

# 1. Logical Systems

This section provides a comprehensive introduction to the notion of a logical system, that a logical theory can describe logical systems, and helps the reader see that a financial report is a logical system.

In order to understand a logical theory, we must first explain the terms we will be using to describe that logical theory. This section provides that explanation in simple terms that is approachable to business professionals. Technical professionals implementing software applications have other methods of describing formalisms of such logical systems such as UML and OWL.

## 1.1. Knowledge

Knowledge is a form of familiarity with information from some specific area. Knowledge is often understood to be awareness of facts, having learned skills, or having gained experience using the things and the state of affairs (situations) within some area of knowledge. Professional accountants, auditors, and analysts understand all this for their area of knowledge, their industry specialty, for the financial reporting schemes with which they work.

Knowledge of facts is distinct from opinion or guesswork by virtue of justification or proof. Knowledge is objective. Opinions and guesswork are subjective. In our case we are talking about certain specific knowledge, the facts that make up that knowledge, being able to create a proof to show the logic of a knowledge graph system is complete, consistent, and precise; and all of this logic being put into a form readable by a machine and reach a conclusion.

Effectively, a machine can read that logic within a knowledge graph and mimic understanding of that knowledge represented in that logical knowledge graph and the information available to both a human reader and a machine reader would be the same and therefore the human and machine should reach the same conclusion. Regardless of the technical syntax used to represent that logical knowledge graph; the logic of the knowledge representation MUST always be the same no matter what technical format is used to represent the knowledge graph.

Philosophy is a formal discipline which provides tools and techniques for the systematic study of specific things including knowledge and reasoning.

## 1.2. System

A system is a group of interacting or interrelated elements that act according to a set of logical rules to form a unified whole. A system can be natural, such as the solar system, or designed by humans. A system tends to have some deliberate, intentional aim; it has goal(s) and/or objective(s).

## 1.3. Logic

Logic<sup>1</sup> is a tool provided by the discipline of philosophy. Logic is the study of correct reasoning. Logic uses artificial languages with a precise symbolic representation to investigate reasoning. The tools of logic which provide the foundation for

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<sup>1</sup> Wikipedia, *Logic*, <https://en.wikipedia.org/wiki/Logic>

mathematics are leveraged by computers to mimic tools previously available only to humans, opening up the possibility of machines literally mimicking an understanding of knowledge. These tools can perform deductive reasoning, inductive reasoning, and abductive reasoning.

There two broad categories of logical reasoning: **deductive** and **non-deductive**.

Deductive reasoning provides a result that is guaranteed to be **certain**, therefore the result can be relied upon without doubt and humans need not be involved in a process because of the certainty of deductive reasoning. Non-deductive reasoning, on the other hand, is **not certain**, meaning it could be correct but it could also be incorrect. Non-deductive reasoning is based on probability. And so non-deductive reasoning approaches must have a human in the loop to deal with that uncertainty. There are three types of non-deductive reasoning: inductive, abductive, and analogy<sup>2</sup>.

Computational logic is a branch of logic and computer science that relates to getting computers to perform correct reasoning. Logic programming languages express facts using machine-readable logical statements, then use software to make sure all the facts are consistent and then draw inferences from these facts. To perform proper logical reasoning, one needs a complete set of logical statements.

That complete set of logical statements is a logical theory.

## 1.4. Logical Theory

A logical system (a.k.a. formal system<sup>3</sup>), which has logical patterns of behavior, can be explained by a logical theory.

A logical theory is an abstract conceptualization of specific important details of some area of knowledge. The logical theory provides a way of thinking about an area of knowledge by means of deductive reasoning to derive logical consequences of the logical theory.

A 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 logical statements used for capturing meaning or representing a shared understanding of and knowledge in some area of knowledge.

A logical theory is a set of logical statements. Those logical statements can be represented in human-readable form or they could be expressed in machine-readable form. Once in machine-readable form, those logical statements can be interrogated using software applications. To the extent that this can be done effectively; software tools can assist professional accountants, financial analysts, and others working with those logical statements. A logical system is said to be consistent with a logical theory if there are no contradictions with respect to the logical statements made by the logical theory that describes the logical system. **Consistent** is defined as there being no logical contradictions or logical inconsistencies within the logical theory.

A logical theory can have high to low precision and high to low coverage with respect to describing a logical system. **Precision** is a measure of how precisely the information within a logical theory has been represented as contrast to reality of the

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<sup>2</sup> YouTube.com, *Deductive vs Inductive vs Abductive Reasoning*, <https://youtu.be/jX3OXwpEpl8>

<sup>3</sup> Wikipedia, *Formal System*, [https://en.wikipedia.org/wiki/Formal\\_system#Logical\\_system](https://en.wikipedia.org/wiki/Formal_system#Logical_system)

logical system for the area of knowledge. **Coverage** is a measure of how completely information in a logical theory has been represented relative to the reality of the logical system for the area of knowledge.

When a logical system is **consistent** and it has **high precision** and **high coverage** the logical system can be considered a properly functioning logical system. When a system is working right, it creates a virtuous cycle. A logical system can be proven<sup>4</sup> to be operating (a.k.a. properly functioning logical system; satisfies the goals/objectives) per the logical theory that describes the logical system.

## 1.5. Area of Knowledge

An **area of knowledge** is a highly organized socially constructed aggregation of shared knowledge for a distinct subject matter. An area of knowledge has a specialized insider vocabulary, underlying assumptions (axioms, theorems, constraints), and persistent open questions that have not necessarily been resolved (i.e. flexibility is necessary).

Accounting is an area of knowledge. You can explain aspects of the accounting area of knowledge, such as the nature of a financial report, using a logical theory which explains a logical model. A logical theory can be tested and proven by providing a proof. When all the details are worked out, you have a best practice based proven method.

Knowledge can be represented in human-readable form, in machine-readable form, or in a machine-readable form that can be effectively converted into human-readable form.

You can think about an area of knowledge as being characterized in a spectrum with two extremes:

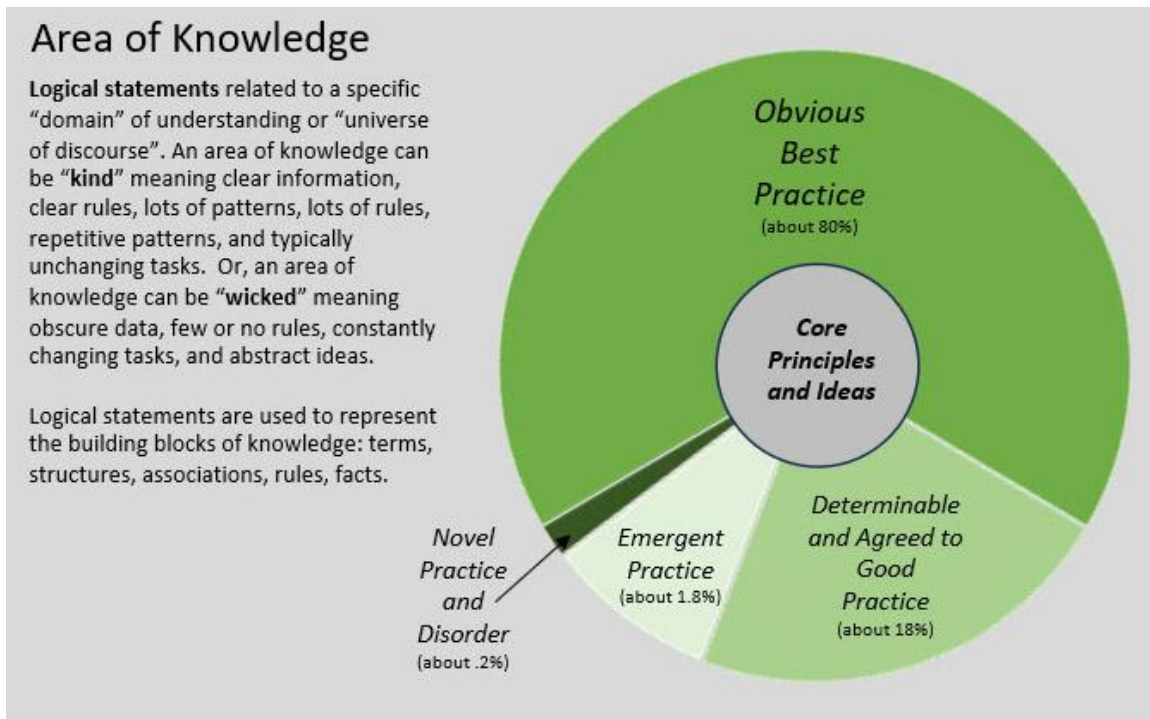
- **Kind area of knowledge:** clear rules, lots of patterns, lots of rules, repetitive patterns, and unchanging tasks.
- **Wicked area of knowledge:** obscure data, few or no rules, constant change, and abstract ideas.

An area of knowledge can have aspects of both extremes, but tends to lean toward one side of the spectrum or the other. Accounting tends to lean more toward the “kind” end.

Another term for area of knowledge is a knowledge domain or simply domain.

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<sup>4</sup> Wikipedia, Proof, [https://en.wikipedia.org/wiki/Proof\\_calculus](https://en.wikipedia.org/wiki/Proof_calculus)



## 1.6. Complexity and Order of System

Difference systems have different levels complexity. Systems can also be ordered or disordered. The Cynefin Framework<sup>5</sup> is a conceptual framework that helps you understand the dynamics that are at work within different types of systems. The framework was created in 1999 by David Snowden of IBM Global Services to help IBM to manage intellectual capital.

The following graphic helps one understand the different levels of complexity: simple, complicated, complex, and chaotic. The graphic also helps one understand the difference between disorder and order.

The video *Using Cynefin to Prioritize and Analyze Features, User Stories, and Functional Requirements*<sup>6</sup> provides an excellent walk through of these ideas.

<sup>5</sup> Cynefin Framework, <http://xbrl.squarespace.com/journal/2021/3/21/cynefin-framework.html>

<sup>6</sup> Using Cynefin to Prioritize and Analyze Features, User Stories, and Functional Requirements, <https://www.youtube.com/watch?v=L5fnxahydXM>



Different skill sets are necessary to be able to create simple, complicated, and complex systems that work effectively.

### 1.7. Symbolic Systems

Stanford University has a unique undergraduate or graduate major offering called the Symbolic Systems Program<sup>7</sup>.

So, what is a symbolic system? Per the associate director of the program when interviewed by The Stanford Daily<sup>8</sup>:

"[The major is] a combination of studying the human mind ... and the intelligence of machines and of the design interaction that happens between them, [as well as] how those things can inform each other," said symbolic systems associate director Todd Davies '84 M.S. '85 Ph.D. '95 in an interview with The Daily.

A symbol is something that represents something else. Symbols can be arranged into structures such as lists, hierarchies, or networks and these structures show how symbols relate to each other.

<sup>7</sup> Stanford University, *Symbolic Systems Program*, <https://symsys.stanford.edu/about/span-dig-deep-solve-complex-problems>

<sup>8</sup> Stanford University, *The Stanford Daily*, <https://www.stanforddaily.com/2019/01/23/unique-to-stanford-symbolic-systems/>

A **symbolic system** is essentially a system built with symbols such as natural language, programming languages, mathematics, or formal logic. Symbolic artificial intelligence<sup>9</sup> uses symbolic systems and rules to restrict systems to operate within permitted boundaries and to reason against the system.

An interesting thing is that symbolic systems are understandable by both humans and by computers.

You can get a more detailed understanding of symbolic systems from the Stanford Bulletin<sup>10</sup> which describes the course. Cognitive science<sup>11</sup> is somewhat similar to symbolic systems. Computational linguistics<sup>12</sup> is also somewhat similar.

Why is this important?

In his book *Saving Capitalism*<sup>13</sup>, Robert Reich describes three categories that all modern work/jobs fit into:

- **Routine production services** which entail repetitive tasks,
- **In-person services** where you physically have to be there because human touch was essential to the tasks,
- **Symbolic-analytic services** which include problem solving, problem identification, and strategic thinking that go into the manipulation of symbols (data, words, oral and visual representations).

In describing the third category, symbolic-analytic services, Mr. Reich elaborates:

"In essence this work is to rearrange abstract symbols using a variety of analytic and creative tools - mathematical algorithms, legal arguments, financial gimmicks, scientific principles, powerful words and phrases, visual patterns, psychological insights, and other techniques for solving conceptual puzzles. Such manipulations improve efficiency-accomplishing tasks more accurately and quickly-or they better entertain, amuse, inform, or fascinate the human mind."

Think Computational Law<sup>14</sup> and Computational Audit<sup>15</sup>. Many tasks in accounting, reporting, auditing, and analysis are related to symbolic-analytic services and rearranging abstract symbols. As I pointed out a while back, the "Learn to code" is a hysteria and is misguided. If you want to understand things like how artificial intelligence actually works and how it will impact accounting, reporting, auditing, and analysis; study symbolic systems.

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<sup>9</sup> Wikipedia, *Symbolic Artificial Intelligence*, [https://en.wikipedia.org/wiki/Symbolic\\_artificial\\_intelligence](https://en.wikipedia.org/wiki/Symbolic_artificial_intelligence)

<sup>10</sup> Stanford University, *Stanford Bulletin*, <https://exploreddegrees.stanford.edu/schoolofhumanitiesandsciences/symbolicsystems/>

<sup>11</sup> Wikipedia, *Cognitive Science*, [https://en.wikipedia.org/wiki/Cognitive\\_science](https://en.wikipedia.org/wiki/Cognitive_science)

<sup>12</sup> Wikipedia, *Computational Linguistics*, [https://en.wikipedia.org/wiki/Computational\\_linguistics](https://en.wikipedia.org/wiki/Computational_linguistics)

<sup>13</sup> Robert Reich, *Saving Capitalism*, page 204-206), <https://www.amazon.com/Saving-Capitalism-Many-Not-Few/dp/0345806220>

<sup>14</sup> *Computational Law*, <http://xbrl.squarespace.com/journal/2020/8/24/computational-law.html>

<sup>15</sup> *Computational Audit*, <http://xbrl.squarespace.com/journal/2020/8/25/computational-audit.html>



A logical system is a type of symbolic system. A logical theory can describe a logical system; for example, the *Logical Theory Describing Financial Report*<sup>16</sup> describes the financial report logical system. Not only is a financial report a type of logical system; that logical system can be readable and understandable by both humans and by machines.

## 1.8. Knowledge Based Systems (Artificial Intelligence)

The document *Expert System for Creating Financial Reports*<sup>17</sup> outlines the vision of a rules-based expert system for creating financial reports that leverages explainable artificial intelligence (XAI)<sup>18</sup>. This vision is based on working software applications, working proof of concepts, reverse engineering of XBRL-based financial reports submitted to the SEC.

Another name for a knowledge-based system is a problem-solving system<sup>19</sup>.

There are two approaches to **artificial intelligence** and, as I have said before, the right approach should be used for the given job<sup>20</sup>. The two approaches are:

- **Rules-based systems** (symbolic systems, good at reasoning, expert systems, three basic types)
  - **Classification or diagnosis type:** helps users of the system select from a set of given alternatives.
  - **Construction type:** helps users of the system assemble something from given primitive components.
  - **Simulation type:** helps users of the system understand how some model reacts to certain inputs.
- **Patterns-based systems** (non-symbolic systems, good at learning, machine learning which can be supervised or unsupervised, five basic types<sup>21</sup>)
  - **Clustering algorithms:** categorize or group things
  - **Explanatory algorithms:** explain the relationships between variables
  - **Ensemble learning algorithms:** use multiple models
  - **Similarity algorithms:** compute the similarity of pairs of things
  - **Dimensionality reduction algorithms:** reduces variables in a dataset

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<sup>16</sup> *Logical Theory Describing Financial Report*,  
[http://www.xbrlsite.com/mastering/Part02\\_Chapter05.B\\_LogicalTheoryDescribingFinancialReport.pdf](http://www.xbrlsite.com/mastering/Part02_Chapter05.B_LogicalTheoryDescribingFinancialReport.pdf)

<sup>17</sup> Charles Hoffman, CPA, *Expert System for Creating Financial Reports*,  
<http://xbrlsite.azurewebsites.net/2022/Library/ExpertSystemForCreatingFinancialReports.pdf>







<sup>18</sup> *Effective Automated Information Exchange and Explainable AI (XAI)*,  
<http://xbrl.squarespace.com/journal/2022/3/21/effective-automated-information-exchange-and-explainable-ai.html>

<sup>19</sup> *Problem Solving System*, <https://digitalfinancialreporting.blogspot.com/2024/03/problem-solving-systems.html>

<sup>20</sup> *Use the Right Artificial Intelligence Approach for the Job*,  
<http://xbrl.squarespace.com/journal/2019/7/12/use-the-right-artificial-intelligence-approach-for-the-job.html>

<sup>21</sup> EDUCBA, Machine Learning Models, <https://www.educba.com/machine-learning-models/>

Another helpful breakdown of pattern-based systems is provided by the article *Top Machine Learning Algorithms for Prediction: A Short Summary*<sup>22</sup>.

Name	Type	Description	Advantages	Disadvantages
Linear Regression		-The best fit line through all data points	-Easy to understand -you can clearly see what the biggest drivers of the model are.	-sometimes simple to capture complex relationships between variables, -Tendency for the model to overfit.
Logistic Regression		-The adoption for linear regression to problems of classification	-Easy to understand	-sometimes simple to capture complex relationships between variables, -Tendency for the model to overfit.
Decision Tree		-A graph that uses branching method to match all possible outcomes of a decision	-Easy to understand and implement.	-Not often used on its own for prediction because it's also often too simple and not powerful enough for complex data.
Random Forest		- Takes the average of many decision trees. Each tree is weaker than the full decision tree, but combining them we get better overall performance.	-A sort of „wisdom of the crowd“, Tend to result in very high quality results. -Fast to train	-Can be slow to output predictions relative to other algorithms. -Not easy to understand predictions.
Gradient Boosting		-Uses even weaker decision trees that increasingly focused on „hard examples“	-High-performing	-A small change in the future set or training set can create radical changes in the model. -Not easy to understand predictions.
Neural Networks		-Mimics the behaviour of the brain. NNs are interconnected Neurons that pass messages to each other. Deep Learning uses several layers of NNs to put one after the other.	-Can handle extremely complex tasks. No other algorithm comes close in image recognition.	-very very slow to train. Because they have so many layers. Require a lot of power. -Almost impossible to understand predictions.

Currently, the expert systems working proof of concepts and commercial software that I have created and experimented with only leverage rules-based systems. But it is pretty clear that machine learning offers additional capabilities that will be inevitably leveraged.

Pacioli<sup>23</sup> is a logic/rules/reasoning/knowledge/insights engine. Frankly, I don't know exactly what to call Pacioli. At first, I called Pacioli a logic/rules/reasoning engine. Then I referred to it as a knowledge engine<sup>24</sup>. Now I am contemplating that Pacioli is an insights engine. For now, I consider Pacioli a logic/reasoning/rules/knowledge/insights engine in order to be complete, I guess.

<sup>22</sup> Medium, *Top Machine Learning Algorithms for Prediction: A Short Summary*, [https://medium.com/@webadmin\\_46735/top-machine-learning-algorithms-for-predictions-a-short-overview-5ed1ff6942ff](https://medium.com/@webadmin_46735/top-machine-learning-algorithms-for-predictions-a-short-overview-5ed1ff6942ff)

<sup>23</sup> AuditChain, *Pacioli Logic and Rules Engine*, <https://docs.auditchain.finance/auditchain-protocol/pacioli-logic-and-rules-engine>

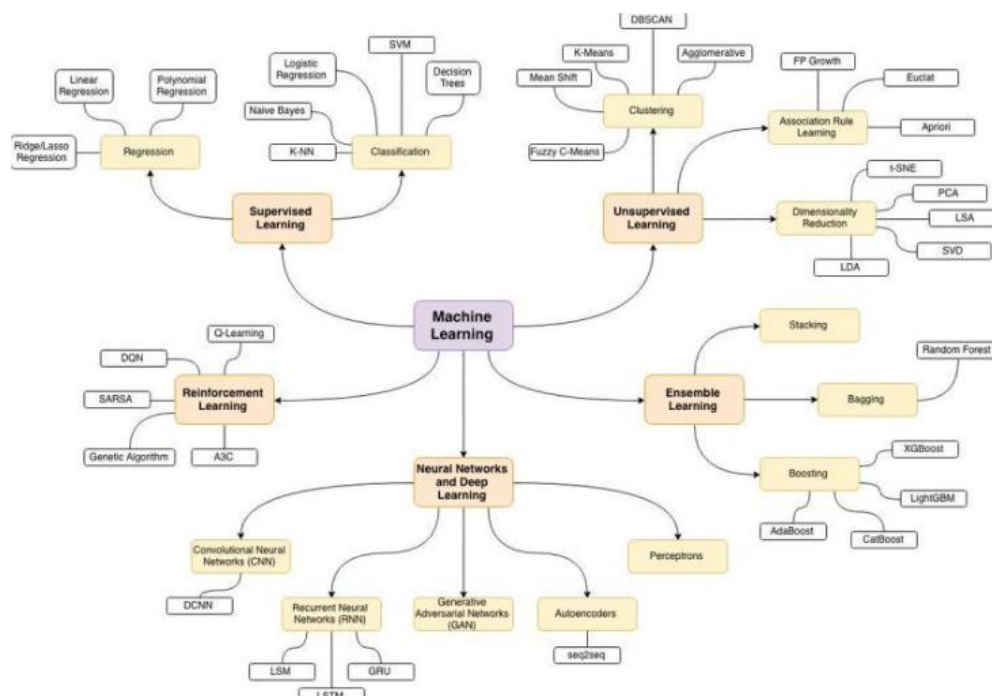
<sup>24</sup> *Pacioli: an XBRL Knowledge Engine*, <http://xbrl.squarespace.com/journal/2022/2/19/pacioli-an-xbrl-knowledge-engine.html>



Pacioli has three roles. The first role of Pacioli is to enforce the financial report logical schema and return information about where a financial report might be violating that logical schema. This is helpful in the process of creating XBRL-based financial reports.

The second role of Pacioli is to leverage the machine-readable logical schema to work with the information that makes up the financial report knowledge graph<sup>25</sup>.

The third role of Pacioli, which similarly leverages the machine-readable logical schema and financial report knowledge graph is effectively extracting information for financial analysis.



## 1.9. Programmed Ability to Process Information

Both symbolic systems and non-symbolic systems offer useful capabilities<sup>26</sup>. Be sure to understand the capabilities of these different approaches and use the right tool for the job.

DARPA and PWC do an excellent job of explaining the capabilities of artificial intelligence. This presentation<sup>27</sup>, video<sup>28</sup> and this article<sup>29</sup> provide a summary worth reading.

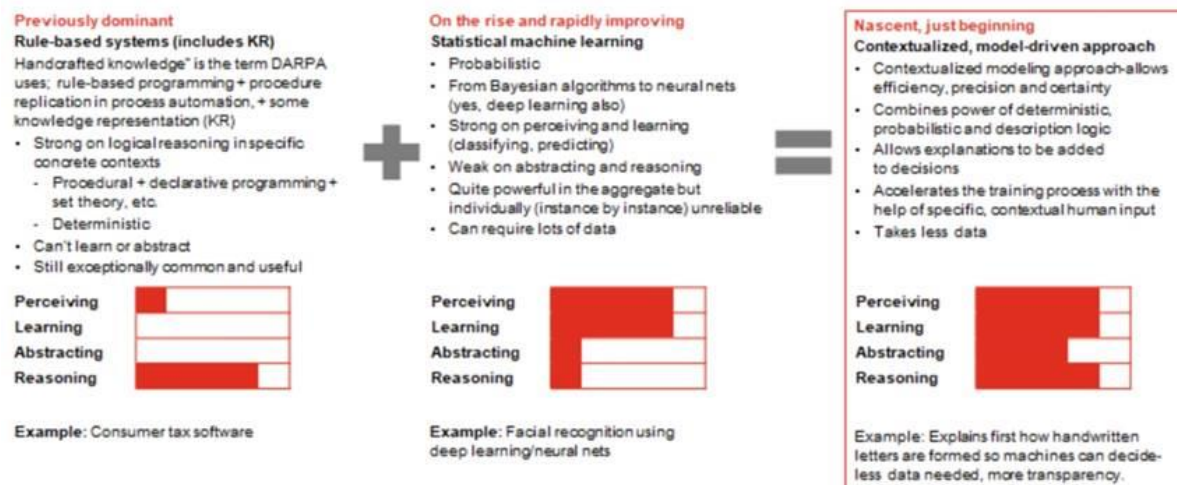
<sup>25</sup> Charles Hoffman, CPA, *Financial Report Knowledge Graphs*, <http://xbrl.azurewebsites.net/2021/Library/FinancialReportKnowledgeGraphs.pdf>

<sup>26</sup> Richa Bhatia, *Understanding the difference between Symbolic AI & Non Symbolic AI*, <https://analyticsindiamag.com/understanding-difference-symbolic-ai-non-symbolic-ai/>

<sup>27</sup> DARPA, *A DARPA Perspective on Artificial Intelligence*, <https://www.darpa.mil/attachments/AIFull.pdf>

<sup>28</sup> YouTube.com, *A DARPA Perspective on Artificial Intelligence*, <https://youtu.be/-O01G3tSYpU>

## The key opportunity – Large-scale integration and model-driven intelligence in a de-siloed and de-duplicated way



John Launchbury of DARPA (<https://www.youtube.com/watch?v=N2L8AqvEDLs>), Estes Park Group and PwC research, 2017

PwC (Scaling the mirrorworld with the knowledge graph)

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The graphic above shows three approaches to implementing artificial intelligence or the programmed ability to process information. Auditchain's Pacioli is a "rule-based system" that uses "handcrafted knowledge" that I created (the LEFT SIDE). Statistical machine learning will be added (the MIDDLE) to Pacioli over time most likely. Ultimately, where Auditchain and others will end up is on the RIGHT side which is the combined capabilities of rules-based systems and statistical machine learning. I suspect that this will occur within three to five years.

Here is another explanation that was inspired from a DARPA presentation<sup>30</sup>. Artificial intelligence is defined as a "**programmed ability to process information**". Sure, software like, Excel and Word can process "stuff"; but they don't really understand anything about accounting, reporting, auditing, or analysis. By "understand", this is what is meant, paraphrasing from the DARPA explanations of these terms:

- **Perceive:** ability to perceive rich, complex, subtle information.
- **Learn:** ability to learn about that information within a specific environment such as within a financial report.
- **Abstract:** ability to create new meaning from existing information.
- **Reason:** ability to plan, ability to decide, ability to verify.

The following graph shows where most software currently is today in terms of helping accountants get their jobs done in terms of accounting knowledge (i.e. basically, you can think of this is the manual tasks and processes that is being done now)

<sup>29</sup> Quora, Alan Morrison, *What is the relation between Semantic Web and AI?*, [https://www.quora.com/What-is-the-relation-between-Semantic-Web-and-AI/answer/Alan-Morrison?ch=2&oid=180785119&srid=Mru&target\\_type=answer](https://www.quora.com/What-is-the-relation-between-Semantic-Web-and-AI/answer/Alan-Morrison?ch=2&oid=180785119&srid=Mru&target_type=answer)

<sup>30</sup> DARPA, *A DARPA Perspective on Artificial Intelligence*, <https://www.darpa.mil/attachments/AIFull.pdf>



But this is where something like Auditchain's Pacioli is in terms of perceiving, learning, abstracting, reasoning when it comes to the information within a financial report: (Pacioli can do this NOW using my "handcrafted knowledge" a.k.a. standard machine-readable rules represented using XBRL)



The next graphic shows where Pacioli might ultimately go when statistical machine learning is combined with the rules-based system. The rules-based system's handcrafted rules act as a starter set of the rules needed to make the statistical machine learning work. Basically, the rules-based system focuses on what it can do best and the statistical machine learning focuses on what it can do best and the result is a combination of the two approaches: (Auditchain will be here in three to five years in my view)



The final graphic is what full automation looks like. To understand what "full automation" is one would need to understand the specific details of what is being automated. But also keep in mind that while automation might be possible for some things, for other things it really is not realistic or even necessary to automate to derive value from automation. Making a process 50% more efficient or even 25% more efficient or only 10% more efficient is still quite valuable.



To summarize, there are three very important points to remember here. First, the right artificial intelligence should be used for each automation task. Second, handcrafted metadata is necessary to make automation actually work. Finally, while it is easy to discuss automation in general high level terms; when you actually automate something you need to work with the details of what is being automated.

## 1.10. Models

Without a model you have an undifferentiated mass of data where there is no way which data can or should interact with other data. A model has little or no significance without the data to describe that model. But put the data and the model together and you get a dynamic web of information that seems almost magical.

Any large group trying to understand a complex phenomenon will find that process challenging. Models helps areas of knowledge make sense of unorganized information.

A model is an abstract description of something that hides certain unimportant details and illuminates other important details. Models help a group trying to describe an area of knowledge to do so effectively. Models do achieve this in the following important ways:

1. Models help groups of people in an area of knowledge to communicate.
2. Models describe, explain, and make predictions about that area of knowledge.
3. Models describe primitive phenomenon. Those primitive descriptions can then be used to describe complex phenomenon that is based on the primitive descriptions.
4. Models provide a way to orchestrate and mediate when you have multiple viewpoints. It is hard enough to get any two people to agree completely agree about something, let alone a significantly larger group. Models help groups represent commonalities while also understanding and exploring their differences.

Formal models are used in many different areas of knowledge when precision and objectivity are necessary. Models are not “black-and-white”. Models organize human thought. Good models offer flexibility where flexibility is necessary.

A model is effectively a logical system. Let’s walk you through a simple explanation of a logical system and how you can use a theory to describe such a system.

### ***1.11. Atomic Design Methodology***

Atomic design methodology<sup>31</sup> is an approach to thinking about logical systems in a deliberate, hierarchical way. The building blocks of a logical system are atoms, molecules, organisms (a.k.a. assemblies).

- **Atoms** are the basic building blocks.
- **Molecules** are combinations of two or more atoms. These combinations of atoms take on their own unique properties, and become more tangible and operational than atoms.
- **Organisms** are assemblies of molecules functioning together as a unit. Organisms are more complex and sophisticated than molecules.

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<sup>31</sup> *Atomic Design Methodology*, <https://digitalfinancialreporting.blogspot.com/2023/12/atomic-design-methodology.html>



### 1.12. Simple Explanation of a Logical System

A system can be explained by a logical theory. A logical theory is an abstract conceptualization<sup>32</sup> of specific important details of some area of knowledge. The logical theory provides a way of thinking about an area of knowledge by means of deductive reasoning to derive logical consequences of the logical theory.

A **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 logical statements used for capturing meaning or representing a shared understanding of and knowledge in some area of knowledge.

A logical theory forms a **logical conceptualization** and is made up of a set of logical *models*, *structures*, *terms*, *associations*, *rules*, and *facts*. In very simple terms,

- **Logical conceptualization:** A *logical conceptualization* is a set of models that are consistent with and permissible per that logical conceptualization.
- **Model:** A *model*<sup>33</sup> is a set of structures that are consistent with and permissible interpretations of that logical conceptualization.
- **Structure:** A *structure* is a set of logical statements which describe the structure.
- **Logical statement:** A *logical statement* is a proposition, claim, assertion, belief, idea, or fact about or related to the area of knowledge to which the logical conceptualization relates. There are four broad categories of logical statements:
  - **Terms:** *Terms* are logical statements that define ideas used by the logical theory such as “assets”, “liabilities”, “equity”, and “balance sheet”.
  - **Associations:** *Associations* are logical 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”.
  - **Rules:** *Rules* are logical statements that describe what tend to be convertible into IF...THEN...ELSE types of relationships such as “IF the

<sup>32</sup> Wikipedia, *Conceptual Model*, [https://en.wikipedia.org/wiki/Conceptual\\_model](https://en.wikipedia.org/wiki/Conceptual_model)

<sup>33</sup> Wikipedia, *Model Theory*, [https://en.wikipedia.org/wiki/Model\\_theory](https://en.wikipedia.org/wiki/Model_theory)



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

- **Facts:** *Facts* are logical statements about the numbers and words that are provided by an economic entity within a business report. For example, the financial report, a type of business report, might state “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.

**Properties:** Properties are logical statements about the important qualities and traits of a model, structure, term, association, rule, and fact.

Fundamentally, a logical theory is a set of logical statements. Those logical statements can be represented in human-readable form or they could be expressed in machine-readable form. Once in machine-readable form, those logical statements can be interrogated using software applications. To the extent that this can be performed effectively; software tools can assist professional accountants, financial analysts, and others working with those logical statements.

### 1.13. Proper Functioning Logical System

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

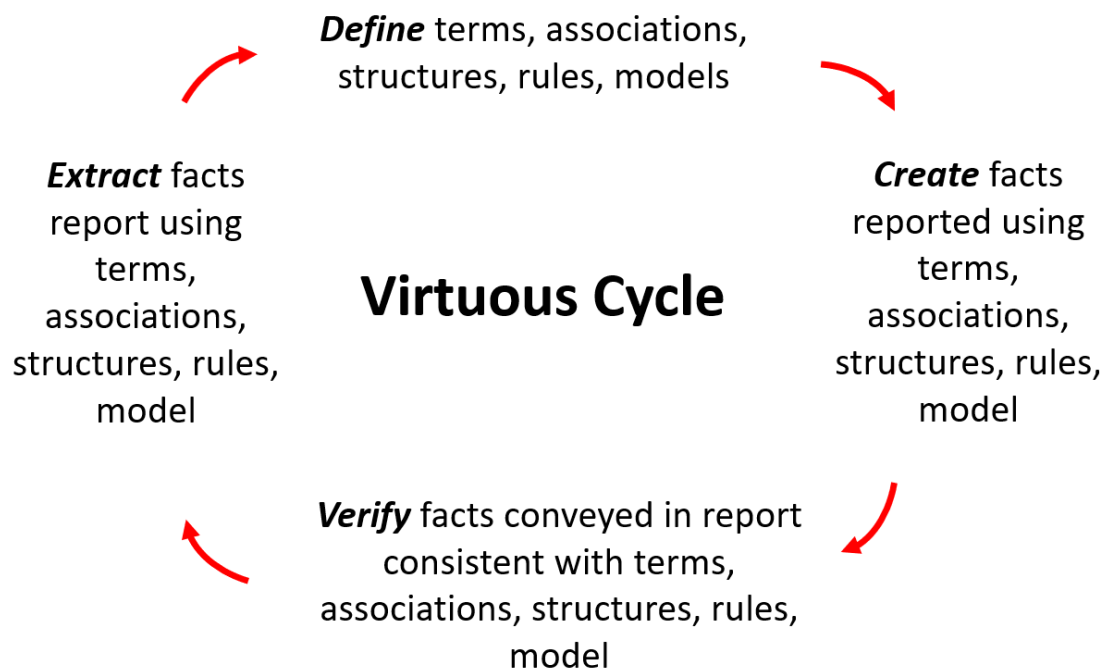
A logical theory can have high to low **precision** and high to low **coverage** with respect to describing a logical system.

*Precision* is a measure of how precisely the information within a logical theory has been represented as contrast to reality of the logical system for the area of knowledge. *Coverage* is a measure of how completely information in a logical theory has been represented relative to the reality of the logical system for the area of knowledge.

When a logical system is consistent and it has high precision and high coverage the logical system can be considered a **properly functioning logical system**. When a logical system is properly functioning, it creates a virtuous cycle<sup>34</sup>.

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<sup>34</sup> Charles Hoffman, CPA, *Virtuous Cycle*, <http://xbrl.squarespace.com/journal/2020/4/29/virtuous-cycle.html>



A logical theory conveys knowledge and that knowledge can be represented within a knowledge graph. For more detailed information related to logical theories and logical systems, please see *Logical Systems*<sup>35</sup>.

### 1.14. Very Simple Example of Logical System

A very simple example of a logical system is the accounting equation. Here is a description of the accounting equation logical system in both human-readable terms and machine-readable terms using XBRL<sup>36</sup>:

**Terms:** Three simple terms are defined: Assets, Liabilities, Equity. One complex term is defined, balance sheet.

**Structure:** One structure is defined, the balance sheet, and identified using the term balance sheet.

**Associations:** The three terms Assets, Liabilities, and Equity are associated in that they are all PART-OF the structure balance sheet.

**Rules:** A mathematical assertion is made that "Assets = Liabilities + Equity".

**Facts:** Instances of three facts are established to exercise the model: Assets of \$5,000; Liabilities of \$1,000; Equity of \$4,000.

**Model:** All of the terms, associations, assertions, structures, and facts describe the model. We created only one model, or permissible interpretation, of the logical theory. (As accountants know, if you reverse the equation using the rules of math to "Equity = Assets - Liabilities" and change the term "Equity" to "Net Assets"; then you get another permissible interpretation or model.)

<sup>35</sup> Charles Hoffman, CPA, *Logical Systems*,  
[http://www.xbrlsite.com/mastering/Part02\\_Chapter05.A\\_LogicalSystems.pdf](http://www.xbrlsite.com/mastering/Part02_Chapter05.A_LogicalSystems.pdf)

<sup>36</sup> Charles Hoffman, *Accounting Equation*, <http://xbrlsite.azurewebsites.net/2020/master/ae/>

Because this is a very simple example with only a few statements it is easy to get your head around this system and see that it is consistent, complete, and precise. As expected, you see three facts described by three terms which are related to one structure and the one rule is consistent with expectation:

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

**Consistent**

**Complete**

**Precise**

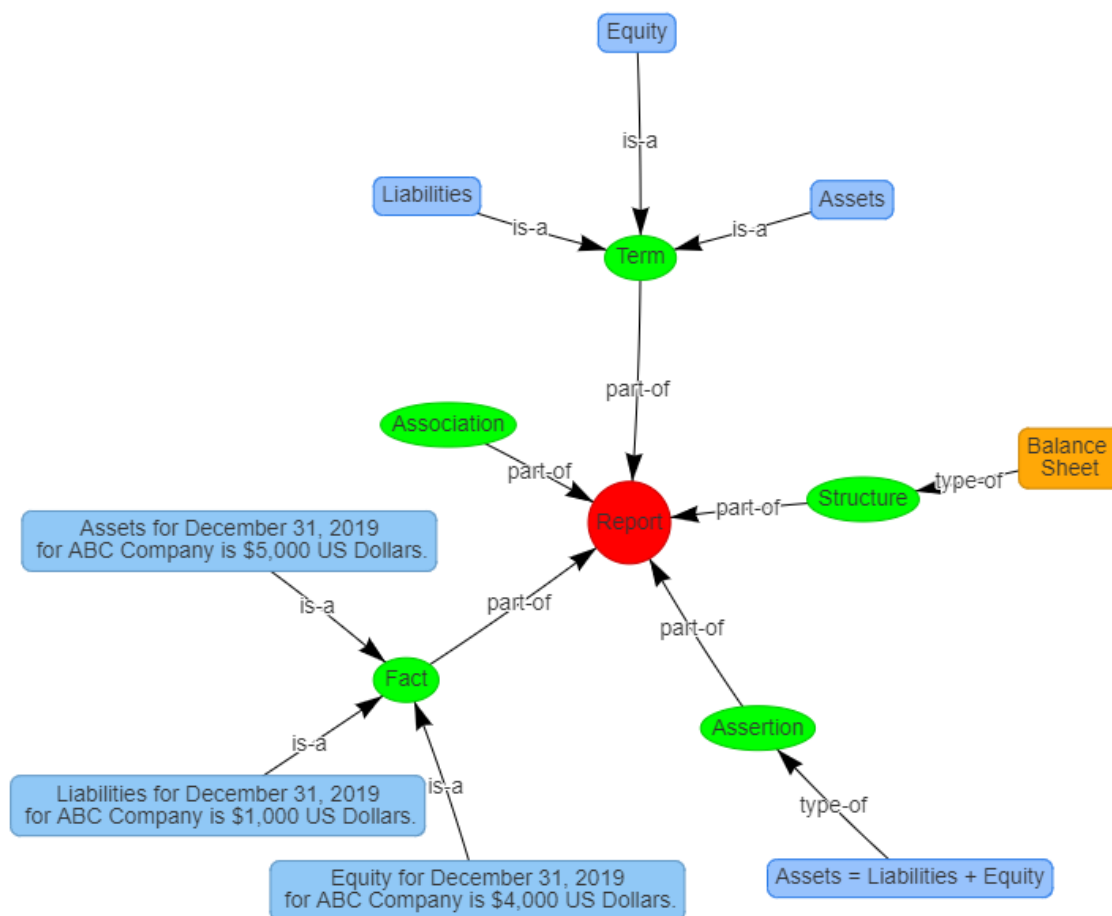
**Balance Sheet**

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

Result	Rule
Pass	\$Assets = \$Liabilities + \$Equity

As the size of the logical system increases it becomes increasingly more challenging to verify that the logical system is properly function using manual processes. But, covering the impediments to a properly functioning logical system are beyond our scope here<sup>37</sup>. Essentially, the models, terms, structures, rules, and facts form a directed acyclic graph such as:

<sup>37</sup> Charles Hoffman, CPA, *Impediments to Creating Properly Functioning XBRL-based Reports*, <http://xbrlsite.azurewebsites.net/2020/core/master-ae/Documentation.pdf>



While a typical financial report is significantly larger (i.e. the Microsoft 2017 10-K is made up of 194 structures) every financial report works the same as this very simple example but just has more pieces.

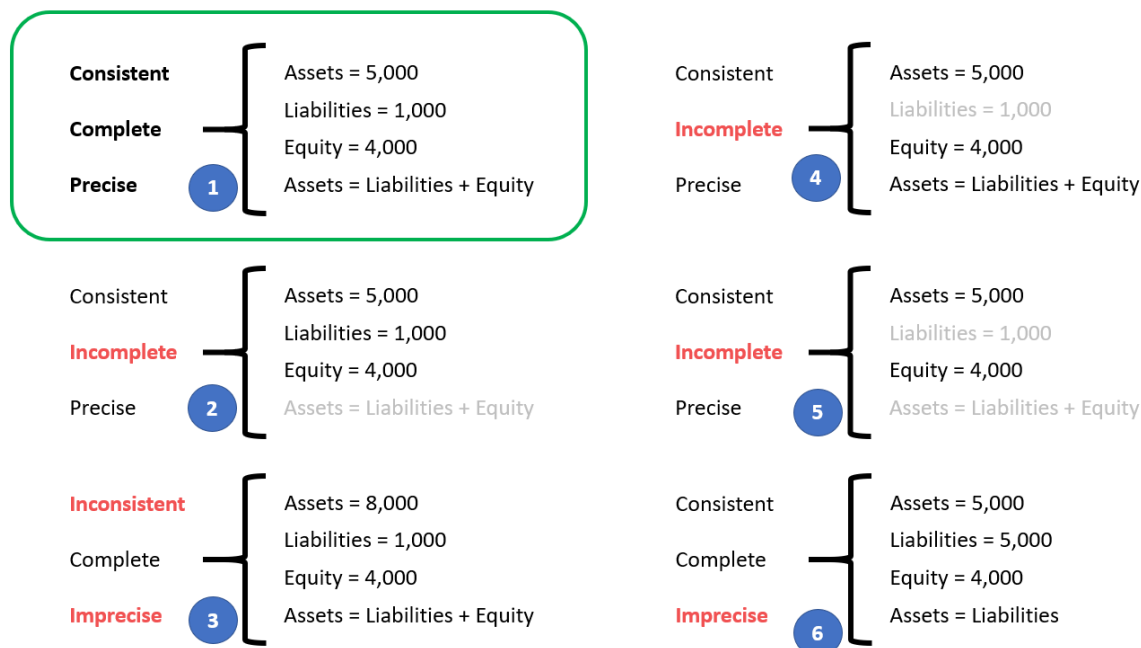
## 1.15. Impediments to a Properly Functioning Logical System

A good way to understand properly functioning logical systems is to understand the impediments to a properly functioning logical system. In this section we will start with a very simple logical system, the accounting equation which was described above, show the properly functioning version of that system, and then describe several states where that logical system becomes an improperly functioning logical system.

### 1.15.1. Properly and Improperly Functioning Logical Systems

Below you can see examples of each of six possible states of the accounting equation logical system. For example, the logical system can be functioning improperly if a single statement is left out, if one statement contradicts another statement within the logical system, if a statement is imprecise with respect to reality; all of these situations impact (a) the logical system and (b) what information is necessary to include within the logical system.

Here is a graphic depicting the first 6 states including the first which is a properly functioning logical system:



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. To the six examples above I will add three additional examples. 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<sup>38</sup>.

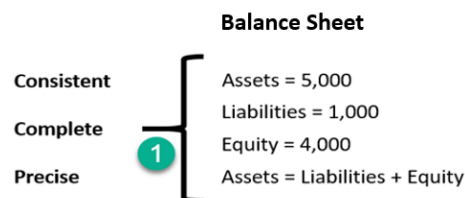
Before we get to the improperly functioning logical systems, let's take one final look at the properly functioning logical system so that you can compare and contrast the properly functioning and improperly functioning logical systems.

### 1.15.2. 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



<sup>38</sup> Understanding the Financial Report Logical System,  
[https://www.youtube.com/playlist?list=PLqMZRUzQ64B7EWamzDP-WaYbS\\_W0RL9nt](https://www.youtube.com/playlist?list=PLqMZRUzQ64B7EWamzDP-WaYbS_W0RL9nt)



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”<sup>39</sup> 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”<sup>40</sup>. You understand your system but you have to map every external system into your system<sup>41</sup>. Your internal system understands more that the accounting equation system (i.e. you have LiabilitiesAndEquity). You have to be able to compute that value based on some other system’s information<sup>42</sup>. 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<sup>43</sup>.

### 1.15.3. 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**.

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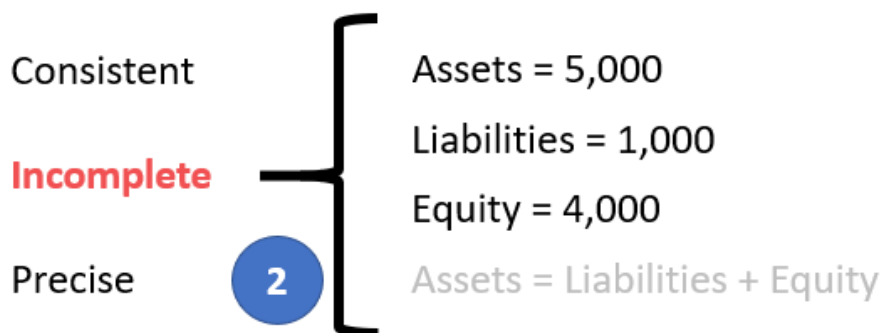
<sup>39</sup> YouTube, *Reality*, <https://youtu.be/eq2Jw6waaCI>

<sup>40</sup> Fundamental accounting concepts, <http://xbrlsite.azurewebsites.net/2020/core/master-ae/fac.xsd>

<sup>41</sup> Mapping from accounting equation to fundamental accounting concepts in our system, <http://xbrlsite.azurewebsites.net/2020/core/master-ae/fac-mapping-definition.xml>

<sup>42</sup> XBRL Formula to derive the value for LiabilitiesAndEquity, <http://xbrlsite.azurewebsites.net/2020/core/master-ae/fac-ImputeRule-LiabilitiesAndEquity-formula.xml>

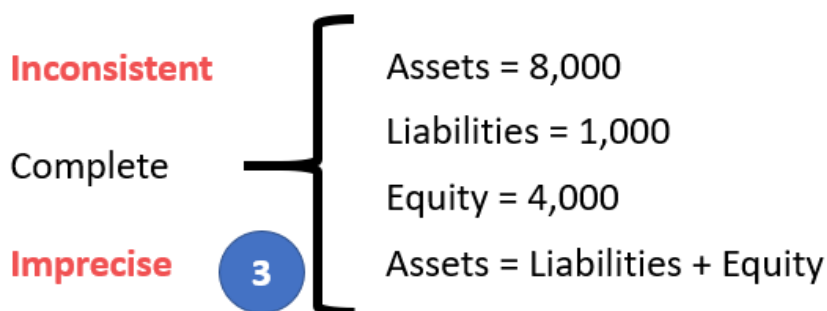
<sup>43</sup> Charles Hoffman, CPA, *Special Theory of Machine-based Automated Communication of Semantic Information of Financial Statements*, <http://xbrl.squarespace.com/journal/2019/12/30/special-theory-of-machine-based-automated-communication-of-s.html>



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.

#### 1.15.4. 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.



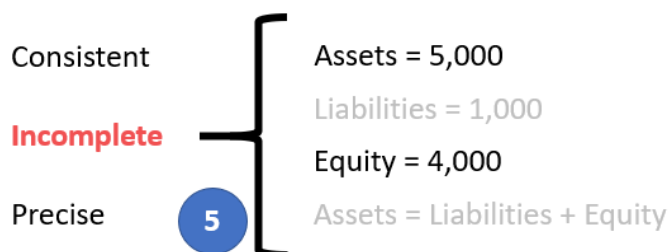
However, given that we know from state #1 that the value for Assets is 5,000 and not 8,000; the facts in this system is imprecise because the fact for Assets does not reflect reality.

#### 1.15.5. 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



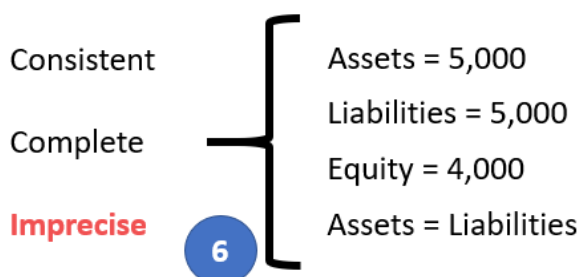


Again, consistent with state #4; Assets and Equity would require similar rules and there is no parity check of reported information.

#### 1.15.7. State 6: Imprecise

A logical system is a true and fair representation of some agreed upon realism. **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.

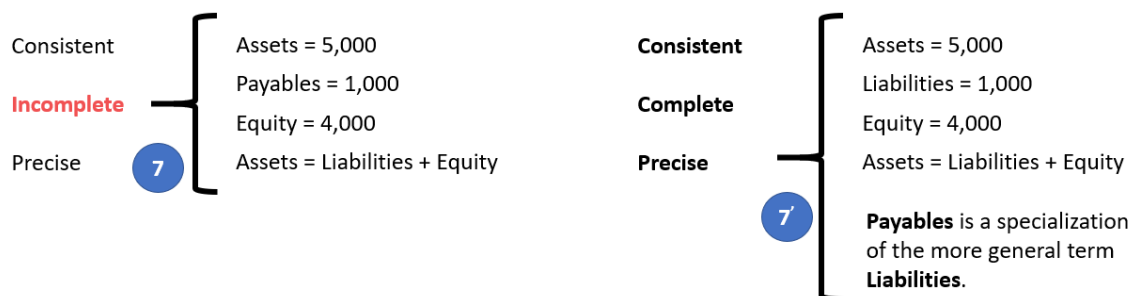
Remember that in state #1 we formalized our truth to be that "Assets = Liabilities + Equity". As such, this logical system can be described as being imprecise. To make this logical system precise, all that needs to be done is to fix the rule.



#### 1.15.8. 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<sup>50</sup>.

<sup>50</sup> XBRL Definition relations showing example of a mapping rule,  
<http://xbrlsite.azurewebsites.net/2020/core/master-ae/fac-mapping-definition.xml>

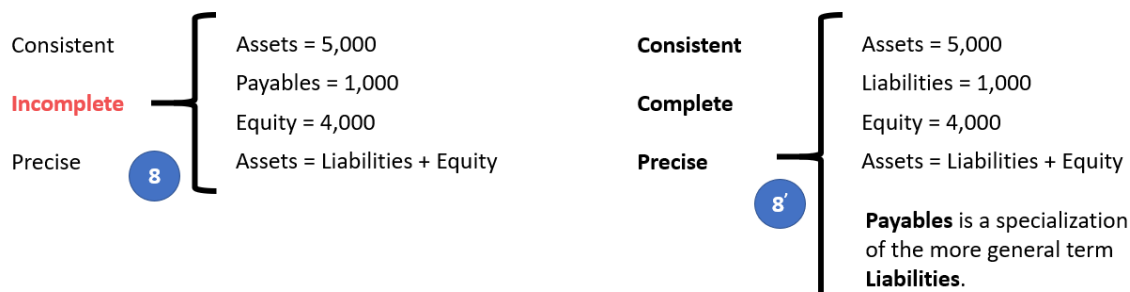


### 1.15.9. State 8: Base Taxonomy Wider/Narrower Concept Use

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 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"<sup>51</sup>.



### 1.15.10. 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-readable rules<sup>52</sup>. Even base taxonomy structures need to be defined in order to be referred to<sup>53</sup>. When you say "Balance Sheet" you know what that means. But a machine does not know.

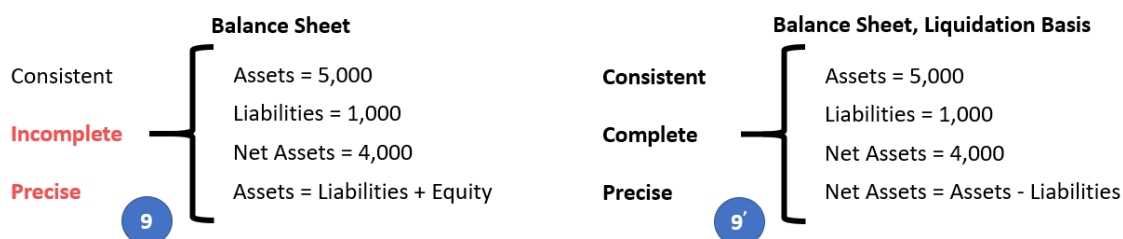
<sup>51</sup> XBRL Definition relations showing example of a mapping rule,  
<http://xbrlsite.azurewebsites.net/2020/core/master-ae/fac-mapping-definition.xml>

<sup>52</sup> XBRL Definition relations used to represent structure rules,  
<http://xbrlsite.azurewebsites.net/2020/core/master-ae/dm-1355-rules-def.xml>

<sup>53</sup> XBRL taxonomy schema used to define "Balance Sheet",  
<http://xbrlsite.azurewebsites.net/2020/core/master-ae/disclosures.xsd>



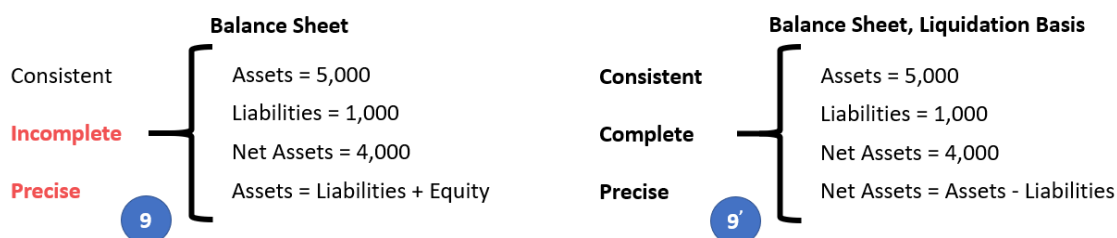
A base taxonomy should (a) provide all necessary structures separately, not intermingle different models in the same set of associations and (b) define what each structure must look like. Remember, computers are like babies and need to be led by the hand in order to understand the details you need them 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<sup>54</sup>. Other logical systems with more disclosures will have more rules relating to when a disclosure is required to be provided in a report.

#### 1.15.11. State 10: Organizing Disclosures Using Topics

State #10 points out that while the accounting equation logical system has one structure, the balance sheet, ultimately if a complete financial reporting scheme were represented one might have hundreds or even thousands of disclosures. Disclosures can be organized into topics<sup>55</sup>. Then, rather than having one flat list of disclosures, they can be organized into a handy hierarchy<sup>56</sup>.



### 1.16. Standard Business Report Model (SBRM)

The Object Management Group (OMG) is taking XBRL-based business reports to a new level, leveraging what has been learned from creating XBRL-based financial reports over the past 10 years. The Standard Business Report Model (SBRM)<sup>57</sup> is described as follows:

<sup>54</sup> XBRL Definition relations used to represent a reporting checklist or disclosure rules, <http://xbrl.azurewebsites.net/2020/core/master-ae/reporting-checklist-rules-def.xml>

<sup>55</sup> XBRL taxonomy schema used to represent topics, <http://xbrl.azurewebsites.net/2020/core/master-ae/topics.xsd>

<sup>56</sup> XBRL definition relations used to create a hierarchy of disclosures, <http://xbrl.azurewebsites.net/2020/core/master-ae/disclosures-with-topics-def.xml>

<sup>57</sup> Object Management Group and Standard Business Report Model (SBRM), <http://xbrl.squarespace.com/journal/2019/6/25/object-management-group-and-the-standard-business-report-mod.html>

“SBRM formally documents a logical conceptualization of a business report in both human-readable and machine-readable models.”

SBRM goes on to explain that through the use of standard models, business experts can define the structure and content of their reports and extensions using high-level logical business report objects, possibly presented in the form of semantic spreadsheets and pivot tables rather than with lower level technical syntax.

While XBRL has mainly been employed for financial reporting, leveraging the nature of financial accounting rules<sup>58</sup>; digital business reporting will benefit from the capabilities pioneered by XBRL-based financial reporting. Further, business reporting will not be limited to only one syntax but rather the arbitrary preferred syntax of can be used and systems can still be consistent with one conceptual model of a business report.

Financial reporting will likewise benefit from SBRM because SBRM helps business professionals and technical professionals constructing systems where flexible reporting is a requirement to effectively control variability and still have high-quality information exchanges.

## 2. Elements of Logic

This blog post was inspired by the article, *Elements of Logic*<sup>59</sup>. For more background details, please see this blog post *Elements of Logic for Accountants*<sup>60</sup>. An area of knowledge can describe the important logic of that system using these building blocks.

There tends to be several different sources of explanations of the elements of logic: philosophy, ontology and knowledge engineers, and computer scientists. These explanations tend to be inconsistent, many are incomplete, and most are either too high level to be useful or provide too much details which becomes overwhelming for business professionals and accountants.

This explanation of the elements of logic is tuned specifically for accountants and is intended to help them understand how to think about XBRL-based digital financial reports.

This is my current best take:

The **elements of logic** are the fundamental **building blocks** of logical theories that describe the logical conceptualization of some natural or man-made logical system.

- **Logical statement:** A logical statement is a proposition, claim, assertion, belief, idea, or fact about or related to the area of knowledge to which the logical conceptualization relates. A logical statement is a declarative sentence. Not all sentences are statements; for example, a question such as "What is your name?", or a command such as "Stop!", are not statements. There are five broad categories of logical statements:

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<sup>58</sup> Charles Hoffman, *Leveraging the Theoretical and Mathematical Underpinnings of a Financial Report*, <http://xbrlsite.azurewebsites.net/2018/Library/TheoreticalAndMathematicalUnderpinningsOfFinancialReport.pdf>

<sup>59</sup> OpenAI, *Elements of Logic*, <https://chat.openai.com/share/b2d1dc31-4afd-49e1-8fd2-33b0d651890a>

<sup>60</sup> *Elements of Logic for Accountants*, <https://digitalfinancialreporting.blogspot.com/2023/10/elements-of-logic-for-accountants.html>

- **Terms:** Terms are important logical statements that define ideas or "things" used by a logical conceptualization. For example, "assets", "liabilities", "equity", and "balance sheet" are things or ideas used in a logical conceptualization.
- **Associations:** Associations are important logical 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". Associations can be grouped into two broad groups:
  - **"Is-a"** (a.k.a. general-special, association, type-subtype, class-subclass, equivalent-class)
  - **"Has-a"** (a.k.a. part-of, has-part, part-whole, composition, aggregation)
- **Rules:** Rules (a.k.a. assertions, restrictions, constraints) are important logical statements that describe what tend to be convertible into 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". One rule can be connected to another rule using logic gates<sup>61</sup> (AND, OR, NOR, NAND, XOR, XNOR, NOT) to form complex logical statements. Rules can assert mathematical relationships or derive mathematical relationships to form new facts.
- **Facts:** Facts are important logical statements that are known to be true. In the context of databases and knowledge representation, facts are often used to represent known information. Facts are logical statements about the numbers and words that are provided by an economic entity within a financial report. For example, the financial report might state "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.
- **Properties:** Properties are important logical statements about the important qualities and traits of a model, structure, term, association, rule, and fact.
- **Axioms:** Axioms are foundational logical statements that are fundamentally accepted as being true per some logical system.
- **Theorems:** Theorems are logical statements that are determined to be true per logical steps that can be taken to arrive at a conclusion using axioms, other theorems, of facts.
- **Restriction:** Restrictions are a special type of axiom or theorem that is imposed by some authority which chooses to restrict, constrain, limit, or otherwise impose some range on some logical artifact.
- **Classification:** Classification is the grouping of logical artifacts into sets.

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<sup>61</sup> Logic Gates: The Building Blocks of Digital Circuits, <https://www.linkedin.com/pulse/logic-gates-building-blocks-digital-circuits-deekshith-kumar/>

- **Logical structure:** A logical structure is a set of logical statements which describe the structure. An "infor" which is defined by Situation Theory is a unit of information<sup>62</sup>. Infor is a type of logical structure. An infor is a useful, convenient unit or "set" of information.
- **Logical model:** A logical model is a set of specific structures that are consistent with and permissible interpretations of that model. Models add flexibility to logical conceptualizations.
- **Logical conceptualization:** A logical conceptualization is a set of models that are consistent with and permissible per that logical conceptualization. A logical conceptualization is made up of a set of models, structures, terms, associations, rules, and facts.
- **Logical theory:** A logical theory is described per some logical conceptualization forms a logical theory that explains what is permitted and what is not permitted per a logical conceptualization which is made up of a set of logical models, structures, terms, associations, rules, and facts.
- **Logical system:** A logical system can be explained by a logical theory. A logical theory is an abstract conceptualization of specific important details of some area of knowledge. The logical theory provides a way of thinking about an area of knowledge by means of deductive reasoning to derive logical consequences of the logical theory.

A logical system described by a logical theory and described by a logical conceptualization enables a community of stakeholders trying to achieve a specific goal or objective or a range of goals/objectives for an area of knowledge to agree on important logical statements used for capturing meaning or representing a shared understanding of and knowledge in some area of knowledge.

A logical conceptualization must be **consistent** (as opposed to inconsistent, making contradictory statements), **complete** (as opposed to incomplete, leaving a piece out), and **precise** (as opposed to imprecise, describing an area of knowledge incorrectly).

### 3. Further Reading

For more information please see:

- **Logical Theory Describing Financial Report**<sup>63</sup>
- **Processing Logical Systems**<sup>64</sup>
- **Computer Empathy**<sup>65</sup>

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<sup>62</sup> Describing Situation Semantics Using Situation Theory,  
<https://digitalfinancialreporting.blogspot.com/2023/10/describing-situation-semantics-using.html>

<sup>63</sup> *Logical Theory Describing Financial Report*,  
[http://www.xbrlsite.com/mastering/Part02\\_Chapter05.B\\_LogicalTheoryDescribingFinancialReport.pdf](http://www.xbrlsite.com/mastering/Part02_Chapter05.B_LogicalTheoryDescribingFinancialReport.pdf)

<sup>64</sup> *Processing Logical Systems*,  
[http://www.xbrlsite.com/mastering/Part05\\_Chapter08.A\\_ProcessingLogicalSystems.pdf](http://www.xbrlsite.com/mastering/Part05_Chapter08.A_ProcessingLogicalSystems.pdf)

<sup>65</sup> *Computer Empathy*,  
[http://www.xbrlsite.com/mastering/Part00\\_Chapter01.C\\_ComputerEmpathy.pdf](http://www.xbrlsite.com/mastering/Part00_Chapter01.C_ComputerEmpathy.pdf)