included within the financial report representation.
- **Existence**: No statement exists which should not be included in the financial report has been included.
- **Accuracy**: The statements are included in the financial report are accurate, correct, and precise.
- **Fidelity**: Considered as a whole; the statements provided in the financial report are a loyal representation of the actual financial position and financial performance of the reporting economic entity.
- **Integrity**: The statements that describe each part of a financial report provide a true and fair representation of such part and no parts are inconsistent with or contradict any other financial report part.
- **Consistency**: The statements are consistent with prior periods and with the reporting entity's peers as is deemed appropriate.
- **True and fair representation**: The statements of the financial report are a true and fair representation of the information of the reporting economic entity.

Optimally, the terms used to describe logical systems and the terms used by professional accountants and auditors should be reconcilable from one to the other.

Very Basic Example

The following provides a very basic example of the statements that might exist within a financial report. This very basic example provides statements for the accounting equation[42] and facts for an economic entity. Here is a robust sample that helps you understand, but not 100%, of all statements:

- Terms:

[41] Wikipedia, *Logic*, *Logical System*, https://en.wikipedia.org/wiki/Logic#Logical_systems
[42] *Accounting Equation*, http://xbrlsite.azurewebsites.net/2019/core/core-ae/Documentation.pdf

  - Assets is-a term.
  - Liabilities is-a term.
  - Equity is-a term.
  - Balance sheet is-a term.
- Associations:
  - Assets has-property balance of debit.
  - Liabilities has-property balance of credit.
  - Equity has-property balance of credit.
  - Assets has-property period of instant.
  - Liabilities has-property period of instant.
  - Equity has-property period of instant.
- Structure
  - Balance sheet has-part Assets.
  - Balance sheet has-part Liabilities.
  - Balance sheet has-part Equity.
- Assertions:
  - Assets = Liabilities + Equity
- Facts:
  - ABC Company is an economic entity.
  - Assets for December 31, 2019 for ABC Company is $5,000 US Dollars.
  - Liabilities for December 31, 2019 for ABC Company is $1,000 US Dollars.
  - Equity for December 31, 2019 for ABC Company is $4,000 US Dollars.

The statements are not machine readable, but they could be[43]. So above you see all of the statements that exist within this very basic example of a financial report. Per all the statements, the system appears to be properly functioning. But, suppose that the value for the fact "Assets" was changed to say $5,500. If that were the case, because there is a assertion that specifies "Assets = Liabilities + Equity" and because of the values of Liabilities and Equity, the logical system would NOT be functioning properly. If that assertion did not exist, the system would not be considered "complete".

Here is this same example represented in XBRL including the facts[44], terms[45], associations[46], and assertions[47]. There is not a 100% correlation to keep the example easy to follow. The XBRL can be processed using global standard off-the-shelf software. In fact, two completely different

[43] Wikipedia, *Attempto Controlled English*, https://en.wikipedia.org/wiki/Attempto_Controlled_English
[44] XBRL instance, http://xbrlsite.azurewebsites.net/2019/Core/core-audit/instance.xml
[45] XBRL taxonomy schema, http://xbrlsite.azurewebsites.net/2019/Core/core-audit/core.xsd
[46] XBRL presentation relations, http://xbrlsite.azurewebsites.net/2019/Core/core-audit/core-presentation.xml
[47] XBRL formula, http://xbrlsite.azurewebsites.net/2019/Core/core-audit/core-formula.xml

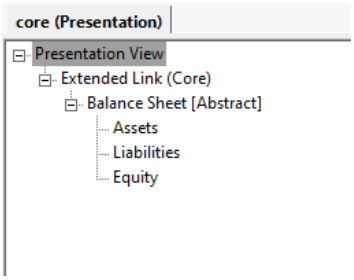
XBRL processing tools were used created by different software vendors and each software application provides the same results.

Software #1:

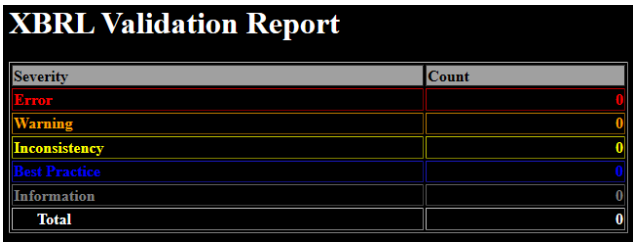
Terms and property associations:

Prefix	Label	Name	Data Type	Abstr...	Substitutio...	Balance	Period Type
core	Assets	Assets	Monetary	False	xbrli:item	Debit	Instant
core	Balance Sheet [Abstract]	BalanceSheetAbstract	String	True	xbrli:item		Instant
core	Equity	Equity	Monetary	False	xbrli:item	Credit	Instant
core	Liabilities	Liabilities	Monetary	False	xbrli:item	Credit	Instant

Structure:



XBRL syntax validation report:



XBRL Validation Report

Severity	Count
Error	0
Warning	0
Inconsistency	0
Best Practice	0
Information	0
Total	0

Assertions validation:

Summary

Formulas Compiled	Formula Fired	Assertions Compiled	Assertions Fired	Assertions Satisfied	Assertions Not Satisfied
0	0	1	1	1	0

Assertion Report

Value Assertions

id	satisfied	message
ASSERTION_CORE_Equality_AccountingEquation (evaluation 1)	satisfied	$Assets=5000 = $Liabilities=1000 + $Equity=4000

Software #2:

Human readable representation[48]:

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

Terms and associations[49]:

#	Label	Report Element Class	Period Type	Balance	Name
1	**Core [Table]**				(Implied)
2	*Balance Sheet [Abstract]*	[Abstract]			core:BalanceSheetAbstract
3	Assets	[Concept] Monetary	As Of	Debit	core:Assets
4	Liabilities	[Concept] Monetary	As Of	Credit	core:Liabilities
5	Equity	[Concept] Monetary	As Of	Credit	core:Equity

Facts[50]:

#	Reporting Entity [Axis]	Period [Axis]	Concept	Fact Value	Unit	Rounding	Parenthetical Explanations
1	GH259400TOMPUOLS65II (http://standards.iso.org/iso/17442)	2020-12-31	Assets	5000	USD	INF	
2	GH259400TOMPUOLS65II (http://standards.iso.org/iso/17442)	2020-12-31	Liabilities	1000	USD	INF	
3	GH259400TOMPUOLS65II (http://standards.iso.org/iso/17442)	2020-12-31	Equity	4000	USD	INF	

XBRL technical syntax validation[51]:

[48] Human readable rendering, http://xbrlsite.azurewebsites.net/2019/Core/core-audit/evidence-package/contents/index.html#Rendering-Core-Implied.html
[49] Human readable model structure, http://xbrlsite.azurewebsites.net/2019/Core/core-audit/evidence-package/contents/index.html#NetworkStructure-Core-Implied.html
[50] Human readable facts, http://xbrlsite.azurewebsites.net/2019/Core/core-audit/evidence-package/contents/index.html#NetworkFacts-Core-Implied.html
[51] Human readable report properties including validation, http://xbrlsite.azurewebsites.net/2019/Core/core-audit/evidence-package/contents/index.html#ReportProperties.html

Verification Summary		
	A	M
XBRL Technical Syntax Rules	OK	OK
Model Structure Rules	OK	OK
Business Rules	OK	OK
Roll Up Rules	NS	NS
Other Manual Review Tasks	NS	NS
Other Rules and Best Practice Tasks	OK	OK

Assertions validation[52]:

#	Label	Result	
1	Accounting Equation (Assets = Liabilities and Equity) (ASSERTION_CORE_Equality_AccountingEquation)	Pass	$Assets = $Liabilities + $Equity

While XBRL processors cannot currently perform all the tasks that logic programming implementations can perform, they do an appropriate job when there is only one model.

The logical system can be called properly functioning because all of the statements are consistent with one another, there are no contradictions, it can be established that the logical system created precisely reflects the reality of the logical system and all the statements seem to be included within the logical system.

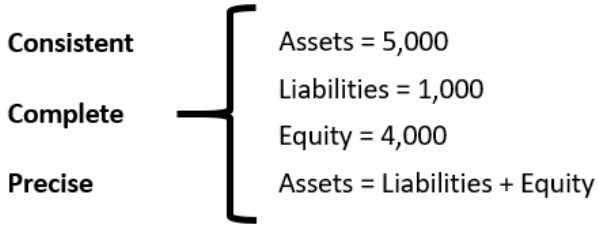
A software application can take all of the statements made within the machine-readable version of this logical system and perform work. Below you see a human-readable rendering of a balance sheet:

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

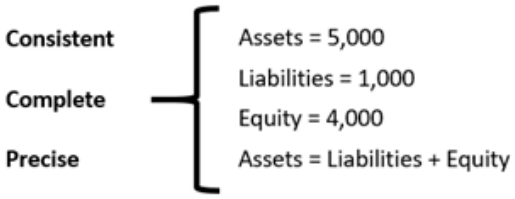
Result	Rule
Pass	$Assets = $Liabilities + $Equity

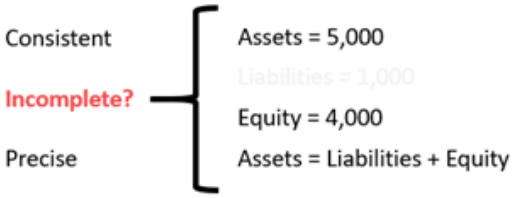
[52] Business rules summary, http://xbrlsite.azurewebsites.net/2019/Core/core-audit/evidence-package/contents/index.html#BusinessRulesSummary.html

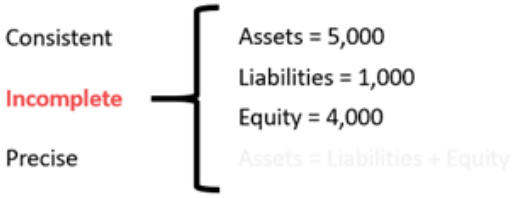
The logical system of the accounting equation in this case is precise and complete because all the statements are consistent with one another:

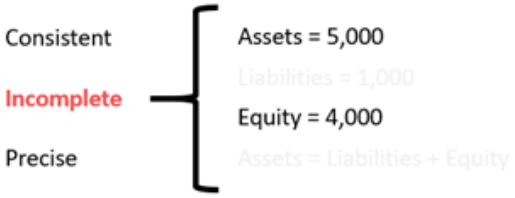


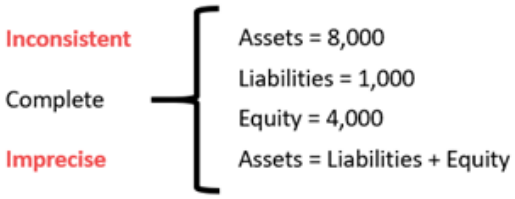
Below you can see examples of possible states of the accounting equation logical system. If a statement is left out, if one statement contradicts another statement, if statements are imprecise, etc.; the logical system is impacted.

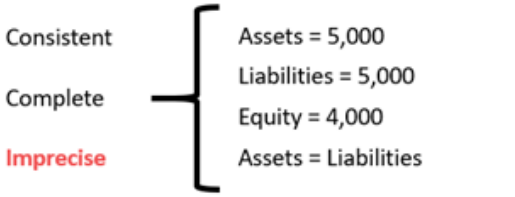












Again, keep in mind that we are trying to keep this example very basic. However, these same principles apply to, say, the Microsoft 10-K which has 194 different structures, many thousand associations, hundreds of assertions, and many thousand facts. This also works with US GAAP and IFRS.

In fact, every XBRL-based financial report submitted to the SEC or otherwise works exactly the same way as the accounting equation example. The other reports simply have different and more terms, associations, assertions, facts, and structures.

Expanded Example

Typical XBRL taxonomy creation practices focus on concept creation prematurely, before they have considered the broader motivating goals and objectives. This approach is like starting to build a house by laying bricks, rather than drawing plans and establishing foundations. It is critical to a framework and theory that will assure that your goals and objectives will be realized. A **framework** is a set of principles, assumptions, ideas, concepts, values, rules, laws, agreements, and practices that establishes the way something operates. A **theory** is a tool for understanding, explaining, and making predictions about a system.

Principles help you think about something thoroughly and consistently. Overcoming disagreements between stakeholders and even within groups of stakeholders is important. Agreement between stakeholder groups and within stakeholder groups contributes to harmony. Lack of agreement contributes to dissonance. Principles help in the communications process.

The first very basic example proves the notion that a financial report logical system can be in equilibrium and be proven to be a properly functioning. Because the example is so basic it is hard to believe that first very basic example proves anything.

But consider three things. First consider the following expanded example that builds on the first example. The expanded example[53] builds on the accounting equation[54], "Assets = Liabilities and Equity", expanding that equation twice. The first expansion is adding seven *Elements of Financial Statements* explicitly defined in the FRF for SMEs financial reporting framework published by the AICPA[55]: assets, liabilities, equity, revenues, expenses, gains, losses. Second, I expanded on that framework in order to get to an additional level of detail. This level of expansion allows professional accountants to begin to wrap their heads around the idea that a financial reporting scheme[56] can be represented in machine-readable form and it looks very similar to the US GAAP and IFRS financial reporting schemes. This information was represented within an XBRL instance[57] and XBRL taxonomy[58] and has these 23 elements of financial statements:

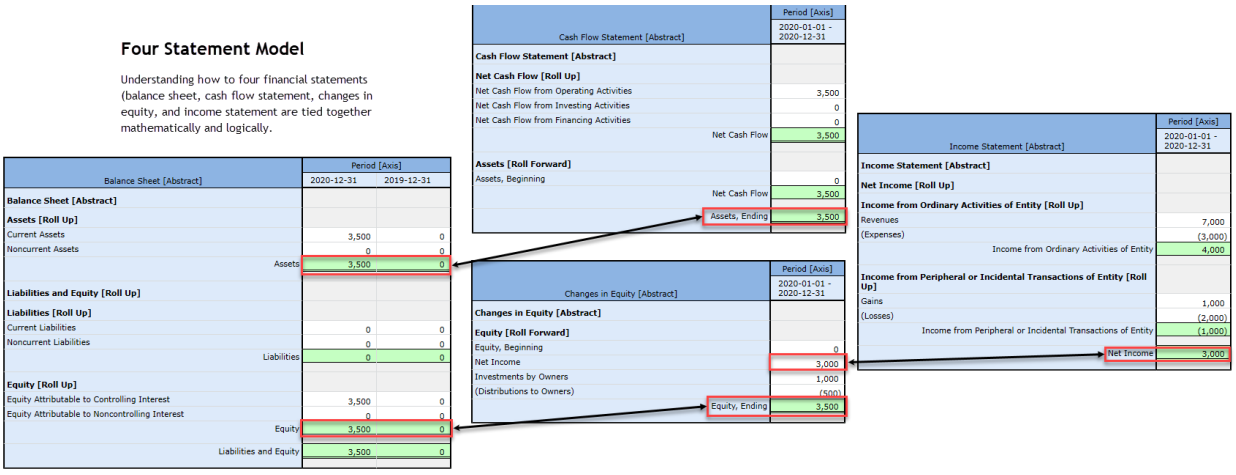
[53] Human readable information about expanded example, http://xbrlsite.azurewebsites.net/2019/Core/core-audit2/evidence-package/
[54] Wikipedia, *Accounting Equation*, https://en.wikipedia.org/wiki/Accounting_equation
[55] AICPA, *Financial Reporting Framework for Small- and Medium- Sized Enterprises*, https://www.aicpa.org/content/dam/aicpa/interestareas/frc/accountingfinancialreporting/pcfr/downloadabledocuments/frf-sme/frf-smes-framework.pdf#page=21
[56] Charles Hoffman, CPA, *Comparison of Financial Reporting Schemes High Level Concepts*, http://xbrlsite.azurewebsites.net/2018/Library/ReportingSchemes-2018-12-30.pdf
[57] XBRL instance, http://xbrlsite.azurewebsites.net/2019/Core/core-audit2/instance.xml
[58] XBRL taxonomy schema, http://xbrlsite.azurewebsites.net/2019/Core/core-audit2/core.xsd

Elements [Abstract]	Period [Axis]	
	2020-01-01 - 2020-12-31	2019-12-31
Elements [Abstract]		
Elements of Financial Statements [Set]		
Assets	3,500	0
Current Assets	3,500	0
Noncurrent Assets	0	0
Liabilities	0	0
Current Liabilities	0	0
Noncurrent Liabilities	0	0
Equity	3,500	0
Equity Attributable to Controlling Interest	3,500	0
Equity Attributable to Noncontrolling Interest	0	0
Revenues	7,000	
Expenses	3,000	
Gains	1,000	
Losses	2,000	
Net Income	3,000	
Investments by Owners	1,000	
Distributions to Owners	500	
Enhanced Elements of Financial Statements Added [Set]		
Liabilities and Equity	3,500	0
Net Cash Flow	3,500	
Net Cash Flow from Operating Activities	3,500	
Net Cash Flow from Investing Activities	0	
Net Cash Flow from Financing Activities	0	
Income from Ordinary Activities of Entity	4,000	
Income from Peripheral or Incidental Transactions of Entity	(1,000)	

These core, high-level elements of financial statements were used to create shells of each financial statement. For example, here are the beginning and ending balance sheets:

Balance Sheet [Abstract]	Period [Axis] 2020-12-31	2019-12-31
Balance Sheet [Abstract]		
Assets [Roll Up]		
Current Assets	3,500	0
Noncurrent Assets	0	0
Assets	3,500	0
Liabilities and Equity [Roll Up]		
Liabilities [Roll Up]		
Current Liabilities	0	0
Noncurrent Liabilities	0	0
Liabilities	0	0
Equity [Roll Up]		
Equity Attributable to Controlling Interest	3,500	0
Equity Attributable to Noncontrolling Interest	0	0
Equity	3,500	0
Liabilities and Equity	3,500	0

The four financial statements were tied together within the machine-readable representation[59] just like they are tied together in any paper-based or "e-paper" based representation:



Machine-readable rules that are provided within the XBRL-based financial report as statements to prove that the statements made to report facts are consistent with what is expected per the machine-readable rules. An XBRL processor and XBRL formula processor confirms that the

[59] Four statement model, http://xbrlsite.azurewebsites.net/2019/Core/core-audit2/FourStatementModel.jpg

reported facts are, in fact, consistent with what is expected per the machine-readable assertions (i.e. rules)[60]:

#	Label	Result	Rule
1	0 = (Equity{T0} + (Revenue{P1} - Expenses{P1} + Gains{P1} - Losses{P1}) + (InvestmentsByOwners{P1} - DistributionsToOwners{P1})) + Liabilities{T1} - Assets{T1} (ASSERTION_CORE_CONCEPTUAL_FRAMEWORK_RECONCILATION)	Pass	0= ($Equity_BalanceStart + $Revenues - $Expenses + $Gains - $Losses + $InvestmentsByOwners - $DistributionsToOwners) + $Liabilities_BalanceEnd - $Assets_BalanceEnd
2	Net income foots (ASSERTION_Core_ROLLUP_NetIncome)	Pass	$NetIncome = ($Revenues + $Gains - $Expenses - $Losses)
3	Equity roll forward (Equity{P0} + NetIncome + InvestmentsByOwners - DistributionsToOwners = Equity{P1}) (ASSERTION_CORE_ROLLFORWARD_Equity)	Pass	$Equity_BalanceStart + $NetIncome + $InvestmentsByOwners - $DistributionsToOwners = $Equity_BalanceEnd
4	Assets roll forward (Assets{P0} + NetCashFlow = Assets{P1}) (ASSERTION_CORE_ROLLFORWARD_Assets)	Pass	$Assets_BalanceStart + $NetCashFlow = $Assets_BalanceEnd
5	Accounting Equation (Assets = Liabilities and Equity) (ASSERTION_CORE_Equality_AccountingEquation)	Pass	$Assets = $Liabilities + $Equity
6	Accounting Equation (Assets = Liabilities and Equity) (ASSERTION_CORE_Equality_AccountingEquation)	Pass	$Assets = $Liabilities + $Equity

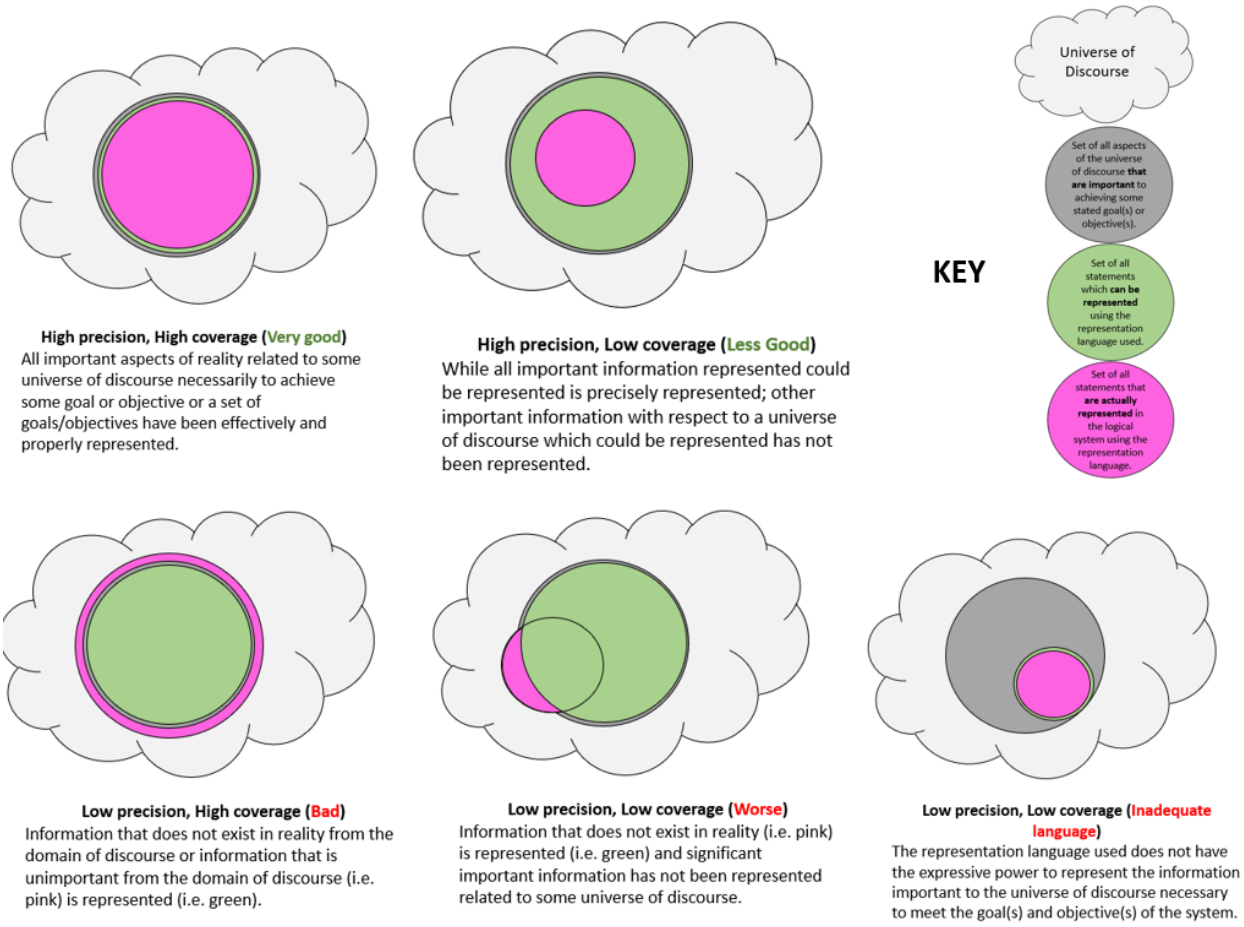
And so, the first thing to consider is this rather small be significant expansion of the first very basic example to this slightly more detailed example that provides what amounts to the key high-level concepts or "cornerstones" of the foundation of a financial report.

Second thing to consider is that imagine if one were to keep going into more, and more, and more detail of a financial report. It is not that much of a stretch to recognize that if the XBRL-based financial report is kept in a state where it is proven to be properly functioning and have all the other characteristics of a well-defined and properly functioning logical system.

Basically, you keep building, and building, and building on this well established and rock-solid foundation until you have a "fully expressed" financial report logical system.

Another way to measure if a logical system is fully expressed is to use the notions of "precision" and "coverage" as is explained by C. Maria Keet, *An Introduction to Ontology Engineering*[61], pages 8-9. Inspired by Keet's graphic and notions, I created the following graphic which slightly modifies her version to try and make it clearer[62].

[60] Mathematical assertions, http://xbrlsite.azurewebsites.net/2019/Core/core-audit2/evidence-package/contents/index.html#BusinessRulesSummary.html
[61] C. Maria Keet, *An Introduction to Ontology Engineering*, pages 8-9, https://people.cs.uct.ac.za/~mkeet/files/OEbook.pdf#page=23
[62] Charles Hoffman, CPA, *Measuring Precision and Coverage*, http://xbrlsite.azurewebsites.net/2019/Core/core-audit2/MeasuringPrecisionAndCoverage.jpg



And so, the point is that if one keeps the statements that describe the report and the reported facts in equilibrium and in a state of being properly functioning and one continues to do this until the financial report logical system is fully-expressed; then one would have a provably well-defined logical system. I am going to test this by creating a complete representation of the AICPA's FRF for SMEs financial reporting framework[63].

Third and lastly, consider the clarity of the description of the financial reporting scheme conceptual framework and the fact that the description is in machine-readable form and that automated machine-based processes can be used to both clarify and prove the financial reporting scheme.

[63] Charles Hoffman, CPA, FRF for SMEs Ontology, http://xbrlsite.azurewebsites.net/2016/conceptual-model/reporting-scheme/frf-sme/documentation/Home.html

Understanding the Logical Errors that Occur

There are common situations of logical errors that occur in XBRL-based financial reports. The document *Proving Accounting, Structural, Mathematical, and Other Logic of XBRL-based Financial Reports*[64] provides detailed information about nine common errors which are summarized here:

1. Using an existing base taxonomy concept intended to represent one class of concept inadvertently to represent some other class of concept.
2. Lack of clarity as to the meaning of extension concepts.
3. Unreported high-level subtotals.
4. Variability allowed for reporting high-level accounting relationships.
5. High-level financial report line item inconsistencies and contradictions.
6. Presentation relations model structure association logic errors.
7. Issues related to the mechanics of each report fragment.
8. Mathematical relations are not explained using machine-readable rules and then verified against that machine-readable explanation.
9. Verification that each report fragment that is required to be disclosure exists within the financial report.

Additional information is available that helps professional accountants and auditors understand the types of errors that exist in XBRL-based financial reports[65].

Variability Caused by Alternative Intermediate Components

While financial reports must fit within the elements of a financial report defined by a financial reporting scheme; financial reports are not forms. Specific variability is anticipated and allowed by financial reporting schemes such as US GAAP, IFRS, IPSAS, GAS, FAS, etc.[66] By far, the most

[64] Charles Hoffman, CPA, *Proving Accounting, Structural, Mathematical, and Other Logic of XBRL-based Financial Reports*, http://xbrlsite.azurewebsites.net/2019/Library/ProvingAccountingStructuralMathematicsLogic.pdf
[65] Charles Hoffman, CPA, *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
[66] Charles Hoffman, CPA, *Comparison of Elements of Financial Statements*, http://xbrlsite.azurewebsites.net/2019/Core/ElementsOfFinancialStatements.pdf

variability that exists within a set of financial statements exists on the income statement. SFAS 6 discusses the notion of intermediate components[67] of comprehensive income:

"Examples of intermediate components in business enterprises are gross margin, income from continuing operations before taxes, income from continuing operations, and operating income. Those intermediate components are, in effect, subtotals of comprehensive income and often of one another in the sense that they can be combined with each other or with the basic components to obtain other intermediate measures of comprehensive income."

Variability can be caused by choosing to report different common subtotals, by choosing to report specific line items rather than others, by either providing or not providing a subtotal such as "Noncurrent assets", etc. This variability is not random, arbitrary, or illogical; there are common patterns.

Here are common examples of variability using the accounting equation terms, association, and facts:

- **Add new term**: As mentioned, the term "Net Assets" is not provided in this model but is a permissible alternative to the term "Equity" for specific industries with which an economic entity is associated.
- **Add new association**: If a new term such as "Net Assets" is created, then a new association will always be necessary to relate the new term within some a structure to existing terms.
- **Change existing association**: If an existing association exists such as the association of "Equity" to "Balance Sheet"; it is possible to change that existing association and replace it with another permissible association.
- **Add new assertion**: If a new term is created it is likely that a new assertion will also tend to be necessary. For example, if the term "Net Assets" is created, the new assertion "Net Assets = Assets + Liabilities" would be created.
- **Change existing assertion**: Usually, existing assertions would not be changed but rather the existing assertion would not be used and would be replace by some other permissible assertion.
- **Add new structure**: An economic entity could decide to add an entirely new additional disclosure, creating a new structure that is used to articulate the associations between the terms that make up the new structure.
- **Change existing structure**: An economic entity could choose to modify the associations within an existing structure to provide a different but still permissible alternative disclosure.

[67] FASB, SFAC 6, page 47, paragraph 77.

- **Unreported fact**: An economic entity could choose to modify an existing structure to remove an association that provided an optional subtotal term and if so then the fact used to report that optional subtotal would not be provided within a report.

Note that "Change existing term" is not included in the list because it is never permissible to change the meaning of an existing term.

And so, the variability caused by these sorts of adjustments to some base model of a financial report must be managed and controlled in order be certain that the adjusted version of the model is still a permissible interpretation of a financial report and that the report is properly functioning.

Core Purpose of Financial Statement

The core purpose of a financial statement is to transfer information. Consider the following scenario:

> 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, inductive reasoning, etc.), **common financial reporting standard concepts and relations** (terms, relations, assertions for 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, relations, assertions), and common world view; and vice versa; and similarly for the investor and economic entity B.

Utility for Accounting and Transaction Processing

These same ideas apply not only to the financial report itself, but also to the trial balance[68] from which much of the report information comes, the transactions and processes that are used to account for information that ends up in reports, and even the non-financial and financial

[68] Charles Hoffman, CPA, *General Ledger Trial Balance to External Financial Report*, http://xbrlsite.azurewebsites.net/2018/RoboticFinance/TrialBalanceToReport.pdf

information generated outside the double-entry accounting system[69] such as from spreadsheets and content management systems.

Utility for General Business Reporting

The object here is to agree on a logical system such that the logical system can be leveraged to perform practical, reliable, dependable work. This logical system could be limited to only financial reports. However, I believe that it could be expanded to the more general business report; the financial report being a specialization of the more general business report. The system must be consciously unambiguously and completely as is necessary and practical in order to achieve a specific goal or objective or a range of goals/objectives. The system should error on the side of practicality and safety and perhaps sacrifice expressiveness and therefore functionality if necessary.

[69] Charles Hoffman, CPA and Andrew Noble, PNA, BBus, *Introduction to the Fact Ledger*, http://xbrlsite.azurewebsites.net/2018/Library/IntroductionToTheFactLedger.pdf